

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/315380364>

# Design and semantics of form and movement (DeSForM 2015): Aesthetics of interaction: Dynamic, Multisensory, Wise

Book · January 2015

CITATIONS

0

READS

612

9 authors, including:



**Tom Djajadiningrat**  
Philips

37 PUBLICATIONS 1,221 CITATIONS

[SEE PROFILE](#)



**Loe Feijs**  
Eindhoven University of Technology

317 PUBLICATIONS 3,203 CITATIONS

[SEE PROFILE](#)



**Jun Hu**  
Eindhoven University of Technology

358 PUBLICATIONS 3,209 CITATIONS

[SEE PROFILE](#)



**Steven Kyffin**  
Northumbria University

12 PUBLICATIONS 117 CITATIONS

[SEE PROFILE](#)

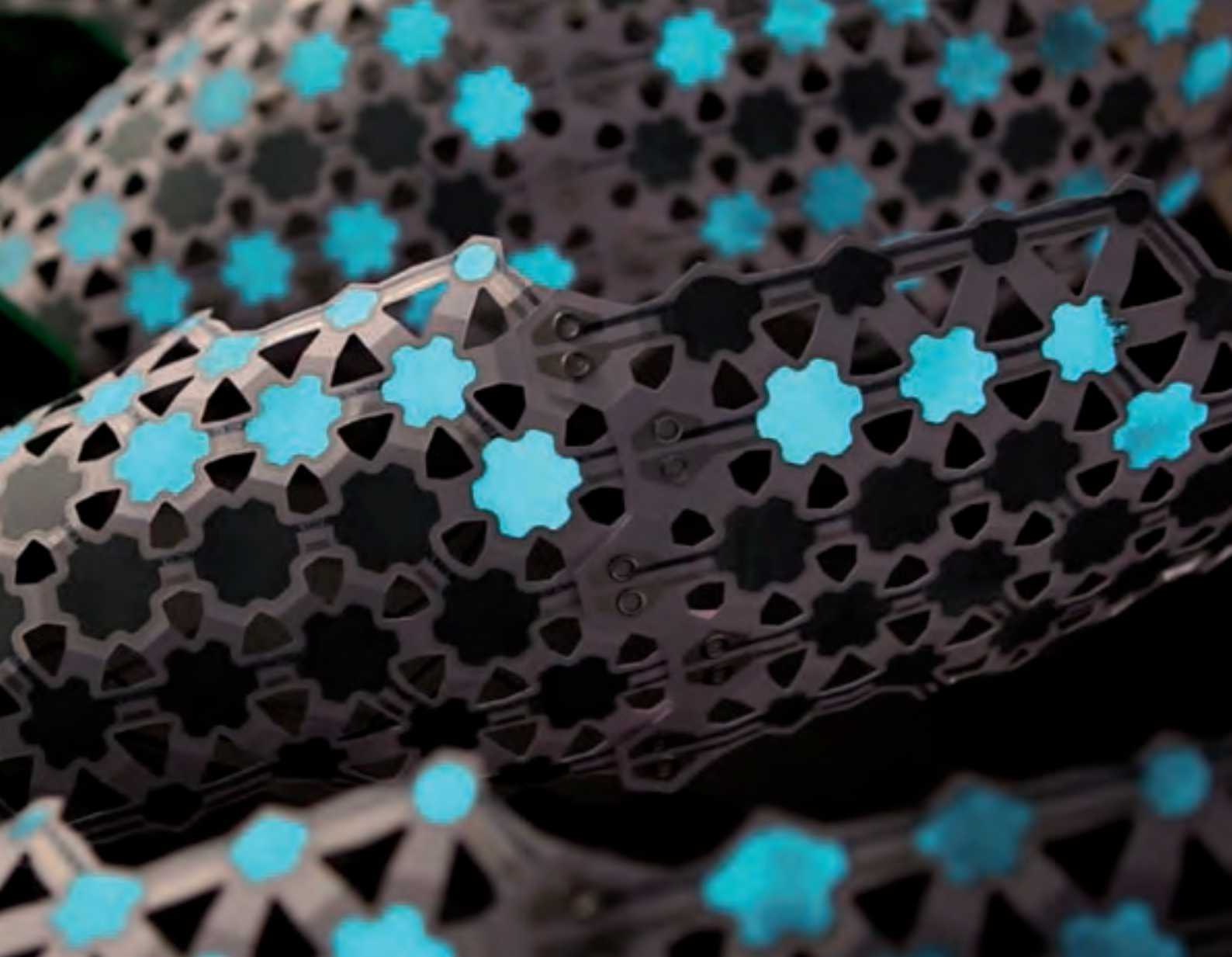
Some of the authors of this publication are also working on these related projects:



wearables for vitality [View project](#)



Cliff: the automatized zipper [View project](#)



Lin-Lin Chen, Tom Djajadiningrat, Loe Feijs, Jun Hu, Steven Kyffin, Lucia Rampino, Edgar Rodriguez, Dagmar Steffen

# Design and semantics of form and movement

DeSForM 2015

Aesthetics of interaction: Dynamic, Multisensory, Wise



Cover image: Electroluminescent surface printed on folded paper (Karmen Franinovic and Luke Franzke, "Luminous Matter: Electroluminescent Paper as an Active Material", page 37-47)

---

DeSForM 2015 is supported by:



**PHILIPS**

**TU/e**



Lucerne University of  
Applied Sciences and Arts

**HOCHSCHULE  
LUZERN**



**金印良品**  
JINYINLIANGPINPAPER



With the financial support of Telecom Italia



ISBN 978 88 6493 031 2

# Design and semantics of form and movement

## **DeSForM 2015**

Aesthetics of interaction:  
Dynamic, Multisensory, Wise

### **Edited by**

Lin-Lin Chen

Tom Djajadiningrat

Loe Feijs

Jun Hu

Steven Kyffin

Lucia Rampino

Edgar Rodriguez

Dagmar Steffen

General conference chair

**Lucia Rampino,**  
Politecnico di Milano, Italy

Topic 1

***Tangible, smart and dynamic objects: how the new aesthetics affects meaning and experience***

Chair

**Lucia Rampino,**  
Politecnico di Milano, Italy  
*Co-Chairs*

**Sara Colombo,**  
Politecnico di Milano, Italy  
**Tom Djajadiningrat,**  
Philips Design,  
The Netherlands

Topic 2

***Design and virtualization of multi sensory experiences with products***

Chair

**Monica Bordegoni,**  
Politecnico di Milano, Italy  
*Co-chair*  
**Marina Carulli,**  
Politecnico di Milano, Italy  
**Steven Kyffin,**  
Northumbria University  
School of Design, UK

Topic 3

***From smart to wise: toward a new conception of digital products and services***

Chair

**Margherita Pillan,**  
Politecnico di Milano, Italy  
*Co-chair*  
**Elisa Giaccardi,**  
Delft University of  
Technology, The Netherlands  
**Edgar Rodriguez,**  
Victoria University of  
Wellington, New Zealand

Seminar

***Capturing value in design intensive startups***

Chair

**Cabirio Cautela,**  
Politecnico di Milano, Italy

Demo Session

Chair

**Alessandro Biamonti**  
Politecnico di Milano, Italy  
*Exhibition design*  
**Alessia Viano**  
**Martina Sartor**  
Lab.I.R.Int. Research Group  
Politecnico di Milano, Italy

DeSForM Committee

**Lin-Lin Chen,**  
National Taiwan University  
of Science and Technology,  
Taiwan  
**Tom Djajadiningrat,**  
Philips Design Eindhoven,  
The Netherlands  
**Loe Feijs,**  
Eindhoven University of  
Technology, The Netherlands  
**Jun Hu,**  
Eindhoven University of  
Technology, The Netherlands  
**Steven Kyffin,**  
Northumbria University  
School of Design, UK  
**Lucia Rampino,**  
Politecnico di Milano, Italy  
**Edgar Rodriguez,**  
Victoria University of  
Wellington, New Zealand  
**Dagmar Steffen,**  
Lucerne University of  
Applied Sciences and Arts,  
Switzerland

DeSForM 2015 Scientific

Committee

**Monica Bordegoni,**  
Department of Mechanical  
Engineering, Politecnico di  
Milano, Italy  
**Marina Carulli,**  
Department of Mechanical  
Engineering, Politecnico di  
Milano, Italy  
**Sara Colombo,**  
Department of Design,  
Politecnico di Milano, Italy  
**Margherita Pillan,**  
Department of Design,  
Politecnico di Milano, Italy  
**Lucia Rampino,**  
Department of Design,  
Politecnico di Milano, Italy

DeSForM 2015 Local

Committee

**Sara Bergamaschi,**  
**Ilaria Mariani, Marco**  
**Spadafora, Annamaria**  
**Andrea Vitali**  
PhD Students, Department  
of Design, Politecnico di  
Milano

**13 October 2015**

- 15.00 Seminar "Capturing value in design-intensive start-ups"  
Venue: Sala Arena, PoliHub - Startup District & Incubator, Fondazione Politecnico di Milano,  
via Durando 39, Milan

**14 October 2015**

Topic 1 | Tangible, smart and dynamic objects: how the new aesthetics affects meaning and experience

Venue: Sala Rossa, Politeca, Bovisa Campus, Politecnico di Milano, Via Durando 10, Milan

- 8.30 Conference Registration
- 9.00 Opening Ceremony and Topic introduction
- 9.30 Keynote speech by Johan Redström "Project, Program, Practice"
- 10.15 Paper session
- Janne van Kollenburg, Eva Deckers, Paul Gardien, Caroline Hummels, "People Research for Eco-system Propositions: a Theoretical Framework towards the Future of Interaction Design"
  - Mads Nygaard Folkmann, "The Aesthetics of Digital Objects"
- 11.15 Coffee break
- 11.30 Paper session
- Nazli Cila, Marco Rozendaal, Michaël Berghman, Paul Hekkert "Searching for balance in aesthetic pleasure in interaction"
  - Patrizia Marti, "Poetry in design"
  - Jelle Stienstra, Sander Bogers, Joep Frens, "Designerly Handles: Dynamic and Contextualized Enablers for Interaction Designers"
- 13.00 Lunch + Interactive Demo session
- 14.00 Paper session
- Karin Niemantsverdriet, Joep Frens, "Design for Attachment: an explorative search for product qualities that enhance our emotional bond with digital products"
  - Hendrik N.J. Schifferstein, Elif Özcan, Marco C. Rozendaal, "Towards the maturation of design: From smart to wise products"
  - Fang-Wu Tung and Hui-Yu Tseng, "Enriching the Expressiveness of Products with Life Experiences"
- 15.30 Coffee break
- 16.00 Paper session
- Karmen Franinović, Luke Franzke "Luminous Matter. Electroluminescent Paper as an Active Material"
  - Valentina Rognoli, "Dynamic and imperfect as emerging material experiences. A case study"
- 17.00 Interactive Demo session
- 18.00 Sound design performance by Lorenzo Palmeri + Happy hour

**15 October 2015**

Topic 2 | Designing and virtualizing the multisensory product experience

Venue: POLIfactory, Bovisa Campus, Politecnico di Milano, Via Durando 10, Milan

- 9.15 Topic introduction
- 9.30 Keynote speech by Giorgio Metta “The iCub Project: an Open Robotic Platform for Research in Embodied AI”
- 10.15 Paper session
- Shuichi Fukuda “Design for flow in an age of material digitalization”
  - Theo Mahut, Carole Bouchard, Jean-François Omhover, Carole Favart, Daniel Esquivel, “Interaction, the core of User Experience”
- 11.15 Coffee break
- 11.30 Paper session
- Claudio Germak, Maria Luce Lupetti, Luca Giuliano “Ethics of Robotic Aesthetics”
  - Serena Camere, Hendrik N.J Schifferstein, Monica Bordegoni “The Experience Map. A Tool to Support Experience-driven Multisensory Design”
  - Attalan Mailvaganam and Miguel Bruns Alonso, “Haptic Beats: Designing for Rich Haptic Interaction in a Music Controller”
- 13.00 Lunch + Interactive Demo session
- 14.00 Paper session
- Murat Bengisu and Marinella Ferrara “Kinetic Materials Experience”
  - Saskia Bakker, Simone de Waart and Elise van den Hoven “Tactility Trialing: Exploring Materials to Inform Tactile Experience Design”
  - Bahareh Barati, Elvin Karana, Paul Hekkert “From Way Finding in the Dark to Interactive CPR Trainer: Designing with Computational Composites”
- 15.30 Coffee break
- 16.00 Paper session
- Edgar R. Rodriguez Ramirez, Kah Chan, Simon Fraser, Keith Thurlow, Sebastien Voerman, Dana Fridman, Scott Brebner, “3D Printing Sensor-enabled Splints and Exergaming”
- 16.30 Speech by Francesco Trabucco “The beauty of things”
- 17.00 Interactive Demo session
- 20.00 Social dinner

**16 October 2015**

Topic 3 | From smart to wise: toward a new conception of digital products and services

Venue: Saletta Lab, Triennale di Milano, Viale Alemagna 6, Milan

- 9.15 Topic introduction
- 9.30 Keynote speech by Jodi Forlizzi “Designing Today’s Product-Service Ecologies”
- 10.15 Paper session
- Elif Özcan “Towards wise experiences: The role of wisdom in design for well-being”
  - Xinchu Zhang, Lois Frankel, Audrey Girouard, “Examining Sensorial Interfaces as the Stimuli for Remote Affective Communication”
- 11.15 Coffee break
- 11.30 Paper session
- Marc Hassenzahl, Eva Lenz, Sarah Diefenbach, Nigel Geh Keong Teck, “The delicacy of handshakes: Reflections on the aesthetics of interaction”
  - Jacklynn Pham “Expanding the Palette of Digital Interaction”
  - Bin (Tina) Zhu, Yanqing Zhang, Xiaojuan Ma, Haibo Li, “Bringing Chinese Aesthetics into Designing the Experience of Personal Informatics for Wellbeing”
- 13.00 Lunch + Interactive Demo session
- 14.00 Paper session
- Shushu He “The Social Shopping in Smart Space”
  - Marco Spadafora, “Object’s Personality, a Tool to Chase an Aesthetic Approach in the Design of Smart Objects”
  - Ilaria Mariani, Ida Telalbasic, “The Reverse Engineering of Emotions”
- 15.30 Coffee break
- 16.00 Paper session
- Mizuki Sakamoto and Tatsuo Nakajima, “In Search of the Right Design Abstraction for Designing Persuasive Affordance towards a Flourished Society”
  - Annamaria Andrea Vitali, “Play design and sense-making: players and games as digital interactive contexts for effects of sense”
- 17.00 Conference Closing Ceremony
- 17.30 Possibility to visit the Triennale Design Museum

**17 October 2015 (morning)**

Guided Visit to Expo 2015



### **Keynotes**

- 009 Jodi Forlizzi, “*Designing Today’s Product-Service Ecologies*”
- 010 Giorgio Metta, “*The iCub Project: an Open Robotic Platform for Research in Embodied AI*”
- 011 Johan Redström “*Project, Program, Practice*”

### **Topic 1: Dynamic**

- 012 Sara Colombo, Tom Djajadiningrat, Lucia Rampino  
*Tangible, Smart and Dynamic Objects. How the New Aesthetics Affects Meaning and Experience*

–

### **Papers**

- 019 Nazli Cila, Marco Rozendaal, Michaël Berghman, Paul Hekkert  
*“Searching for balance in aesthetic pleasure in interaction”*
- 028 Mads Nygaard Folkmann  
*“The Aesthetics of Digital Objects”*
- 037 Karmen Franinović, Luke Franzke  
*“Luminous Matter. Electroluminescent Paper as an Active Material”*
- 048 Patrizia Marti, “*Poetry in design*”
- 057 Karin Niemantsverdriet, Joep Frens  
*“Design for Attachment: an explorative search for product qualities that enhance our emotional bond with digital products”*
- 066 Valentina Rognoli  
*“Dynamic and imperfect as emerging material experiences. A case study”*
- 077 Hendrik N.J. Schifferstein, Elif Özcan, Marco C. Rozendaal  
*“Towards the maturation of design: From smart to wise products”*
- 086 Jelle Stienstra, Sander Bogers, Joep Frens  
*“Designerly Handles: Dynamic and Contextualized Enablers for Interaction Designers”*
- 095 Fang-Wu Tung and Hui-Yu Tseng  
*“Enriching the Expressiveness of Products with Life Experiences”*
- 102 Janne van Kollenburg, Eva Deckers, Paul Gardien, Caroline Hummels, “*People Research for Eco-system Propositions: a Theoretical Framework towards the Future of Interaction Design*”

### **Topic 2: Multisensory**

- 111 Monica Bordegoni, Marina Carulli, Steven Kyffin  
*Designing and virtualizing the multisensory product experience*

–

### **Papers**

- 119 Saskia Bakker, Simone de Waart and Elise van den Hoven  
*“Tactility Trialing: Exploring Materials to Inform Tactile Experience Design”*

- 129 Bahareh Barati, Elvin Karana, Paul Hekkert  
*"From Way Finding in the Dark to Interactive CPR Trainer: Designing with Computational Composites"*
- 138 Murat Bengisu, Marinella Ferrara, *"Kinetic Materials Experience"*
- 147 Serena Camere, Hendrik N.J Schifferstein, Monica Bordegoni  
*"The Experience Map. A Tool to Support Experience-driven Multisensory Design"*
- 156 Shuichi Fukuda  
*"Design for flow in an age of material digitalization"*
- 165 Claudio Germak, Maria Luce Lupetti, Luca Giuliano  
*"Ethics of Robotic Aesthetics"*
- 173 Theo Mahut, Carole Bouchard, Jean-François Omhover, Carole Favart, Daniel Esquivel,  
*"Interaction, the core of User Experience"*
- 184 Attalan Mailvaganam and Miguel Bruns Alonso  
*"Haptic Beats: Designing for Rich Haptic Interaction in a Music Controller"*
- 193 Edgar R. Rodriguez Ramirez, Kah Chan, Simon Fraser, Keith Thurlow,  
 Sebastien Voerman, Dana Fridman, Scott Brebner  
*"3D Printing Sensor-enabled Splints and Exergaming"*

### **Topic 3: Wise**

- 200 Margherita Pillan  
*"Aesthetic and ethic issues in interaction design"*

–

### **Papers**

- 206 Marc Hassenzahl, Eva Lenz, Sarah Diefenbach, Nigel Geh Keong Teck  
*"The delicacy of handshakes: Reflections on the aesthetics of interaction"*
- 215 Shushu He  
*"The Social Shopping in Smart Space"*
- 223 Elif Özcan  
*"Towards wise experiences: The role of wisdom in design for well-being"*
- 233 Ilaria Mariani, Ida Telalbasic  
*"The Reverse Engineering of Emotions"*
- 241 Jacklynn Pham  
*"Expanding the Palette of Digital Interaction"*
- 251 Mizuki Sakamoto, Tatsuo Nakajima  
*"In Search of the Right Design Abstraction for Designing Persuasive Affordance towards a Flourished Society"*
- 261 Marco Spadafora  
*"Object's Personality, a Tool to Chase an Aesthetic Approach in the Design of Smart Objects"*
- 271 Annamaria Andrea Vitali  
*"Play design and sense-making: players and games as digital interactive contexts for effects of sense"*

- 280 Xinchu Zhang, Lois Frankel, Audrey Girouard  
*"Examining Sensorial Interfaces as the Stimuli for Remote Affective Communication"*
- 289 Bin (Tina) Zhu, Yanqing Zhang, Xiaojuan Ma, Haibo Li  
*"Bringing Chinese Aesthetics into Designing the Experience of Personal Informatics for Wellbeing"*

### **Demo session**

- 399 Monica Bordegoni, Sara Colombo, Margherita Pillan, Lucia Rampino  
*Exploring aesthetic interactions through prototyping. The role of experiential prototype in design knowledge generation*

—

### **Interactive Demos**

- 306 Venanzio Arquilla, Giulia Fiorinelli, *"The role of design in the development of interactive product service system for the next generation of asthma treatment. The SOFI case."*
- 312 Licia Calvi, Moniek Hover, Frank Ouwens, Juriaan van Waalwijk  
*"Visualising Vincent's life: An engaging experience into Van Gogh's heritage"*
- 316 Misha Croes and Loe Feijs, *"Family Arizing"*
- 308 Ruben Daems, Marina Toeters, Loe Feijs, *"Activating Wearables: The Butterfly Effect"*
- 321 Joep Elderman, Yeup Hur *"Exploration of Interaction Methods for Shape-Changing Interfaces"*
- 326 Loe Feijs, Jun Hu, *"Dynamic aesthetics of generative two-dimensional geometric art"*
- 332 Tamara Hoogeweegen, Marina Toeters, Loe Feijs  
*"Aires: a wearable for women in their menopause"*
- 335 Hao-Xiang Lin, Rung-Huei Liang, Po-Hao Wang, Yuan-Yao Hsu, *"Animism Expression: Materializing Basic Principles of Animation for Interaction Design"*
- 339 Patrizia Marti, Jeroen Peeters, Ambra Trotto  
*"Ethics in Aesthetics: Experiencing Women's Rights"*
- 342 Bettina Neu, James Irvine, *"Exploring computational aesthetics for golf club design"*
- 347 Ruben Post, Daniel Saakes, Paul Hekkert  
*"A Design Research Methodology using 3D-Printed Modular Designs to Study the Aesthetic Appreciation of Form and Material"*
- 351 Vincent van Rheden, Bart Hengeveld  
*"An Exploration In Kitchen Blender Interactions Aimed At Designing For Higher Levels of Engagement"*
- 356 Bin Yu, Yue Song, Loe Feijs  
*"Light Bird: An Animated Biofeedback Interface for Coherent Breathing"*
- 361 Stijn Zoontjens, Doenja Oogjes, Jun Hu  
*"Unify: Sharing Digital Media Content from the Cloud through Physical Interaction"*

**Jody Forlizzi**

Associate Professor at Carnegie Mellon University, School of Design and Human-Computer Interaction Institute



# Designing Today's Product-Service Ecologies

**Abstract**

A recent New York Times article boldly stated that the Golden Age of Design is upon us. Our society is certainly in the midst of a great shift in how we view the world. In the past century, we have moved from the Age of Craft to the Industrial Age; we are currently on the cusp of the Age of Information. In the 20th century, innovations including the personal computer, the internet, smart phones, cloud computing, wearable computers and 3D and CNC printing have helped to radically change our conception of what we design. Today, designers no longer create products; they instead create platforms for open innovation.

This talk will reflect on the discipline of design's many eras and shifts, in order to understand this movement from designing products to designing platforms. The eras of user-centered design, experience design, service design, and systems design will be explored to better understand this migration. An alternative framing, product-service ecologies, will be introduced to stress a systemic and ecological view as a design approach to designing the products, services, environments, and platforms of today. An ecological view ensures that the designer can identify a need and understand the implications of designing something to impact the ecology in a positive way. An ecological view helps move the designer from problem solving to problem seeking, from modeling to understanding relationships, and from prototyping to perturbing the system to understand outcomes. It also ensures that designers are creating pragmatic and purposeful systems that will improve the state of today's world.



Jodi Forlizzi is a Professor in the Human-Computer Interaction Institute and the School of Design at Carnegie Mellon University. Her research ranges from understanding the limits of human attention to understanding how products and services evoke social behavior. She designs and researches systems ranging from peripheral displays to social and assistive robots. Her current research interests include designing educational games that are engaging and effective, designing services that adapt to people's needs, and designing for healthcare. Jodi is a member of the Association for Computer Machinery Computer-Human Interaction Academy and has been honored by the Walter Reed Army Medical Center for excellence in design research. Jodi has consulted with Disney and General Motors to create innovative product-service systems.

**Giorgio Metta**

Professor, Director of the iCub Facility Department,  
Istituto Italiano di Tecnologia (Italy)



Prof. Giorgio Metta is Director of the iCub Facility department at the Istituto Italiano di Tecnologia (IIT) where he coordinates the development of the iCub robotic platform/project. He is Deputy Director of IIT delegate to the international relations and external funding. In this role he is member of the board of directors of euRobotics aisbl, the European reference organization for robotics research. He was previously with the University of Genoa and, since 2012, has been Professor of Cognitive Robotics at the University of Plymouth. From 2001 to 2002, he was postdoctoral associate at the MIT AI-Lab. He holds an MSc cum laude (1994) and PhD (2000) in electronic engineering both from the University of Genoa.

His research activities are in the fields of biologically motivated and humanoid robotics and, in particular, in developing humanoid robots that can adapt and learn from experience. Giorgio Metta is author of approximately 250 peer-reviewed publications. He has been working as principal investigator and research scientist in about a dozen EU projects.

# The iCub project: an open robotic platform for research in embodied AI

**Abstract**

I will present the iCub humanoid, a robotic platform designed for research in embodied cognition. At 104 cm tall, the iCub has the size of a three and half year old child. It can crawl on all fours, walk and sit up to manipulate objects. Its hands have been designed to support sophisticated manipulation skills. The iCub is distributed as Open Source following the GPL/LGPL licenses and can now count on a worldwide community of enthusiastic developers. The entire design is available for download from the project homepage and repository (<http://www.iCub.org>). More than 25 robots have been built so far which are available in laboratories in Europe, US, Korea and Japan. It is one of the few platforms in the world with a sensitive full-body skin to deal with the physical interaction with the environment including possibly people.

The iCub stance on artificial intelligence posits that manipulation plays a fundamental role in the development of cognitive capability [1-4]. As many of these basic skills are not ready-made at birth, but developed during ontogenesis [5], we aim at testing and developing this paradigm through the creation of a child-like humanoid robot: i.e. the iCub. This "baby" robot is meant to act in cognitive scenarios, performing tasks useful for learning while interacting with the environment and humans. The small (104cm tall), compact size (approximately 25kg and fitting within the volume of a child) and high number (53) of degrees of freedom combined with the Open Source approach distinguish the iCub from other humanoid robotics projects developed worldwide.

**References**

- [1] L. Fadiga, L. Craighero, and E. Olivier, "Human motor cortex excitability during the perception of others' action," *Current Biology*, vol. 14 pp. 331-333, 2005.
- [2] L. Fadiga, L. Craighero, G. Buccino, and G. Rizzolatti, "Speech listening specifically modulates the excitability of tongue muscles: a TMS study," *European Journal of Neuroscience*, vol. 15, pp. 399-402, 2002.
- [3] G. Rizzolatti and L. Fadiga, "Grasping objects and grasping action meanings: the dual role of monkey rostroventral premotor cortex (area F5)," in *Sensory Guidance of Movement*, Novartis Foundation Symposium, G. R. Bock and J. A. Goode, Eds. Chichester: John Wiley and Sons, 1998, pp. 81-103.
- [4] D. Vernon, G. Metta, and G. Sandini, "A Survey of Cognition and Cognitive Architectures: Implications for the Autonomous Development of Mental Capabilities in Computational Systems," *IEEE Transactions on Evolutionary Computation*, special issue on AMD, vol. 11, 2007.
- [5] C. von Hofsten, "On the development of perception and action," in *Handbook of Developmental Psychology*, J. Valsiner and K. J. Connolly, Eds. London: Sage, 2003, pp. 114-140.

**Johan Redström**

Rector, Professor, Umeå Institute of Design (Sweden)



# Project, Program, Practice

**Abstract**

There is something intriguing about the ways design allows us to combine otherwise seemingly rather extreme ends of a scale; the very specific and the very general seemingly explored at the same time. In design, there is nothing particularly strange about the idea that one can explore big and general issues such as 'what is a good life?' through the design of a specific house, the 'experience of well-being' through the design of an app for monitoring personal health, or indeed what defines 'speed' from an experiential point of view through the design of a vehicle. However, this ability to engage with the extremes of scale – as in interpreting also foundational concepts through the design of a concrete thing – seems at times also to make us rather blind to matters in the middle. But what if much of what potentially defines a certain way of thinking and doing design exists between such extremes; between problem and paradigm, between questions of how to resolve a particular design problem and foundational notions of what design in general can be said to be.

My suggestion is that it is here we need to look if we are to understand some of our prevalent paradoxes, such as how a discipline so completely devoted to changing existing states into future preferred ones also can be so conservative when comes to parts of its core. And so if (whether in the light of significant contemporary challenges such as sustainable development and living with new technologies) it is significant change in our own discipline we want to bring about, perhaps this is where we need to look? In this talk, I will try to articulate some ways we could use notions of project, program and practice to work with what resides in between problem and paradigm.



Johan Redström is Rector of Umeå Institute of Design and professor in design. He previously held the position of Design Director at the Interactive Institute. His current research is about prototyping new design practices as a response to post-industrial conditions and contemporary challenges such as sustainable development, and recent books include "Share this book: critical perspectives and dialogues about design and sustainability" (w. Mazé, Olausson, Plöjel, Redström, and Zetterlund, eds.; Axl Books 2013) and "Design research through practice: From the lab, field, and showroom" (w. Koskinen, Zimmerman, Binder, Redström and Wensveen; Morgan Kaufmann Publishers Inc 2011).

S. Colombo<sup>1</sup>, T. Djajadiningrat<sup>2</sup>, L. Rampino<sup>1</sup>

<sup>1</sup> Design Department, Politecnico di Milano, Italy

<sup>2</sup> Philips Design, The Netherlands

# Tangible, Smart and Dynamic Objects

How the New Aesthetics Affects Meaning and Experience

## Origins and meanings of Aesthetics of Interaction

The expression “Aesthetics of Interaction” (Aoi) has different meanings and can relate to different concepts, according to the context where it is used [1, p.270]. In order to better understand why and how this expression has entered the design field, and especially the *industrial* design area, it is interesting to step back to its origin and its primary meaning.

Aesthetics of Interaction started to emerge in the field of Human Computer Interaction (HCI), when “effort is [...] put into designing interactive systems beyond rational and functional requirements” [1, p. 270]. Meaning that, next to the systems’ functionality, performance, and usability, attention started to be paid also to other elements of human experience, i.e. the emotional, perceptual and sensory ones. In this effort to overcome the mere functionality, the notion of aesthetics came into play, since “the concepts and vocabulary of aesthetics and critical theory have much to offer HCI, because they emphasize qualities and issues that HCI is obviously concerned with in interaction: experience, symbolic density and cohesion, beauty, enlightenment, social justice, dialogism, identity and the self, form and meaning, taste and judgment [...]” [2, p. 2357].

The question to answer in this “aesthetic turn” was the following: how could the notion of aesthetics, usually related to the appreciation of beauty in arts, be applied to interactive systems, and to the idea of interaction itself? Indeed, interaction is not an object, but “a phenomenon that emerges in-between people and digital artifacts. It is not inside of the artifact. It is continuously going on and changing over time.” [3, p. 245].

New philosophical approaches and strands were adopted in order to answer the question. In particular, Schusterman’s pragmatist aesthetics was taken as reference to explain that “aesthetic is not something a priori in the world, but a potential that is released in dialogue as we experience the world; it is based on valuable use relations influencing the construction of our everyday life” [1, p. 271]. If aesthetics was no more in objects but in the dynamic relation between users and objects, it could be applied to the design of interactive systems.

We are now far away from the concept of aesthetics as related to the object’s intrinsic beauty or to the sensory perception of the user. The idea of beauty is still there, but the pleasure felt by the user is no longer related to just the sensory features of an object, but emerges in interaction, in performing actions, in being challenged by open systems that require imagination to be understood, in perceiving emotions, in being engaged.

In HCI, this new view on aesthetics brought to build what Udsen and Jørgensen [4] call a “functionalist approach” to aesthetics. Indeed, many theories in the field started to argue that aesthetics should be aimed at making

“attractive things”, which “work better” [5]. Aesthetics was intended as a means to improve the system’s usability. Although many subsequent theories and approaches, especially in the design field, challenged this view, it still has the merit to be the first attempt to move beyond the mere cognitive skills in the interaction with smart systems, towards the investigation of a broader view of human experience in interaction. One that encompasses its three fundamental aspects: the sensory-motor, the cognitive and the emotional ones.

Among the first scholar to refer to such a broader view and to mention this “trinity of interaction” was Kees Overbeeke: “We believe that respect for man as a whole should be the starting-point for design. For the sake of analysis, man’s skills, which are used when interacting with products, may be considered on three levels, the wholly trinity of interaction: cognitive skills, perceptual-motor skills and emotional skills. In other words, knowing, doing and feeling.” [6, p. 8].

## **Aesthetics of Interaction in industrial design**

It is now worth addressing why the notion of Aesthetics of Interaction can be connected to product design. Aesthetics intended in its primary sense, as the beauty related to the physical appearance of arts objects or nature has always been part of industrial design theories and practice [4]. In industrial design, traditionally product aesthetics equals visual appearance. In this view, the user is seen “only as an onlooker and not as an actor”. [7, p. 298]. Whereas still primarily connected to visual appearance, in the last two decades aesthetics in product design has started to be investigated also in relation to other senses, bringing to the emergence of a more “synesthetic” idea of beauty [8].

Moreover, beauty and pleasure in design have been recently connected not only to (multisensory) appearance, but also to other aspects of products, such as the product use. As argued by Jordan [9] based on Tiger [10], there are different kinds of pleasure emerging by the interaction with products. Among them, psycho-pleasure emerges in the use of products and can be generated by the pleasant way in which a product performs an action, under the control of the user.

Already in these theories, aesthetics in product design enlarges its meaning, and embraces not only the product’s perceivable features, but also its use. However, in all these cases (be pleasure related to appearance or use), when talking about aesthetics in product design, products are meant as traditional objects, artefacts characterized by certain physical features and functions, which remain static and defined by the designer once for all.

Nevertheless, in the last decade, the design field has been heavily affected by the technology revolution. Indeed, artefacts are getting embedded with sensors, electronics, processors, smart devices and smart materials. These elements make products dynamic and interactive. Thus, “a domain which was once considered pure industrial design is faced with many interaction design challenges” [7, p. 294]. It is in this historical moment that aesthetics of interaction enters the product design field and starts to be investigated as an essential part of the user experience also with physical artefacts.

## **Dynamic and interactive products**

In our discourse on aesthetics, compared to what we call traditional products (the static ones), smart and interactive products have mainly two distinctive features: their behavior turns from passive to active; their appearance becomes *dynamic*, i.e. it can change over time in a reversible and pro-active way.

Concerning the first feature - the *active behaviour* - we can state that traditional products do not really “behave”, but respond to the user’s behaviour or actions on it. The product’s performance is pre-defined by the designer, and enabled by the user. At the most, we can talk about a passive behavior, because it is the user who acts on the product and makes it behave in certain ways: the control is always in the user’s hands. In smart products, the product’s behavior becomes dynamic, and pro-active: products are able to perform actions, activities, functions,



independently by the presence of users, or as an active response to it, to the environment or to information coming from networks, smart spaces and devices. Products can even take decisions and behave accordingly. The focus on behavior in smart products has been recognized as a fundamental aspect for design: “an essential characteristic of intelligent products and systems is that they portray behavior in interaction” [11, p. 3]. Therefore, in the design of smart tangible products, “the emphasis shifts from an aesthetically controlled appearance to an aesthetically controlled interaction, of which appearance is a part.” [12, p. 66]. Thus, if appearance is just a part of an aesthetic interaction, another layer of complexity is added to smart products: this appearance becomes dynamic as well, requiring new paradigms and approaches to control it. Indeed, the second feature of smart products is their *dynamic appearance*: physical products can now change their tactile qualities (e.g. temperature and texture), their shape, light, colour, sound, smell, etc. in a proactive manner. These sensory changes occurring in products can have different aims. For instance, they can be used for delighting and attracting users (at a sensory level); for engaging users in interaction (at an affective level); for conveying information to users (at a cognitive level) [13].

Obviously, these two changes - (inter)active behavior and dynamic appearance - require a shift in how *aesthetics* should be conceived in product design, since both new appearances and new forms of interaction are emerging. As Ross and Wensveen pointed out, “designing such products and systems requires an aesthetic that goes beyond traditional static form aspects. It requires a new language of form that incorporates the dynamics of behavior.” [11, p. 3] Due to these transformations, aesthetics of interaction – first emerged in HCI – legitimately enters the product design domain, breaking the traditional rules, approaches and tools of industrial design and opening new and exciting challenges. As stated by Lim et al. “a fair amount of research attempts to explore the nature of aesthetics in the design of interactive artifacts [...]— e.g. showing that aesthetics are based not just on visual appearances of an artifact but more on the holistic experience of its use.” [3, p. 240]

Emerged in the product design area to face the new dynamic features of smart products, aesthetics of interaction can still be applied to traditional products, where not only the pleasure generated by appearance, but also the pleasure arising in use is taken into consideration. When applied to “static” products, Aol can be seen as an evolution of the concept of *usability*, where the aim is not only to perform effectively, but also to feel pleasant sensations while performing an action on, or with, products.

In brief, we can affirm that, in designing for an aesthetic interaction, the fourth dimension - time - becomes the fundamental variable, the core of every design choice. At this regard, Anna Vallgård [14] introduces the concept of “temporal form giving”. This new kind of form giving, together with the (traditional) physical form giving and the performances of the interaction gestalt are defined by Vallgård the “trinity of forms” that she proposes as a framework to unfold the practice of interaction design. Indeed, if in traditional product design, time was considered relevant only in designing the user’s actions on products, when it comes to smart and dynamic objects, time becomes essential also in the design of the product’s features and behavior.

Clearly, the concept of aesthetics of interaction applied to tangible products needs further theoretical investigation. Many questions are still open and paradigms keep changing, as technology and society rapidly evolve, making it difficult to take other than quick and partial pictures of reality.

Nevertheless, many big challenges in this area are being investigated by scholars and some of them are addressed by the papers presented at the DeSForM 2015 conference (for more reasoning on these issues, see also the Proceedings of the previous DeSForM conferences, all available at the following link: [www.northumbria.ac.uk/about-us/academic-departments/northumbria-school-of-design/research/desform/previous-conferences-and-proceedings/](http://www.northumbria.ac.uk/about-us/academic-departments/northumbria-school-of-design/research/desform/previous-conferences-and-proceedings/)).

We summarize these challenges in the following paragraphs, also by briefly explaining how the works presented at DeSForM 2015 can contribute to a fruitful debate on these issues.

## Challenges

### What new frameworks are needed to understand aesthetic interactions in design?

*"[...] the scope of design is changing from human/artifact interaction, mainly focused on opening up the functionality of a product, toward a broader approach that seeks to enhance interpersonal and societal values, including personal, aesthetic, and socio-cultural ones, through the application of intelligence (i.e., smart electronics) in artifacts."* [15, p. 70]

If products are no more static and "predictable" as they were before, if they become intelligent, open, and dynamic, then the industrial design community needs to update its traditional theoretical frameworks and principles, adopting a new and open view on products: "[...] products and services do not have to be as fixed as they were before. Since they are part of an interconnected network of other products, services and people that are changing over time, so are the products and services. It is a dynamic network with updates, added propositions, new connections, new functions, etcetera." (DeSForM2015 paper by van Kollenburg, Deckers, Gardien and Hummels)

It is interesting at this regard to mention the concept of "opera aperta" ("open artwork"), introduced by Eco in 1962 [16]. Indeed, as Jones (1992) noted, "designers need to acknowledge their relative ignorance of "temporal design" and can perhaps learn from the "time arts" (music, dance, theatre, film, novel, poetry, etc.) how to compose-in-time with some sense of beauty." (Jones, cited in [17]).

The concept of "opera aperta" refers exactly to artworks – mainly novels, but also musical compositions and performances - opening up to the aspect of time and qualified by being "unfinished". In Eco's view, "opera aperta" is an artwork that allows multiple interpretations, that permits to communicate ambiguous and multi-purpose ideas, that offers itself to endless possibilities of understanding. "The fact that these creations are not finally defined, gives them an openness towards the beholder perception, interpretation or use." [18, p. 331]. The "opera aperta" does not suggest a pre-ordered and univocal set of values, but rather a field of possibilities. For this reason, it always requires an active intervention, an operative choice by the reader or the beholder. Compared to the traditional static idea of an artifact (being it an object d'art or a product), the "opera aperta" has the capacity of being 're-created' each time a new user starts interacting with it. "The momentary aspect of Eco's Opera Aperta opens up to the aspect of time." [18, p. 331]

Interestingly enough, the DeSForM2015 paper "People Research for Eco-system Propositions" by van Kollenburg et al. presents a theoretical framework supporting "open" modalities of user-centered research to be embedded in the design process of dynamic and interconnected eco-systems: "[...] the four people research activities have no specific order of execution; they are neither linear nor iterative by definition. They are dynamic and there is no predefined order or static link to the design process. Hence there is no predefined starting or ending point for the process. Depending on the type of questions and status of the project the design research team can decide where to start and what to do after." Thus, according to the authors of this papers, for designing an open product, an open process is needed.

The attempt to generate new frameworks for the aesthetics of interaction in products is exemplified by the paper "The Aesthetic of Digital Objects" by Folkmann, which presents a new framework where the issues of dynamic appearance, hidden function, and product openness are all taken into consideration.

The paper "Searching for balance in aesthetic pleasure in interaction" by Cila, Rozendaal, Berghman and Hekkert aims to "unravel the general principles that underlie aesthetics of interaction". It describes how visual aesthetic principles (e.g. Gestalt principles) can be applied not just to appearance, but also to "the movements performed while interacting with a product", to generate aesthetic pleasure in interaction. These principles, according to the authors, can adapt to both dynamic and traditional static products.

### **What new tools can be adopted to design aesthetic interactions?**

*“Although there has been a drastic increase in the research of aesthetics of interaction, we still lack well-defined practical knowledge of how to design aesthetic interactions.” [3, p. 239]*

In addition to developing new theoretical frameworks, there is also a need to supply designers with methods and tools helping them in designing for an aesthetic interaction. That is, designing in an integrate manner all the (dynamic) features of the artifact – being them behaviors and/or appearances – and the actions/reactions of the user, so that all this “ingredients” can generate a holistic and pleasurable interaction experience. There is thus a need to develop specific design tools, to be applied in given phases of the design process, from the concept phase (see, for instance, the paper by Patrizia Marti), to the development phase (see the paper by Stienstra, Bogers and Frens).

The paper “Poetry in Design” by Patrizia Marti describes an approach to use contemporary poetry as a tool to experience cultural elements and embed them in the design of meaningful interactions. In Marti’s view, poetry is a precious vehicle able to nourish product design with reflection and sense-making, differentiating it from merely functional solutions. It is also interesting to notice that the Dutch poet Jan Glas, which Marti involved in her teaching activity, explained that he uses: “[...] words with nuanced meanings to allow the reader’s imagination to run wild and form a feeling, meaning or image independently. He highlighted the active role of the reader in experiencing and making sense of the poem.” This is again an interesting, although not explicit, reference to the concept of “opera aperta”.

As Lim et al. noted, it is important to know “what is possible to be manipulated when designing interactions—i.e. attributes of interaction” [3, p. 239]. The DeSForM 2015 paper “Designerly handles” by Stienstra et al. aims to provide designers with new kinds of design tools, which allow them use their typical “pathic” skills and knowledge while designing interactive products, to overcome the limitation of the tools borrowed by other disciplines (e.g. computer science). These tools’ goal is to allow reflection-in-action while designing interactive products, by bringing the digital qualities into the physical realm, to manipulate them in the design process.

### **How can user experience and emotional bond with (dynamic) products be enhanced?**

*“The prospect of beauty of interaction may not only tempt users to engage in interaction, but also tempt them to persevere in interacting.” [7, p. 296]*

The experience generated during the interaction with products has been widely explored in the industrial design field [19]. Such experience is commonly defined as the mix of three levels: experience of meaning, emotional experience, and aesthetic experience. These three components of experience have been studied in traditional static products, especially in relation to their appearances and functions. They now need to be reframed in order to address the category of interactive and tangible products. Relevant questions in this area are: how is meaning created in interaction? How to exploit the product’s dynamic features and “smartness” to improve the user’s life? How to address technology in products towards the creation of pleasant experiences?

The DeSForM 2015 paper “Design for Attachment: an explorative search for product qualities that enhance our emotional bond with digital products” by Niemantsverdriet and Frens explores how dynamic features and behaviours of digital products can adapt to user’s needs and habits in order to create emotional attachment over time.

The contribution “Towards the maturation of design: From smart to wise products” by Schifferstein, Ozcan and Rozendaal reflects over the evolving role of smartness in products. The authors argue that products’ smartness should turn into *wisdom*, in order to create better experiences and to evoke desirable behavior, which “contribute to the user’s and society’s subjective well being”.

In the paper “Enriching the Expressiveness of Products with Life Experiences”, Tung and Tseng investigate how people associate products with their life experience: the aim is to identify elements that can become inspirations for designing original and meaningful products. Indeed, the authors argue that designers increasingly use metaphors that recall common life experiences (such as natural events like thunders during a storm, or common human behaviors, like participating in sports) to enrich the emotional attachment to products: “Through reminding the user of a personal experience and evoking a corresponding emotional response, a unique and meaningful relationship between the user and the product is formed.” Even if examples refer mainly to static products, nevertheless the suggested classification can provide an interesting playground also for dynamic products.

### **How does the concept of “material” change in the aesthetics of interaction paradigm?**

*“Every object made by man is the embodiment of what is at once thinkable and possible.” [20, p. 17]*

Nowadays, the “material of invention” [20] that designers have at their disposal to define new products can be designed as well. Vallgård introduced the idea of “computational” composite in design: “I propose that we begin to understand the computer as a material like any other material we would use for design, like wood, aluminum, or plastic. That as soon as the computer forms a composition with other materials it becomes just as approachable and inspiring as other smart materials.” [21]

Not only can computer be regarded as a new material, but also traditional materials are becoming smart, i.e. able to sense environmental changes and react to them accordingly, with a fast, local, and adaptable response, modifying one or more of their features (mechanical, optical, electrical, magnetic, chemical or thermic ones) [22]. As a consequence, smart materials can be used as active elements in the interaction between the user and the artifact, assuming the role of both sensors and actuators: the material itself detects the user’s action and responds by giving him/her a feedback.

In the smart materials field, designers and chemical engineers are now starting to cooperate. This collaboration is important in order to fill a gap, as underlined by Franinović and Franzke in the DeSForM 2015 paper “Luminous Matter”: “The active properties of novel materials themselves appear to be hard to work with, reflected by the lack of examples that exploit them in design fields.[...] Dealing with materials on a nano scale not only requires specialised facilities, but also removes the creator from the direct sensing and handling of the material. Tacit knowledge of materials plays an essential role in design and arts, as such intimate relationship with a novel material enables a designer or artist to explore its aesthetic potential.” The experiments with electroluminescent paper described by Franinović and Franzke shows a potential for collaboration with material scientist and engineers: novel materials can feed into design research and, vice versa, design experiments can stimulate the development of novel materials.

In her contribution to DeSForM2015, Rognoli proposes two emerging material experiences: dynamism and imperfection. “Both are nowadays considered very promising material experiences in terms of creating meaningful interactions and, as a consequence, user’s attachment to the product. [...] dynamism and imperfection share a changing and evolving nature able to break the monotony of the idealized “perfect” and “static” relationship usually established between user and artefact.” The Sui Bag presented by Rognoli is thus a good example on how designers could take into account materials and manufacturing processes for creating meaningful interactions.

## References:

- [1] Petersen, M. G., Iversen, O. S., Krogh, P. G., & Ludvigsen, M. (2004, August). Aesthetic Interaction: a pragmatist's aesthetics of interactive systems. In *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques* (pp. 269-276). ACM.
- [2] Bardzell, J. (2009) Interaction Criticism and Aesthetics. CHI 2009, April 4–9, 2009, Boston, MA, USA, pp. 2357-2366
- [3] Lim, Y., Stolterman, Erik, Jung, Heekyoung and Donaldson Justin (2007) Interaction Gestalt and the Design of Aesthetic Interactions, *Designing Pleasurable Products and Interfaces* (pp. 239-254), 22-25 August 2007, Helsinki, Finland
- [4] Udsen, L. E., & Jørgensen, A. H. (2005). The aesthetic turn: unravelling recent aesthetic approaches to human-computer interaction. *Digital Creativity*, 16(04), 205-216.
- [5] Norman, D. (2002). Emotion & design: attractive things work better. *interactions*, 9(4), 36-42.
- [6] Overbeeke C.J., Djajadiningrat J.P., Hummels C.C.M., Wensveen S.A.G. (2002) Beauty in usability: forget about ease of use! In: W.S. Green & P.W. Jordan (Eds.), *Pleasure with products: beyond usability*, pp. 9-18. Taylor and Francis, London, UK
- [7] Djajadiningrat, T., Wensveen, S., Frens, J., and Overbeeke, K. (2004) Tangible products: redressing the balance between appearance and action. *Personal and Ubiquitous Comp.* 8, 5, pp. 294-309
- [8] Schifferstein, H.N.J., Hekkert, P. (2008) *Product Experience*, Elsevier.
- [9] Jordan, P. W. (2002) *Designing pleasurable products: An introduction to the new human factors*. CRC press.
- [10] Tiger, L. (1992) *The pursuit of pleasure*. Transaction Publishers.
- [11] Ross, P. R., & Wensveen, S. A. G. (2010). Designing aesthetics of behavior in interaction: Using aesthetic experience as a mechanism for design. *International Journal of Design*, 4(2), 3-13.
- [12] Djajadiningrat, J.P., Gaver, W.W., Frens, J.W. (2000). Interaction Relabelling and Extreme Characters: Methods for Exploring Aesthetic Interactions, *DIS '00*, (pp. 66-71) Brooklyn, New York
- [13] Colombo, S., and Rampino, L. (2013). Beyond Screens. Exploring product dynamic features as communication means. In *Proceedings of DeSForM 2013*, pp. 71-84.
- [14] Vallgård, A., (2014) Giving form to computational things: developing a practice of interaction design, *Journal Personal and Ubiquitous Computing*, Volume 18 Issue 3, pp. 577-592
- [15] Locher, P., Overbeeke, C. J., & Wensveen, S. A. G. (2010) Aesthetic interaction: A framework. *Design Issues*, 26(2), 70-79.
- [16] Eco, U. (1962) *Opera Aperta*. Milano: Bompiani.
- [17] Hallnäs, L. & Redström, J. (2000) *Slow Technology. Designing For Reflection*, *Journal of Personal and Ubiquitous Computing*. Springer-Verlag.
- [18] Eckert J., Scheiber, L., and Schwehr, P. (2014) Are Open Innovation processes structured for disturbance?. In Coletta, C., Colombo, S., Magaudda, P., Mattozzi, A., Parolin, L., and Rampino, L., (eds.) *A Matter of Design: Making Society through Science and Technology*. *Proceedings of the 5th STS Italia Conference*, pp. 329-339, Available at: [http://www.stsitalia.org/conferences/STSITALIA\\_2014/STS\\_Italia\\_AMoD\\_Proceedings\\_2014.pdf](http://www.stsitalia.org/conferences/STSITALIA_2014/STS_Italia_AMoD_Proceedings_2014.pdf)
- [19] Desmet, P., & Hekkert, P. (2007) Framework of product experience. *International journal of design*, 1 (1)
- [20] Manzini, E., (1989) *The Material of Invention*, The MIT Press
- [21] Vallgård, A. (2009) Computational composites, understanding the materiality of computational technology, Manuscript for Ph.D. dissertation submitted to the IT University of Copenhagen, September 2009
- [22] Addington, M., and Schodek, D. (2005) *Smart Materials and Technologies for the Architecture and Design Professions*. Amsterdam: Elsevier.

# Searching for balance in aesthetic pleasure in interaction

## Abstract

In this paper, we investigate the interplay between unity-variety, and novelty-typicality in relation to the beauty experienced in the movements performed while interacting with a product. We conducted a study that explored how these factors affect the aesthetic pleasure elicited from interaction. Results showed that novelty and typicality jointly explained aesthetic pleasure: People derive aesthetic pleasure from interactions that offer a feeling of doing things in a new way within the boundaries of familiarity. Regarding unity-in-variety, we found out that it does not matter how varied the interaction with a product is, as long as this variety combines into a unified, coherent experience of the interaction. The findings are discussed in light of a dual impulses model of aesthetic experience and aesthetics principles of interaction design.

## Keywords

Interaction aesthetics, novelty, typicality, unity, variety.

## 1 Aesthetics and interaction

The *aesthetics of interaction* is a field of design that focuses on the multiple ways in which a user-product interaction can be pleasurable. The term, however, is currently used for mainly referring to a range of pleasant sensations resulting from interactions with digital and intelligent products (Djajadinigrat,

Overbeeke & Wensveen, 2000; Löwgren, 2009; Wright, Wallace & McCarthy, 2008). With the products becoming more networked, proactive, and context-aware, they portray behavior in interaction (Ross & Wensveen, 2010). Consumer products in ordinary use, however, also exhibit a kind of dynamic interaction. An umbrella is opened by pushing a plastic piece on a shaft to extend its telescopic structure and open the ribs, while also holding it firmly with the other hand in a direction pointing outwards from one's body; a vacuum cleaner is operated by pushing the hose forward and backwards over the floor while also carefully pulling the vacuum cleaner behind, and a lighter is flicked by turning down a wheel with one's thumb and immediately after pressing down a tab to hold the fire. In performing these actions, the product responds and provides feedback. We consider that all these actions do not just play a functional role, but performing them can be aesthetically rewarding in itself and thus studied within the scope of aesthetics of interaction.

In this paper, we focus on the *aesthetic* pleasure derived from the physical engagement or interaction with products. Our understanding of aesthetics in the context of interaction is a response that is often regarded as purposeless and distanced in the Kantian sense (Kant, 1952). It is a pleasurable response that people get from perceiving and understanding the things around them, i.e., a pleasure derived from

processing the product for its own sake (Dutton, 2009). We describe this pleasure as appreciation, or beauty (Hekkert, 2014b).

This approach is slightly different from how aesthetics is referred to in interaction design literature: It is generally used in the sense of 'joy of use', i.e., "the overall pleasure found in the function of the product itself" (Overbeeke et al., 2000, p. 2). This inclusive definition is consistent with a pragmatist notion of aesthetic experience (Dewey, 1934; Shusterman, 1992; Petersen et al., 2004), in which an aesthetic experience is shaped by the integration of the sensual, intellectual and emotional aspects of life with social norms and political landscapes (Loke & Robertson, 2010; Rozendaal & Schifferstein, 2010). Here, the boundaries between the concepts of *an aesthetic interaction* and *a pleasurable user experience* become blurred. A product experience is composed of an entire set of effects that is triggered by the interaction between a user and a product, including the degree to which users' senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning), and the emotions that are elicited through interaction (emotional interaction; Hekkert, 2006). These three constituents are conceptually different, yet very much intertwined. In our approach, we consider aesthetic experience as one component of user experience and leave out a product's cultural and social interpretations or the feelings evoked by its use from our scope.

Interaction is one of the ways in which a product can elicit an aesthetic experience (for an overview of other means, see Hekkert, 2014a). Locher, Overbeeke, and Wensveen (2010) state that aesthetic interactions are based on the information flow between a user and a product, where the user perceives, reflects on, and acts upon it through his or her sensory-motor and cognitive capabilities. In this paper, we focus on these levels of human processing and explore the role that two fundamental aesthetic principles play in them: on the sensory-motor level (i.e., perceptual level) *Unity-in-Variety* (UiV), and on the cognitive level *Typicality* and *Novelty* (a.k.a., Most-Advanced-Yet-Acceptable; MAYA). These principles are mainly studied in relation to the visual experience of artworks and products. Here, we attempt to determine if and how UiV and MAYA could account for aesthetically pleasing interactions and assess the relative importance of these

principles to explain aesthetic pleasure in interaction. Drawing on the traditional field of empirical aesthetics, we aim to expand the aesthetics of interaction paradigm by testing certain parameters. Our focus is on the dynamic qualities of the interaction: the connection between the bodily actions of a user and the responses of a product. An interaction with a product can surely be aesthetically appreciated owing to the sounds the product makes, the way the product looks, and so on, however, what is central to the aesthetics of interaction is the movement, bodily awareness and felt experience of users while handling the product (Loke & Robertson, 2010). This is the way we operationalize this concept as well, i.e., how the movement of one's hands and body feel when operating a product (without taking into consideration what the product is for, what it looks like, etc). For this reason, we believe our results can be expanded to bodily actions one performs with different types of products whether they are physical (a hammer), mechanical (a bike), electronic (a mobile phone), or digital (internet radio). Eventually, the principles possibly allow aesthetic interactions to be designed accordingly.

In the coming sections of this paper, we will first present the theoretical underpinnings of our aesthetics model and the aesthetic principles under scrutiny. As a first attempt to offer some empirical ground, we will then present the results of an exploratory study. Finally, we will tentatively discuss our results in the broader light of interaction design.

## 2 Aesthetic pleasure – A magical balance

Hekkert (2014a) proposes an evolutionary framework to product aesthetics so as to explain the factors that make products beautiful to watch, feel and interact with (i.e., the UMA model). Central to this framework is the claim that aesthetic experiences arise in the midst of a balance between two complementary pressures at each level of human processing. One is rooted in humans' need for *safety*—the choices that facilitate perceptual understanding and efficient processing—and the other is derived from the need for *accomplishment*—the choices that facilitate extending capabilities and prompt exploratory behavior. An aesthetic experience is considered maximal when these two opposing needs are met to a high degree. At the perceptual level, these needs are mainly concerned with organization of object properties, and at the cognitive level they have to do

with evaluating how a product compares to others of a similar kind. The question is how they can be understood on a behavioral level.

### 2.1 Unity-in-Variety

Well described by the Gestalt psychologists, people derive pleasure from patterns in the environment that facilitate perceptual organization (Arnheim, 1971). These patterns, such as symmetry, repetition, and continuity, bring order to the flow of information. However, our brains have also evolved to appreciate diversity, complexity, and variety (Berlyne, 1966). Diversity drives us for exploration and learning, as well as helps us to avoid boredom. As a consequence, both unity and variety positively affect aesthetic pleasure: We get the maximum aesthetic pleasure when designers allow for maximum variety whilst establishing an optimum of unity and organization. In other words, we like unity-in-variety (Berlyne, 1971; Fechner, 1876). Post, Blijlevens and Hekkert (2013) have demonstrated this balance for various product types and different types of perceivers in the visual domain. Unity-in-variety has also been demonstrated in some non-visual domains, including music (Brattico, Brattico & Jacobsen, 2009), food (Lawless, 2000) and tactility (Gallace & Spence, 2011).

In the interaction design domain, these principles are also mentioned, albeit theoretically. For instance, Rozendaal and Schifferstein (2010) describe aesthetics as experiencing variety, simplicity, and harmony; whereas Djajadiningrat et al. (2004) list the factors of flow and rhythm that link user actions and product reactions, and variety of orders and combinations of actions as strong influencers of aesthetics of interaction. Yet, they are not tested empirically in combination. In this study, we will test if unity and variety together explain the aesthetic pleasure derived from interacting with a product. Our first hypothesis is:

***H1: Products that maximize the variety of the actions to operate in a unified manner will be aesthetically most appreciated.***

### 2.2 Novelty and Typicality

While some studies have shown that people prefer typical, familiar product designs, others have demonstrated that people also like product designs that are unusual or new (see Hekkert & Leder, 2008

for an overview). As an explanation for these opposing findings, the design principle 'Most Advanced, Yet Acceptable' (MAYA) suggests that people in fact prefer a balance of both typicality and novelty in product designs. This principle has since been tested for a range of consumer products, and it has been found that the most attractive product designs are those that maximize both typicality and novelty simultaneously, such as teakettles that follow the standard teakettle shape and use conventions like bulky body with a spout and a long handle on the top, while having a "twist" in the detailing of these parts like use of bright colors or different materials (Hekkert, Snelders & van Wieringen, 2003). As argued, aesthetic processing as proposed here does not only apply to artifacts as objects for admiration and contemplation in a passive sense. Some artifacts, such as products, demand to be touched and used and this interaction can be pleasing for different reasons, but along similar lines. In this study we will test whether the MAYA principle also holds when considering the aesthetic pleasure derived from interacting with or operating a device. Therefore, our second hypothesis is:

***H2: Products that perform their task in a novel yet familiar fashion will be aesthetically most appreciated.***

## 3 Study

In this study, we investigated the two hypotheses mentioned above through a questionnaire filled in by participants on the basis of real interactions with a product. Below this process and its outcomes will be presented in detail.

### 3.1 Method

**Stimuli.** To investigate the effects of UiV and MAYA on aesthetic pleasure in interaction, a product category had to be selected that included products with variation in interaction. We chose to use "corkscrews" as a product category since opening a wine bottle is a complex action that commonly requires coordination of different hand and body movements and the product category includes a variety of ways to open a bottle. From this category, we chose to use in the study (Figure 1): (a) a basic T-bar shaped corkscrew that requires pushing the worm into the cork by twisting the corkscrew and pulling the cork out with brute force (from now on, "Simple"), (b) a Sommelier type corkscrew ("Sommelier"), (c) a two-



winged corkscrew that requires lowering two handles to pull the cork out with a gear mechanism (“Winged”), (d) a continuous-turn corkscrew that employs the same turning action to twist the worm into the cork and pull the cork out (“Continuous”), (e) a corkscrew with the same continuous turning mechanism but requires an extra squeeze from the sides to keep the corkscrew in place (“Squeeze”), (f) a lever-style corkscrew that lowers the worm into the cork with a push down of the lever and removes the cork out with a simple pull up (“Lever”), and (g) an electric corkscrew that requires pressing a button the pull the cork out (“Electric”).

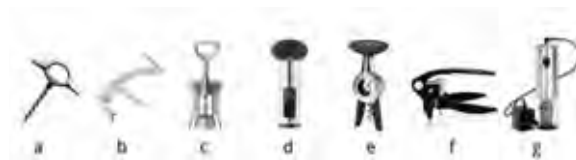


Fig. 1. Corkscrews used in the study together with their given aliases, a: “Simple” (unknown brand), b: “Sommelier” (IKEA), c: “Winged” (IKEA), d: “Continuous” (Brabantia), e: “Squeeze” (IKEA), f: “Lever” (Screwpull), g: “Electric” (Peugeot)

**Participants.** A total of 30 participants (mean age = 25.9, SD = 3.06, 16 female) were recruited from the MSc. and Ph.D. student population of Delft University of Technology, Faculty of Industrial Design Engineering. All participants received 10 Euros for their contribution.

**Procedure.** Before the study, we recorded short movie clips showing the operation of the corkscrews to be used in the experiment. This was done to eliminate the bias that “figuring out” how to use a particular corkscrew could have on their aesthetic evaluation. Since our study was focused on the novelty of performing a particular movement when opening a wine bottle, we intended to establish the condition that the participants should know how to perform the action even though it is the first time they are experiencing it. These movies were embedded in the questionnaire together with the scales to evaluate the corkscrews.

We prepared an experiment room with a separating screen where two participants at once were able to test the corkscrews and take the questionnaire without intervening the other’s process. At the beginning of each session, the participants were introduced to the aim of the study and invited to sit in front of the computer screen to watch the movie clips one after another. Then, they were given the corkscrews one-by-one in random order and asked to open a wine bottle (which was filled with water). The interaction started by picking up the corkscrew from the table, positioning it on the wine bottle and ended by opening the bottle. Slicing open the foil around the bottleneck and removing the pulled-out cork from the corkscrew were left out from the interaction. Respondents were also told that they

Table 1. The items used in the questionnaire

Factors	Scales
Aesthetic appreciation	It was <b>beautiful</b> to uncork a bottle of wine this way. Uncorking the bottle of wine this way was <b>attractive</b> . It was <b>pleasing</b> to uncork a bottle of wine this way. It felt <b>nice</b> to uncork a bottle of wine this way. I <b>liked</b> this way of uncorking a bottle of wine.
Unity	There was <b>unity</b> in the actions that were needed to uncork the bottle this way. The actions that were needed to uncork the bottle of wine formed a <b>whole</b> .
Variety	Uncorking the bottle of wine this way required a <b>variety</b> of actions. There was <b>diversity</b> in the actions needed to uncork the bottle of wine this way.
Novelty	This was a <b>unique</b> way of uncorking a wine bottle. Uncorking the bottle of wine this way felt <b>special</b> .
Typicality	This was a <b>typical</b> way of uncorking a bottle of wine. Uncorking the bottle this way was a <b>common</b> way to do it.

could quit trying out a particular corkscrew if they deemed it too difficult/painful to use. After every trial, we noted down if the attempt for opening the bottle was a success or failure. The participants were then asked to indicate the extent to which they agreed to the statements in Table 1 on 7-point-scales ranging from “not at all” to “very much”. The participants were not allowed to skip any of the evaluations. The various items were adapted from the scales developed and validated for aesthetic appreciation, unity, variety, typicality, and novelty by Blijlevens et al. (2014) in the domain of visual aesthetics.

When filling out the questionnaire, the participants were reminded to think of their experience holistically, i.e., not just focusing on the outcome, but also considering how they held it in their hand, moved the corkscrew, and so on. An unused cork was inserted in the bottle after each trial with a cork inserter. The whole study lasted between 35–40 minutes per participant.

### 3.2 Results

A total of six individual trials, in which the participant was unable to open the bottle, was removed from the data set (4 times with the “Sommelier” corkscrew, 2 times with the “Simple” corkscrew). This was to remove the possible effect of accomplishment from the findings. To estimate the effects of both principles considered in this paper, a series of multivariate regression analyses is performed. In the course of two distinct analyses the effects of UiV and MAYA are analyzed separately. Afterwards, a third regression analysis is run, including both principles together. This procedure allows us to gather whether effects overlap. In other words, it is conceivable that effects of unity and variety at the perceptual level can partly be attributed to the MAYA principle as well. Or, the other way around, effects of novelty and typicality of the interaction may also affect the experience of unity and variety, e.g., the typical way of handling a product might also feel more unified because of its familiarity. We give preference to this course of action over a stepwise procedure, because we have no expectations from the outset about the causal relation between these dimensions. Although it is very well possible that one of the principles concerned causally precedes the other, we do not formulate particular hypotheses about this. In the following analyses, aesthetic appreciation is used as the dependent

variable. It is calculated as the average of the scores attributed by a respondent on the items “beautiful”, “attractive”, “like”, “felt nice”, and “pleasing”.

**Unity and Variety.** For the perceptual level we construct measures of unity and variety experienced in the interaction. Unity is the average of the scores on the items “unity” and “wholeness”. Similarly, for variety, the average is calculated of “variety” and “diversity”. As expected, these measures correlate negatively, albeit moderately ( $r=-0.25$ ,  $p<0.01$ ). Together, these measures constitute a model that significantly explains differences in aesthetic appreciation ( $F(2, 207)=47.758$ ,  $p<0.001$ ). Unity and variety together account for 31% of variance in aesthetic appreciation.

However, when looking at parameter estimates, it turns out that they do so to a very different extent. For unity,  $\beta$  amounts to 0.54 ( $p<0.001$ ). By contrast, the effect of variety on the aesthetic appreciation of the interaction is insignificant. Stated differently, respondents liked a higher sense of unity when interacting with the corkscrews, but the level of felt variety did not impact on their aesthetic appreciation. This lack of effect is interesting, as it seems to suggest that the pleasure people derive from an interaction does not depend on the interaction being either unvaried and monotonous or –on the contrary– overly complicated. This seems unlikely. We would suggest a different interpretation. When performing a univariate regression analysis of the effect of variety on aesthetic appreciation, the relation even turns out to be negative ( $\beta = -0.20$ ,  $p<0.01$ ). In principle, people dislike an interaction involving too many different actions. Hence, the level of variety only becomes irrelevant when taking into account unity. From an aesthetic perspective, it does not matter how varied the interaction with a product is, as long as this variety combines into a unified, coherent interaction experience.

These results are presented graphically in Figure 2. Next to the diamonds representing the individual corkscrew models included in the test, the average score on aesthetic appreciation is stated. We could try to make sense of our findings by taking into consideration the actual corkscrew models that were included into the test, although caution is warranted in doing so, given that only a rather limited number of

products from a single category was tested. We should therefore stress that this interpretation is tentative. It is apparent that variety was interpreted in terms of the number of steps involved in the process of uncorking a bottle with the corkscrew under consideration. The lowest scores were attributed to models that require little handling from the user, whereas higher up the scale we find corkscrews that open a bottle through a series of manipulations.

Unity, on the other hand, seems to have been interpreted primarily in terms of how much the interaction steps differ. To illustrate, “Simple” involves a screwing manipulation, followed by pulling. “Lever”, by contrast, requires manipulating a lever – one downward and one upward movement. Although both “Lever” and “Simple” involve two basic manipulations, only in the case of “Simple” are these actions essentially different. Hence its lower score on unity. Although it is rather obvious that the models higher up the X-axis are liked better, a similar trend is clearly lacking on the Y-axis representing variety. Interestingly, the graph makes quite clear that these findings are not due to limited dispersion on the variety scale. In fact, the range in average variety scores is notably larger than the range on unity. Therefore, once again this substantiates that both varied and unvaried interactions may be aesthetically pleasing, provided that they are experienced as unified.

**Novelty and Typicality.** To test whether the MAYA principle holds for aesthetic pleasure in interaction, the aesthetic pleasure measure is regressed on measures of novelty and typicality. For novelty, per respondent we calculate the mean score of the items “unique” and “special”. For typicality, the average is used of “typical” and “common”. In line with the expectations proposed by UMA, these measures present a strong negative correlation ( $r=-0.75$ ,  $p<0.01$ ). Again, the resulting regression model is highly significant ( $F(2, 207)=72.938$ ) and it accounts for 41% ( $p<0.001$ ) of variance in aesthetic appreciation. For both novelty and typicality, coefficients are significant and quite considerable (novelty  $\beta=0.96$ ,  $p<0.001$  and typicality  $\beta=0.65$ ,  $p<0.001$ ). Moreover, the fact that they are both positive confirms the hypothesis about the MAYA principle. Respondents find an interaction more aesthetically pleasing if they experience it as being both typical and novel.

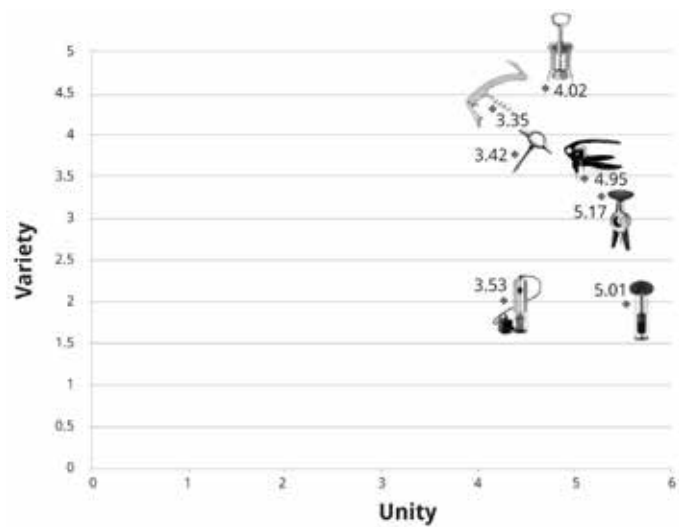


Fig. 2. The scores of the individual corkscrews for unity, variety, and aesthetic appreciation

In Figure 3, again the results are summarized. It can be seen that the corkscrews positioned towards the middle get the higher scores on aesthetic appreciation, meaning that respondents like the interaction to reconcile a sense of novelty as well as typicality. This can be inferred from (tentatively) looking at the individual corkscrews. The group on the top left of the graph could be considered traditional corkscrews, as they clearly require from the user to perform the basic manipulations of opening a bottle – turning a screw and pulling the cork out. By contrast, the models in the bottom right of the graph perform these actions almost invisibly. They do not translate into actions by the user (pushing a button in one case, manipulating a lever in the other). The ones in the middle seem to offer a middle road. Although they do not require a separate pulling manipulation by the user – much like the novel ones – they do visibly translate the user’s manipulations into both a screwing and a pulling action (in line with the typical ones). However, as was also apparent from the higher  $\beta$  coefficient, novelty is slightly predominant. People derive aesthetic pleasure from an interaction that is familiar to them, but even more so they like a feeling of doing things in a new way.

**Interaction of the factors.** The final regression model combines unity and variety with novelty and typicality, as this should allow us to gather whether the principles under scrutiny are related in explaining the aesthetic appreciation of the interaction with a product. Given the significance of the foregoing models, it hardly

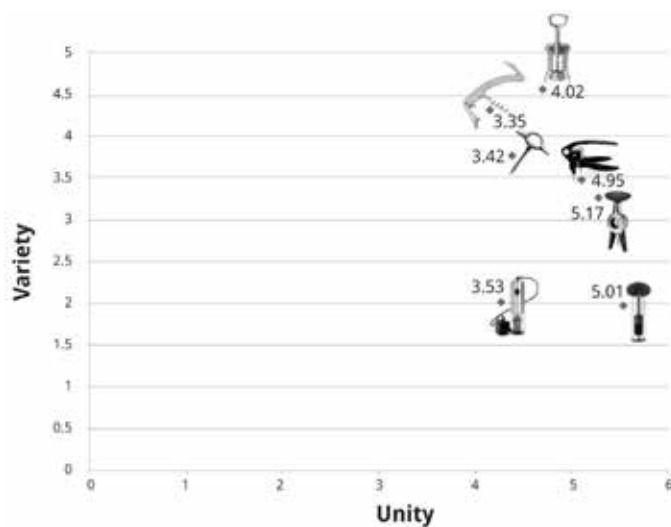


Fig. 3. The scores of the individual corkscrews for novelty, typicality, and aesthetic appreciation

needs explaining that the combined regression model is significant as well ( $F(4, 205)=25.030, p<0.001$ ). The proportion of variance explained by the model further increases to 52% ( $p<0.001$ ), which may already be taken to mean that both dimensions of UMA do not overlap entirely and thus contribute uniquely to the aesthetic appreciation of the interaction.

Again the effect of variety fails to reach significance, but unity still has a significant impact on aesthetic appreciation. However, it has become somewhat weaker ( $\beta=0.36, p<0.001$ ). Also, both measures constituting the MAYA principle maintain large significant effects (novelty  $\beta=0.75, p<0.001$  and typicality  $\beta=0.51, p<0.001$ ), but these have also decreased as a result of including perceptual measures. In sum, although individual effects are preserved in the combined model, the principles share some common ground. Strictly speaking, the design of our study does not allow for causal inferences.

#### 4 Discussion and Conclusion

The study of aesthetics in the design field has concentrated much more on the appearance of products, such as shape, color, or texture, than on the interaction between user and product (Djajadiningrat et al., 2004). In this paper, we intended to answer the question of when people experience the *interaction* with products as aesthetically pleasing. The study we have conducted to address the factors that affect aesthetic appreciation revealed that, (1) the extent to which an interaction is experienced as *novel* for a particular task

must be weighed against to which it is *familiar* in order to attain aesthetic pleasure, (2) unity has a bigger effect on aesthetic pleasure than *variety*, i.e., as long as there is one unified, coherent interaction experience, it does not matter how varied an interaction is.

To start with the latter, it was apparent that the participants liked the smooth and uninterrupted way to exert force upon a cork to open the bottle of wine. Unity is not about simplicity, as indicated by the low aesthetics score of the “Electric” corkscrew which only involves pressing one button down during interaction. We consider that it is mainly about the rhythm and flow in interaction, which exhibited itself in terms of how much the different steps in interaction differ from each other. The “Lever” and “Simple” corkscrews indicated how a continuous flow in movement (pushing down and pulling up a lever) make a difference in liking scores in comparison to the interrupted movements of twisting the worm into cork and putting the bottle between the legs to be able to exert more force, respectively. It is not surprising that the least liked corkscrew among the participants, the “Sommelier”, required a final precise adjustment of the arm to brace the lip of the bottle for leverage. Seemingly, this low degree of liking is not because of the number of steps that are needed to accomplish the task, but it mainly stems from the lack of smooth transition between these steps, as the distribution of the corkscrews indicate.

Variety not having an effect on aesthetic appreciation when there is a felt unity can also be because of the task-orientedness in our experimental setting. The participants probably focused on “opening the bottle” and considered any sort of variety as an obstruction. The visual domain, where UiV is commonly investigated, does not require one to accomplish a task while evaluating unity or variety: The role of the participant is to simply look at the painting, inspect a landscape or observe a car interior. We could speculate that if a similar task were to be given to those participants, such as “explain that painting”, then unity may start to play a more prominent role. Most of the interactions with products require some sort of task accomplishment. It is an interesting question to address in further studies if unity-in-variety could only exist in interaction aesthetics provided that there are sufficient levels of unity to accommodate for variety.

When it comes to the MAYA principle, the results are more definite and clear. People aesthetically prefer to interact with corkscrews when the interaction is both novel and typical for its category. As the results showed, the two corkscrews that scored highest on aesthetic pleasure are the corkscrews with familiar interaction mechanisms that have novel embodiments. For interaction design of computing artifacts, we can therefore hypothesize that when developing novel interaction styles that are aesthetically pleasing, elements of existing action repertoire should be incorporated in the user interface. Examples of tangible interaction have this potential since everyday mechanical and physical products (with familiar interactions) can have new digital functionalities attributed to them.

This finding adds to the growing body of evidence that MAYA is a dominant aesthetic principle that holds for a range of product categories and sensory domains (e.g., Blijlevens, Gemser & Mugge, 2012; Tractinsky et al., 2011). Since any aspect of a product, such as its form, tactile qualities, and the interaction it affords, can be novel or typical to some degree, it would be interesting to examine if the MAYA principle also holds across sensory domains. Would we aesthetically appreciate interacting with a device that is novel in interaction, but very typical in its appearance, and vice versa? Future studies will shed light on this fascinating option.

The results of the combined regression analysis indicated that the two principles explained 52% of aesthetic appreciation for certain interactions ( $p < 0.001$ ). Other variables could be added to this analysis to increase this level of explained variance even further. Based on the ratings for the “Electric” corkscrew, it is apparent that interactions that are too easy are not considered that beautiful. Shusterman (1992) talks about a type of aesthetic appreciation that comes from mastering the technique of playing a challenging part on a musical instrument. Along the lines of the conflicting needs model (specified in the UMA model), this may refer to a trade-off between being challenged by the product while performing those movements in a way that make the user feel in control. As Djajadiningrat et al. (2004, p. 297) aptly put forward, “Whilst we do not intend to turn every product into a calligraphy brush or a violin, there seems to be a fair amount of room to manoeuvre between

the actions required by those objects”. Further studies should test this prediction. Similarly, the “Sommelier” corkscrew might require some mastering, which would make a good product for skill development or showing-off at dinner parties. The extent to which an interaction with a product is appropriate to elicit its intended functionality can also be another factor that has an effect on aesthetic pleasure. This is related to the principle named *Maximum Effect with Minimal Means* (Hekkert, 2006) and also asks for additional studies to investigate how this principle relates to aesthetic appreciation in corkscrews and human-product interactions in general.

Since we aim to unravel the general principles that underlie aesthetics of interaction, we expect that these principles would also apply to a diverse range of products from the physical and mechanical, to the digital. Using a hammer can be beautiful if its particular operation is considered novel yet familiar, just as is liking the movement one has to make to turn up the volume of a particular internet radio app. Whatever the utility and whatever the concrete form the interaction takes, these products have in common that they require hand/body movements to be operated, to which they respond and offer the user feedback.

For this reason, in principle we hypothesize that all types of interaction can elicit aesthetic pleasure through following the principles of UiV and MAYA. What is important for designers is finding ways to implement these principles as physical features in a design. An awareness of the interplay between the aesthetic principles and properties of the interaction could allow designers to design interactions more consciously and hereby have more control on the kinds of experiences people might have with products. The study has opened some interesting directions for future research, mostly in an explorative way. Future studies should provide more definitive corroboration and substantiation of these findings.

### Acknowledgements

We are grateful to Reinier Jansen for his help in programming the questionnaire in MAX. Paul Hekkert was supported by MAGW VICI grant number 453-10-004 from the Netherlands Organization for Scientific Research (NWO).

## 5 References

1. Arnheim, R. (1971). *Art and visual perception: A psychology of the creative eye*. University of California Press.
2. Berlyne, D. E. (1966). Curiosity and exploration. *Science*, 153, 25-33.
3. Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York: Appleton-Century-Crofts.
4. Blijlevens, J., Gemser, G., & Mugge, R. (2012). The importance of being 'well-placed': The influence of context on perceived typicality and esthetic appraisal of produce appearance. *Acta Psychologica*, 139(1), 178-186.
5. Blijlevens, J., Thurgood, C., Hekkert, P., Leder, H. & Whitfield, T.W.A. (2014). The Development of a Reliable and Valid Scale to Measure Aesthetic Pleasure in Design. In A. Kozbelt (Ed.), *Proceedings of the Twenty-third Biennial Congress of the International Association of Empirical Aesthetics* (pp. 100-106), August 22-24, New York, USA.
6. Brattico, E., Brattico, P., & Jacobsen, T. (2009). The origins of the aesthetic enjoyment of music – A review of the literature. *Musicae Scientiae*, Special Issue, 15–37.
7. Dewey, J. (1934). *Art as experience*. New York: Capricorn Books.
8. Djajadiningrat, J. P., Overbeeke, C. J., & Wensveen, S. A. G. (2000) *Augmenting Fun and Beauty: A Pamphlet*. In *Proceedings of DARE'2000* (pp. 131-134). ACM Press.
9. Djajadiningrat, T., Wensveen, S., Frens, J., & Overbeeke, K. (2004). Tangible products: Redressing the balance between appearance and action. *Personal and Ubiquitous Computing*, 8(5) , 294-309.
10. Dutton, D. (2009). *The art instinct*. New York: Oxford University Press.
11. Fechner, G. T. (1876). *Vorschule der Ästhetik*. Leipzig: Breitkopf und Härtel.
12. Gallace, A., & Spence, C. (2011). To what extent do Gestalt grouping principles influence tactile perception? *Psychological Bulletin*, 137, 538-561.
13. Hekkert, P. (2006). Design aesthetics: principles of pleasure in design. *Psychology Science*, 48(2), p. 157-172.
14. Hekkert, P. (2014a). Aesthetic responses to design: A battle of impulses. In T. Smith & P. Tinio (Eds.), *The Cambridge Handbook of the Psychology of Aesthetics and the Arts* (pp. 277-299). Cambridge: Cambridge University Press.
15. Hekkert, P. (2014b). What I Talk About When I Talk About Aesthetics. In A. Kozbelt (Ed.), *Proceedings of the Twenty-third Biennial Congress of the International Association of Empirical Aesthetics* (pp. 244-246), August 22-24, New York, USA.
16. Hekkert, P. & Leder, H. (2008). Product Aesthetics. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product Experience* (pp. 259-286). Amsterdam: Elsevier.
17. Hekkert, P., Snelders, D., & van Wieringen, P. C. W. (2003). 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British Journal of Psychology*, 94, 111-124.
18. Kant, I. (1952). *The critique of judgement*. (J.C. Meredith, Trans.). Oxford: Clarendon Press. (Original work published 1790).
19. Lawless, H.T. (2000). Sensory combinations in the meal. In H.L. Meiselman (Ed.), *Dimensions of the meal: the science, culture, business and art of eating* (pp. 92-106). Gaithersburg, MD: Aspen.
20. Locher, P., Overbeeke, C. J., & Wensveen, S. A. G. (2010). Aesthetic interaction: A framework. *Design Issues*, 26(2), 70-79.
21. Loke, L., & Robertson, T. (2010). Studies of dancers: Moving from experience to interaction design. *International Journal of Design*, 4(2), 39-54.
22. Löwgren, J. (2009). Toward an articulation of interaction esthetics. *New Review of Hypermedia and Multimedia*, 15(2), 129-146.
23. Overbeeke, C.J., Djajadiningrat, J.P., Hummels, C.C.M. & Wensveen, S.A.G. (2000). Beauty in usability: Forget about ease of use! In W.S Green & P. W. Jordan (Eds.), *Pleasure with products: Beyond usability* (pp. 9-18). London: Taylor & Francis.
24. Petersen, M. G., Iversen, O. S., Krogh, P. G., & Ludvigsen, M. (2004). Aesthetic interaction: A pragmatist's aesthetics of interactive systems. In *Proceedings of the 5th Conference on Designing Interactive Systems* (pp. 269-276). New York: ACM.
25. Post, R. A. G., Blijlevens, J., and Hekkert, P. (2013). The influence of unity-in-variety on aesthetic appreciation of car interiors, In K. Sugiyama (Ed.), *Consilience and Innovation in Design: Proceedings of the 5th International Congress of International Association of Societies of Design Research*. Tokyo: Shibaura Institute of Technology.
26. Ross, P. R., & Wensveen, S. A. G. (2010). Designing aesthetics of behavior in interaction: Using aesthetic experience as a mechanism for design. *International Journal of Design*, 4(2), 3-13.
27. Rozendaal, M. C., & Schifferstein, H. N. (2010). Pleasantness in bodily experience: A phenomenological inquiry. *International journal of design*, 4(2), 55-63.
28. Shusterman, R. (1992). *Pragmatist aesthetics. Living beauty, rethinking art*. Blackwell.
29. Tractinsky, N., Abdu, R., Forlizzi, J., & Seder, T. (2011). Towards personalisation of the driver environment: Investigating responses to instrument cluster design. *International Journal of Vehicle Design*, 55, 208-236.
30. Wright, P., Wallace, J., & McCarthy, J. (2008). Aesthetics and experience-centered design. *ACM Transactions on Computer-Human Interaction*, 15(4), 1-21.

# The Aesthetics of Digital Objects

## Abstract

This paper is a contribution to the conceptualization of the aesthetics of digital objects. Taking its starting point in the challenge posed by digital technology for the perception and ontology of design objects, the paper discusses how a theory of aesthetics can be developed that fits the kinds of objects which can be open in intention, interactive, and dynamic in their extension and transformative capabilities. The paper argues that a new interpretive framework is required for us to comprehend the new kinds of dynamic objects enabled by digital technology. It is not enough to speak of aesthetics in general as a theory of, e.g., appeal and sensation but vital to seek specific concepts for contemporary objects in terms of a) how they operate as means of creating new kinds of experience, b) how they create dynamic meeting points between subject and object, and c) how new aesthetic categories are produced, for example by companies, to frame the aesthetic meaning of objects. This kind of theory is relevant for design practice as a means of clarifying dimensions of product aesthetics that are incorporated and addressed in product design.

## Keywords

Digital design, design ontology, aesthetic theory, aesthetic categories

## 1 Introduction

With the incorporation of digital technology, design has changed. We can no longer speak of closed, static objects with a given, material extension to be perceived and to frame the reading of the function and idea of the objects. Digital technology changes the objects from the inside out: Incorporated into material objects digital technology may enable the objects to be open in their inner expansion (such e.g., in all types of computers from smartphones to laptops) and may let them appear as interactive, dynamic objects, always on the verge of or with the potential of constant transformation (e.g. gesture-sensitive artefacts), but also as inaccessible, verging on unreadable (for example the way a screen may appear as an 'opaque surface' [1]).

With the change of design due to digitization, both the perception and the conceptualization of design may also take on a different character. With its focus on meaning, product semantics has, at an early stage, adapted the challenge of digitization, as evidenced by the recent DeSForM conferences. When 'form follows meaning', to repeat an almost classical phrase [2], meaning becomes the generative principle of design, and, hence, digitization can be seen as a formative principle of meaning. In other design disciplines, digitization still presents a challenge. In the culturally oriented disciplines of design history and design culture, the focus has been on questioning the roles of designed objects in their specific context, network and circuit of

production, mediation and consumption, at least with regard to contemporary approaches to design history [3] and design culture [4]. But often, these disciplines have not conceptualized digital design objects. To quote the design historian Kjetil Fallan from a keynote lecture at a conference on design culture: 'The digitalization of design culture [...] is a rich and thus far virtually unexplored terrain for design history, and certainly one that holds the potential of reconnecting design history with design practice' [5]. Fallan states that 'the digitalization of design and manufacturing processes [...] has been the greatest paradigm shift in the design profession and the manufacturing industry since the industrial revolution'.

The conceptualization of aesthetics in design is also affected and challenged by digitization, as digital objects are interesting both as material objects and as containers of interactive meaning, as static entities and as dynamic, often mediatized creators of new experiences. Traditionally, aesthetics has been employed to express both the specifics of material, 'beautiful' objects and the more dynamic sensations and experiences evoked by objects or conditions in human life. In the following, I discuss how we can conceptualize an *aesthetics of digital objects*. I set out by discussing the ontology of digital objects as a platform for proposing a differentiated conception of design aesthetics that shifts attention away from the classical notion of (and obsession with) the concept of beauty to effects of sensation, challenging of meaning and framing of context. The Beolit 12 music device from B&O Play will be used to illustrate the potential of the aesthetics of digital objects in terms of sensual appeal, dynamic effects of interaction and the understanding and role of the cultural context for what we perceive and construct as aesthetic.

## 2 Digital Design

Seen from the perspective of the material culture of design, design objects employing digital technology present a challenge as well as a new culture of design where objects are capable of more than is visible to the eye. Increasingly, objects and products contain or are enabled by digital technology which, in turn, fundamentally structures their functions, usability and character. This phenomenon affects everyday objects in particular, from smartphones and computers employing interactive interfaces to low-tech products such as

toasters and watches. The world is still full of low-tech objects such as bottles and cups, but even so, a revolution is affecting the world of design: A *digital turn* has taken place in the way that objects are conceived, designed and meet users and consumers.

The important question is how digitization affects the perception and conception of design objects *qua* objects with a specific material character and extension, that is, how we can speak of a specific ontology of digital objects, and what this means for the way we meet and engage with them. In a recent discussion, the German design theorist Gert Selle labels these new kinds of objects half-things, objects that still have the character of a material thing to be grasped, 'but which cannot be comprehended in the richness of its optional functions' [6]. For Selle, the difference between things and half-things lies in our ability to engage directly with the thing and to read its implicit purpose. With Martin Heidegger's concept of *Zeug*, things ready at hand, Selle asks how the design object 'places us in the present'; that is, how we meet the design, but also how it meets us and reaches out for us. For, as Selle clearly states, with new kinds of design the conditions of experiencing change: 'every new technology changes the cultural spectrum of experience' [6].

Following Selle's point about half-things, digital objects can be said to rely less on appearance and more on function. They rely less on appearance, as the digital objects can never fully communicate their function at a single glance. Far from the dictum of 'form follows function' in industrial Modernism, where objects were supposed to signal their function, many digital objects are discreet objects, which display less than their full capability. This aspect of the design is epitomized by the Cube Click Clock, a simple alarm clock, which only reveals its function when touched; otherwise, it appears as a simple wood block (with an artificial wood finish) (Figure 1). This quality resonates the design of an early consumer electronic object, the seminal TV Black 201 (1969) designed by Marco Zanuso and Richard Sapper for Brionvega, which in its off-position appears as an enigmatic black object and only reveals its function when it is switched on. What is new about the Cube Click Clock in this context is the discreet handling enabled by touch technology. The Cube Click Clock may also be seen as an ironic play on the meaning of the 'black box' as a metaphor for digitally operating objects: As a basic condition, we cannot assume that



digital objects are easily decoded based on their appearance. Thus, digital objects may contain more functionality than meets the eye. To take the Cube Click Clock again, the user may need to spend some time with the object to discover its functions, as the surface of the object does not display them or exhaust their potentials. In general, we can speak of digital objects as being inherently limitless and potentially open-structured in their intension which may, despite their material limitation qua material objects, provide access to new spaces of possibility in and through the objects [7]. Thus, digital objects often have a dynamic and changeable character, which may affect their external appearance (as in the Cube Click Clock or in interfaces) or may not do so (if only the function changes but not the appearance of the design).



Fig. 1. Cube Click Clock. Gingko Electronics

The constitution of the digital design object as a half-thing with a wider potential of generating possibilities than is displayed in its outer appearance has an effect on the human experiencing of the object world. Within the framework of a design phenomenology, we may question how design objects, in their many types of appearance and creation of the tactile and visual surfaces of the modern world, affect and structure experience (cf. [8], [9]). We may ask how the meeting point between the objects and the human subjects is structured; that is, on the one hand, how the objects are designed in order to reach out for our engagement

with them, and, on the other hand, how, by what means, and through which senses we engage with them.

Regarding the latter, in the 1970s, based on the developing field of information technology, the early design phenomenologist (among other roles) Vilém Flusser prophesied that the *fingertip* would become the most important meeting point between us and the world; he saw that humans of his age consume not only products but also – and to an even higher degree – information, and that this relationship goes through and is organized by the touch of the fingertip, in a physical interactive sense [10]. Flusser makes an important claim: that our bodily interaction with the object world changes according to the constitution of the objects and the kind of interaction they invite. Accordingly, Flusser's idea of the role of the fingertip is motivated by the early information and computer technology; in today's technologies with interactive screens and wireless exchange of information, the fingertips are more important than ever (even to the point of producing urban legends about finger mutations in teenagers), along with other, emerging kinds of dynamic interaction, e.g. gestures, voice recognition or the remote control of devices by other devices.

In the following, I use aesthetics as a platform for discussing how digital design objects stage experiential meeting points with us when we consider their constitution as half-things, which often have a gap between appearance and function, and which may be dynamic and flexible in nature: The digital design object is an open, changeable object that encourages new forms of interaction in our meeting with it.

### 3 Aesthetics

In its philosophical tradition, aesthetics has often dealt with Truth, Beauty and the Good [11] and has especially been related to judgments of beauty, e.g. beauty as a specific connection of unity and complexity in either nature or art [12]. Often, aesthetic judgments have been related to static objects of contemplation. One reason for this may have been the concept of 'disinterested pleasure' ('*interesseloses Wohlgefallen*' [13]) coined by one of the founding fathers of philosophical aesthetics, the German late-eighteenth-century philosopher Immanuel Kant. With this concept, however, Kant did not seek to suggest meditative contemplation; instead, within a framework of epistemology, he sought to designate the engagement with something concrete

without subsuming it to a specific concept, that is, to meet the concrete phenomenon without a specific interest or intention.

Still, much aesthetic theory has been associated with specific modes of judgment and appreciation of certain kinds of objects, often praised for their formal qualities and often of a static character – frequently in the form of paintings or sculptures, that is, works of art with a physical extension. When we engage in the field of design, and this applies even more to the field of digital design objects, we need to reconsider how to approach the objects qua their aesthetic qualities, and which concepts to apply in this endeavour. The aesthetic theory related to design is still rather sparse, although exceptions do exist, both within the discipline of philosophical aesthetics, where the concept of beauty still plays a role [14], [15], and in cultural-historical descriptions of the role of aesthetics in design [16]. The question, then, is how to conceptualize the aesthetics of design, that is, to take into consideration that we are dealing with objects of function and use and, further, when digital technology is embedded, with dynamic, open, and often interactive objects.

My goal in proposing the conceptualization of an aesthetics specific to design is to offer an interpretive framework for investigating the formation and articulation of aesthetic meaning in design. I will point to three levels of aesthetics that are reflected within aesthetic theory, and which can be employed to

describe the meeting points between the objects and the human subjects, that is, the way the objects aim for engagement and interaction: a sensual, conceptual, and contextual dimension of aesthetics, which I have elsewhere called a sensual-phenomenological level; a conceptual-hermeneutical level; and a discursive-contextual level [7]. I describe their focus and discuss how they may, in relation to digital design objects, indicate a move from a traditional approach to a more apt, contemporary application. Table 1 summarizes these levels, their points of investigation, and their specific application in relation to Beolit 12.

As an illustrative example I relate my discussion to the portable music device Beolit 12 (Figure 2) by the Danish electronics manufacturer Bang & Olufsen, which praises the product as ‘a small but mighty music system that sports a powerful punch in a stylish package’ [17]. The Beolit 12 is a combined amplifier and loudspeaker with a wireless connection to Apple’s iPhones based on the AirPlay technology. It appears as a reinterpretation of the traditional transistor radio, as reflected in the name, which refers to a line of transistor radios reaching back, among others, to the (not portable) Beolit 39 (1939) and the compact Beolit 400 (1970). The Beolit 12 is a part of B&O Play which is a sub-brand of Bang & Olufsen aimed at consumers who prioritize mobility and a contemporary design expression. The object carries the signature of the well-renowned Danish designer

Table 1. Dimensions of aesthetics

Dimension of aesthetics	Sensual	Conceptual	Contextual
<b>Focus</b>	Sensual appearance	Framing of understanding and world-meeting in aesthetic media; self-referential aesthetic effect	Ideologies of aesthetic meaning; aestheticization
<b>Traditional point of investigation</b>	Form	Static objects as meeting points: subject vs. object	Beauty as central aesthetic category; beautification, style
<b>New point of investigation – especially in digital design</b>	Creation of new kinds of experience	Dynamic objects as meeting points: subject ↔ object	Production of new aesthetic categories, e.g. the interesting and the cute
<b>Beolit 12</b>	Production of mobile music experience	Production of a personalized, changeable design object and of new patterns of engagement	Production of interesting cuteness/ interactive openness/ modern enigma

Cecilie Manz, who plays a central role in the media representations of the object [17]. As is typical of high-profile lifestyle-oriented types of design, the designer name is employed as an asset in the meaning production of the product (cf. [4]).



Fig. 2. Beolit 12. B&O Play. Design: Cecilie Manz.

What makes the Beolit 12 relevant for my discussion of aesthetics is that as an object it combines a distinct physical entity with a digital device operating through wireless technology, and that on a cultural level it may create new possibilities of interaction and production of meaning. As a marketed product (as opposed to an experimental studio object), it is associated with a corporate communication effort that aims for certain, specific meanings and seeks to embed the product in specific contexts: The Beolit 12 is a digital design object aimed at a cultural context of engaging with mobile music devices.

### 3.1 Sensual aesthetics

The sensual level of aesthetics in design takes its starting point in an investigation of the sensuous communication of the form and material dimension of the designed object. This interest is rooted in a trend in aesthetic theory that revisits Alexander Baumgarten's original idea of applying aesthetics to sensuous matter, which he presented in *Aesthetica* (1750-58; in Old Greek, *aisthetá* means 'that which can be sensed'). This idea was also embraced by other, later philosophers, including Martin Seel [18], Gernot Böhme [19], [20],

and, drawing on John Dewey's Pragmatist aesthetics [21], Richard Shusterman [22]. These inquiries deal with aspects of sensual appeal and the question of sensual appearance, that is, on the one hand, how people respond to certain kinds and structures of appearance, and, on the other hand, how these are constituted in order to evoke a response. The question, then, for contemporary design aesthetics is to investigate the object and its formal and sensuous-tactile qualities in relation to the creation of conditions of *experience*. The investigation of aesthetics as the creation of specific experiences of e.g. elevation, reflection, feeling or harmony and unity is already established within aesthetic theory, e.g. in Pragmatism, when Dewey speaks of 'having an experience' with distinct, delimited qualities of, e.g., unity or fulfillment [21].

With regard to digital design objects, the question arises how the form of the object is related to the creation of experiences when we consider the new concept of form in digital design, that is, the non-direct relationship between outer appearance and inner function. In case of the Beolit 12, its appearance presents a design object with an emphasis on formal qualities. In its sensual appearance, the Beolit 12 reflects a strong emphasis on look, texture, high-end materials and quality workmanship as evident in the detailing of the assembly and seamless fittings. It is designed as an object with a closed extension and a formal expression as an enigmatic block whose function may be hard to detect at first glance. With regard to materials, the designer has used plastic in order to keep the product lightweight, mobile and affordable; at the same time, however, the more expensive material aluminum is used on the front, in accordance with the company's signature design idiom [23].

This aspect of the formal and material properties of the design object contributes to its sensual-aesthetic appeal: its immediate appearance and appeal to the user. However, its creation of experiences goes beyond its immediate sensual appeal, as the function of the product is to provide mobile music experiences for the user.

Thus, the kind of experience offered by the object is not obtained simply by an appreciation of its external formal and sensuous qualities (whether experienced remotely by looking or up-close by touching) but revolves around the possibilities enabled by the use of digital technology to enhance and create new experiences for the user. In case of the Beolit 12, this involves experiences of mobile

music transmitted wirelessly by an iPhone to the Beolit 12 and perhaps to the iPhone via a streaming service. In the perspective of the creation of experiences, the aesthetics of the object should be judged not only on its external qualities but also on its specific capability of easily, innovatively or provocatively creating new experiences. Still, however, all media of experience are mediated and communicated through a material expression: The sensual aesthetics of digital design objects relies on their ability to create new experiences through their use of digital technology *and* through their sensuous and formal qualities.

### 3.2 Conceptual aesthetics

The conceptual level of aesthetics deals with analyzing aesthetic artefacts as media of new patterns of understanding. This notion of aesthetics can be traced back to Kant's seminal *Kritik der Urtheilskraft* (1790), where aesthetics was conceived as a basic aspect of epistemology in a bridging of sensual appearance and conceptually formulated meaning. This understanding eventually developed into philosophical aesthetics and art-oriented aesthetic theory with an interest in meaning constitution (e.g. [11], [18], [24], [25]). A crucial aspect of this line of aesthetic theory has been an immense interest in the extra- and trans-communicative effects of the aesthetic artefact beyond normal communicative abilities. In relation to the framing of experience by design objects, the questions are how and by what means design objects enable and construct meaning and appeal to understanding, and what the nature of this meaning is, for example whether it transcends any limitations, and what its implications are. Further, in the process of constructing meaning and appealing to understanding, design objects may prove to be reflective of themselves as sites of meaning construction.

Exemplary in this context is Martin Seel's discussion about the capacity of aesthetic media to create new frames of understanding and serve as media for comprehending and meeting the world. Focusing on the function of human perception in the process of confronting something 'other', he claims that the capacity of aesthetic media is to 'bring forward otherwise unrepresentable circumstances' and that this capacity has to do with 'ways of human commitment in the real or the unreal, in conditions of the world in the past, the present, or the future. Ways of meeting the

world [*Weltbegegnung*] are put forward, whereby ways of meeting the meeting of the world [*Begegnung mit Weltbegegnung*] will be possible' [18]. Unlike art, design objects are often not obviously selfreflective of their own being as creators of meeting points between us and the world; nevertheless we may still ask how design objects are conceived and operate as such, and what the role of the digital technology is in this respect. Importantly, design objects incorporating digital technology often have the effect of staging *dynamic meetings with the world*, that is, they produce a meeting with the world that enables new kinds of meeting of the world, to rephrase Seel. This is an aspect that touches upon the element of interaction with the design, not just in terms of how to handle a specific physical object, even if this handling may be seen as the way in which the thing literally as *Zeug*, ready at hand, may serve as our access point to experiencing the world, but also in terms of how the object may alter its character in our interaction with it.

The Beolit 12 creates a meeting point between us and the world both through its static, material character and through its dynamic potentials of use. In its immediate appearance, it is an object that is designed for physical handling and to be carried around. As a distinct signature element, it is designed with a leather strap. The leather is a material that the designer has brought into the design of consumer electronics from her original field as a furniture designer. Also, the use of the leather strap refers to the design history of portable devices, e.g. the portable transistor radio/phonograph TP1 (1969) designed by Dieter Rams for Braun, which features a leather strap. From a sensuous perspective, the leather makes carrying the product more comfortable. Thus, the organic material of the leather strap softens our concrete, tactile meeting with an otherwise hard and geometrically distinct object. Next, the Beolit 12 also serves as a dynamic access point to experience by allowing music to be carried around and consumed in new and, from the perspective of the company, hopefully, innovative ways, as that would allow the company to project a self-image of being innovative. In its scope of operation, the Beolit 12 may encourage new kinds of mobile use. The potential of design objects to be used in different and maybe unforeseen ways is enhanced by the opportunities offered by digital technology, adding renewed relevance to the question of how aspects and situations of use can be designed,

and how use can be seen as design [26]. Thus, the real impact of creating new world meetings lies in the product's intension and its inner potentialities of being not merely a static, material object (which it also is) but also a dynamic object of interaction that through its use by different users is constituted as a personalized, changeable design object, capable of creating new patterns of engagement in its wireless interaction with, first, an iPhone and, second, surroundings that are increasingly pervaded by wireless information. Seen in the perspective of conceptual aesthetics, a product such as the Beolit 12 may have an aesthetic effect in challenging the habits of use, the way we understand an object (what is it for?), and the way meet the world through the object. This meeting builds upon sensuous effects but also on the more or less self-referential creation of the object as an interface between us and the world.

### 3.3 Contextual Aesthetics

While the two previous dimensions of aesthetics deal with aspects of meaning of the given design object, the contextual dimension of aesthetics focuses on the wider implications of the circulation of designed objects on a cultural, social and political level. Thus, aesthetics can be investigated as a political power issue in relation to the distribution of sensuous material and the ability to determine 'what presents itself to sensory experience' and be seen as 'a delimitation of spaces and times, of the visible and the invisible, of speech and noise, that simultaneously determines the place and the stakes of politics as a form of experience' [27]. In this conception, aesthetic media not only serve as transmitters of new possible meaning but also produce possibilities by defining and conditioning domains of the sensuous experience. A central aspect of this contextual conditioning of meaning is the production of aesthetic categories to frame our understanding of aesthetic meaning. In an illuminating study, *Our Aesthetic Categories*, Sianne Ngai states that 'aesthetic experience has been transformed by the hypercommodified, information-saturated, performance-driven conditions of late capitalism' [28]. She points, rightly, to the fact that aesthetic categories are variable and suggests replacing the major aesthetic categories of the late eighteenth century, such as beauty and the sublime, in part with the new, minor and more 'trivial' categories of the cute, the zany, and the interesting. She proposes a 'commodity aesthetic

of cuteness', a 'discursive field of the interesting' and a 'performative aesthetic of zaniness'.

In the process of total culturalization and radical commodification, aesthetic experience is no longer confined to the traditional domains of beauty, distance, and disinterested pleasure: To Ngai, aesthetic styles are culturally produced and codified as such. Thus, ultimately, a style is not just a matter of the object in question but can be understood as a way of 'perceiving an object', a way of producing a specific perceptual setting and creating a specific setting or contextual frame for the object in question. Ngai rightly problematizes the prevalent aesthetic categories, which may be relevant for design discourse where a concept such as beauty is still in circulation as the pivotal element of aesthetics (e.g. [29]). Even so, Ngai's own categories may also be questioned, and other categories might arguably be suggested. One such proposal might be to regard 'openness' as a relevant aesthetic category for digital design.

With this perspective on aesthetics, we may ask how aesthetic categories are culturally produced to enable objects to contain different aspects and kinds of aesthetic meaning. An important element in this investigation is to look at culturally productive framings of design, such as their 'mediation' [30] and the omnipresent 'media environments' of late modern societies [31], where things turn into and are engulfed by media expressions which in turn condition our experience of them.

From a perspective of consumption (and not just use situations), media contexts are effective in producing the meaning of products. To illustrate with the Beolit 12, we may ask how the meaning of the product is culturally produced and within which aesthetic categories. Thus, the company's strategies of mediation may not merely reflect certain aesthetic categories but also contribute to producing them. I will point to two seemingly contradictory examples where the company actively produces the frame of judgment of the aesthetic qualities of the Beolit 12 by establishing ways of perceiving the products, their style and their implications.

The first example can be found in the static visual mediation of the Beolit 12 on the website of the sub-brand B&O Play (Figure 3). Here, the product is displayed in a setting that reflects the company's view of the optimal value context of the product: co-branding

with Apple; coffee table books, perhaps study books or books on art or design, designating cultural capital; a coffee-to-go cup, signalling mobility; and posters and a bike in the background connoting a modern, urban, active lifestyle. In terms of aesthetic categories, the setting balances the *interesting* (in the dynamic content of cultural information related to the context of product) with *beauty* in the simplified and stylized set-up in bright, harmonized colours. The visual mediation is an example of aesthetization as beautification, which is not uncommon in contemporary design and not specific to digital design: The objects are set up to look their best.



Fig. 3. Product setting by the company Bang & Olufsen

The second example is a 2012 commercial for the Beolit 12 playing on the theme of Little Red Riding Hood getting lost before eventually finding her way again [32]. In a desolate, urban industrial setting, the Little Red Riding Hood character is carrying the Beolit 12 as her basket of goodies and seems to feel stalked by sudden flashing, rectangular lights. Eventually, the lights surround her, but at the end of the 1:18-minute film she is able to control the lights and make them go away by touching her iPhone, revealing that the flashing lights were iPhone screens. At the point of resolution, a female voice whispers, 'Wireless sound system for your iPhone – by B&O Play'. In this commercial, the main aesthetic category applied is the *interesting* (questioning the meaning of the product) mixed with elements of the *uncanny*, which may reflect Ngai's concept of the cute, as the feeling of suspense is resolved when Little Red Riding Hood makes the right connection between the Beolit 12 and its iPhone app. Further, we may also wonder what aesthetic category might fit the perception of the dynamics of the action in the film and the role

of Beolit 12 as an object of resolution that integrates all the supposedly wireless streams of information indicated by the rectangular lights. It might be a category of *interactive openness*, as the object is opened in its interaction with the surroundings (it is not just a static object of contemplation), or it might be a category of the *modern enigmatic*, as the Beolit 12 plays out the digital magic of being more than meets the eye. In this contextual approach to aesthetics, aesthetic meaning is seen to be produced by means of actors and powers outside the design object, for example, a company in the commercial context of the Beolit 12. The product is *created as aesthetic*, not only as a matter of discursive, performative action, as when Manz is quoted as saying that she thinks 'great design should be 90% functionality and 90% aesthetics' [25], thus pointing to aesthetics as a central concept for the product, but also, and more effectively, in the confirmation, reflection, and production of both old and new categories in a differentiated mix aimed at framing *how* the product is aesthetic in the sense of being beautiful but also interesting and enigmatic.

#### 4 Conclusion

In the same way that the incorporation of digital technology in objects challenges our notion of design, it also moves the concept of aesthetics in new directions. As the theoretical debate shows, the traditional notion of aesthetics as narrowly associated with beauty and disinterested pleasure is obsolete, although it still applies in certain contexts, and is ready to be replaced by new notions that match our time and our culture of objects. Digital technology has led to a radical change in the conception and perception of objects, and my proposal in this paper has been, first, to state the new ontology of the digital design object, and second, to present a framework of aesthetics that may be appropriate for framing the generation of meaning in the new culture of objects in the digital age. I have discussed digital design in the light of sensual, conceptual and contextual aesthetics and looked at digital design objects a) as means of creating new kinds of experience, b) as dynamic objects that serve as meeting points between subject and object and c) as framed by the ongoing production of new aesthetic categories, which may be seen both as a trait of contemporary design culture and, further, as an asset for commercial enterprises. As design evolves, so does design aesthetics.

## References

1. Forster, K.W.: Above the Trash. Momente eines objective turn in Architektur und Design. In Gleiter, J. (ed.) *Symptom Design*, pp. 21-38. transcript verlag, Bielefeld (2014)
2. Krippendorff, K.: On the Essential Contexts of Artifacts or on the Proposition That 'Design Is Making Sense (of Things).' *Design Issues* 5 (2), pp. 9-39 (1989)
3. Fallan, K.: *Design History. Understanding Theory and Method*. Berg, Oxford (2010)
4. Julier, G.: *The Culture of Design*. Sage, London (2014)
5. Fallan, K.: Design Culturing: Making Design History Matter. Keynote, *Design Culture: Object, Discipline and Practice*, SDU Kolding, Sep. 18-19 (2014)
6. Selle, G.: Ding, Halb-Ding, Nicht-Ding, In-Ding, Über-Ding. In Gleiter, J. (ed.) *Symptom Design*, pp. 39-67. transcript verlag, Bielefeld (2014)
7. Folkmann, M.N.: *The Aesthetics of Imagination in Design*. MIT Press, Cambridge MA (2013)
8. Vial, S.: *Court traité du design*. Presses Universitaires de France, Paris (2014)
9. Verbeek, P.-P.: *What Things Do: Philosophical Reflections on Technology, Agency, and Design*. University Park, Pennsylvania State University Press (2015)
10. Flusser, V.: *The Shape of Things*. Reaktion Book, London (1999)
11. Adorno, T.W.: *Ästhetische Theorie*. Suhrkamp, Frankfurt am Main (1970)
12. Schweppenhäuser, G.: *Ästhetik*. Campus, Frankfurt a. M. (2007)
13. Kant, I.: *Kritik der Urtheilskraft*. Könnemann, Köln (1995)
14. Steinbrenner, J., Nida-Rümelin, J. (eds.): *Ästhetische Werte und Design*. Hatje Cantz, Ostfildern (2010)
15. Forsey, J.: *The Aesthetics of Design*. Oxford University Press, Oxford (2013)
16. Stockmarr, P.: *Det æstetiske i design*. [PhD thesis]. Copenhagen: The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation (2014)
17. Beolit 12. <http://www.beoplay.com/products/beolit12>
18. Seel, M.: *Ästhetik des Erscheinens*. Hanser, München (2000)
19. Böhme, G.: *Aisthetik. Vorlesungen über Ästhetik als allgemeine Wahrnehmungslehre*. Wilhelm Fink Verlag, München (2001)
20. Böhme, G.: *Atmosphäre. Essays zur neuen Ästhetik*. Suhrkamp, Frankfurt a.M. (2013)
21. Dewey, J.: *Art as Experience*. Penguin, New York (2005)
22. Shusterman, R.: *Pragmatist Aesthetics. Living Beauty, Rethinking Art*. Rowman & Littlefield Publishers, Lanham & Oxford 2000)
23. Kaufholz, M.: Made For Use: Meet Cecilie Manz. <http://journal.beoplay.com/index.php/2013/12/made-for-use-meet-cecilie-manz/> (2014)
24. Menke, C.: *Die Souveränität der Kunst*. Suhrkamp, Frankfurt am Main (1991)
25. Menke, C.: *Die Kraft der Kunst*. Suhrkamp, Frankfurt am Main (2013)
26. Bredies, K.: *Gebrauch als Design*. transcript verlag, Bielefeld (2014)
27. Rancière, J.: *The Politics of Aesthetics*. Continuum, London (2004)
28. Ngai, S.: *Our Aesthetic Categories*. Harvard UP, Cambridge, MA (2012)
29. da Silva, O., Crilly, N., Hekkert, P.: Can a Light Switch Be Beautiful? Aesthetic Appreciation of Products as Means. *DRS Proceedings* (2014)
30. Lees-Maffei, G.: The Production-Consumption-Mediation Paradigm. *Journal of Design History* 22 (4), pp. 351-376 (2009)
31. Lash, S., Lury, C.: *Global Culture Industry: The Mediation of Things*. Polity Press, Cambridge (2007)
32. Little Red Riding Hood - BeoLit 12 Commercial. <https://www.youtube.com/watch?v=DURcvvn2Pgl> (2012)

# Luminous Matter

## Electroluminescent Paper as an Active Material

### **Abstract**

Materials play a vital role in tangible interaction design. However, the materials are often used passively, as elements to be actuated by ready-made electronic components rather than inherently active parts of an interactive system in their own right. In this paper, we challenge that approach through a series of material experiments involving electroluminescent paper. The results are different types of self-illuminating paper which exhibit peculiar responsive behaviours while maintaining the affordances and ephemeral qualities of conventional paper. We demonstrate a number of techniques for expressive design through hand painting, folding and using water as an activator and distributor of light. We show how direct engagement with inherent active qualities of materials leads to novel creation processes and design ideas.

### **Keywords**

Active Materials, Electroluminescent Paper, Ephemeral Interfaces, Smart Materials

### **1. Introduction**

For more than ten years, physical computing has dramatically changed the way in which we use digital technologies in design and architecture. Today, interactive objects are a collage of interconnected sensors and actuators that can electromechanically move, emit light or sounds. Designers can easily

prototype using tools such as Arduino combined with these various hardware components. Such electronic components are often combined with traditional materials such as wood or metal for their durability, flexibility or tactile qualities. Those materials can be activated by motors or other types of actuators. They do not move or actuate by themselves - they are being acted upon.

There is a range of materials, however, whose inherent properties allow them to act and respond to certain environmental conditions or specific stimuli such as electricity, vibration, pressure or light. Such materials are often not commercially available or the processes of creating them are too complex to be brought to a design studio or teaching environment. In order to address this issue, we need to develop processes, methods and tools that can allow designers, artists and architects to create novel materials and to work with their inherent responsive properties. A new kinds of aesthetic experiences may be enabled when classical physical computing is extended to material experimentation on the threshold between the mechanic, chemical and electronic.

### **2. Background**

#### **2.1. Active Materials**

In the context of interaction design, some projects have utilised the inherent properties of materials to sense



different stimuli such as sound or temperature, or to actuate with movement, sound or vibration [1]. One interesting example comes from a musical interface design where conductive inks and various substrate materials were used to create paper sensors that can detect position, pressure and bending [2]. However, many projects are based on off-the-shelf actuators that move passive surface elements such as metal, for example in *Aegis Hyposurface* [3]. A more promising example is the use of pneumatic actuators as a part of the architectural structure itself, like the *Muscle Body* project by Hyperbody research group at TU Delft [4]. Other approaches use weaving of commercially available materials such as optical fibres into fabric, as in *Energy Curtain* [5]. Rare examples of using inherent properties of materials include the use of wood, which can deform in response to varying humidity [6] and the use of bimetals which change shape according to variations of temperature [7]. The active properties of novel materials themselves appear to be hard to work with, reflected by the lack of examples that exploit them in design fields.

However, material sciences are increasingly developing so-called smart materials that can respond to stimuli and environmental changes in a controlled way. Many such materials are engineered on a molecular scale and thus can only be fabricated in a laboratory. Dealing with materials on a nano scale not only requires specialised facilities, but also removes the creator from the direct sensing and handling of the material. Tacit knowledge of materials plays an essential role in design and arts, as such intimate relationship with a novel material enables a designer or artist to explore its aesthetic potential. Artworks resulting from the *Liquid Things* research project are an interesting example of aesthetic outcomes that a long-term engagement with novel materials may lead to [8]. The project's practical research is grounded on theoretical discourse examining the coupling of material, process and imagination [9].

The authors of the *Transitive Materials* approach argue that working with novel materials requires an embodied understanding similar to those found in craft practices [10]. This enables the designer to develop material composites which may function as frame, skeleton, sensor, actuator and/or processor. Examples from the authors make use of smart materials combined with

traditional ones and electronic hardware for various functional and aesthetic goals. For example, in so called *Pulp-based Computing* where electronic components, conductive inks, shape-memory alloy and LEDs were integrated into the paper during the papermaking process. Their loud-speaker example combines a sensor and actuator, as a screen-printed spiral of conductive ink both reacts to touch and emits sound [11]. The idea of *Transitive Materials* is to seamlessly couple input, output, processing, communication, power distribution and storage. However, an example which accomplishes all these goals through smart materials is yet to be seen.

A more recent conceptual framework for so-called *Becoming Materials* focuses on temporal and responsive aspects of novel computational materials [12]. Their prototypes are an example of a classical physical computing approach with sensors and actuators added to conventional materials. In *PLANKS* a hardware microphone was added to plywood boards which were then moved by motors when activated by sound [13], while in the *Telltale* project air pressure is used to inflate and deflate furniture in order to communicate household energy consumption. However, the *Becoming Materials* approach points to the importance of temporal aspects in materials and explores their relationship to context and use.

In this paper, we introduce the term *Active Materials*, as a working concept to describe our approach that engages with inherently active properties of materials and sets to uncover aesthetic potential hidden in the material. *Active Materials* are inherently capable of changing their states and/or properties when exposed to specific stimuli such as light, temperature or electrical charge. For example, electroactive polymers (EAPs) stretched into thin foils attached to flexible frames can change their shapes under an electrical field, as shown in *ShapeShift* [14]. Although EAPs were originally developed for robotic applications and haptic interfaces, in *ShapeShift* they were modified to explore their aesthetic potential in an architectural context. Similarly, our goal is to approach such novel materials in a way that enables a larger spectrum of aesthetic expression. Conceptually, it is grounded in a material turn in humanities, more specifically theories that see materials as a part of a continuous flow of matter in the environment. This conceptual framework requires

a new understanding of creative practices in design, arts and architecture [15], as well as new techniques of approaching *Active Materials* in a more embodied and tacit way. Only in this way can we explore their aesthetic qualities and shift focus from performance and durability typical of an engineering approach to qualities such as ephemerality and aliveness.

## 2.2 Ephemerality in Paper Interfaces

The material explored in this paper, namely electroluminescent (EL) paper, challenges us with issues of longevity and durability. The fragile qualities of the EL paper we created are in direct opposition to what we expect from the converging areas of consumer electronics, digital technology and architectural environments. They also appear to contradict findings from *Sustainable Interaction Design* which emphasises designing for long lasting utility not for the transient [16]. The rapid fabrication and obsolescence of electronic devices clearly leads to waste and resource issues, so by extending utility we can somewhat alleviate these environmental consequences. However, longevity poses its own problems, as the materials that lend to a greater sense of durability and therefore supposed emotional attachment to electronic devices [17], are also the materials that will persist for decades or potentially millennia after the device becomes obsolete. As we increasingly apply electronics to artefacts and environments, following the ambient computing paradigm, this issue will become an ever pressing consideration. The emerging field of *transient electronics* may offer a solution through electronic devices that are designed to dissolve or biodegrade over a predefined time frame [18].

Electronics that can biodegrade similar to paper have an interconnectivity with the environment, ourselves and other agents, potentially opening up new insights and novel forms of interaction. Döring, Sylvester and Schmidt proposed *Ephemeral User Interfaces* “as having at least one UI element that is intentionally created to last for a limited time only” [19]. They point out that experiencing something fleeting and transient has a special resonance with people, and by incorporating such qualities into interaction design practices new avenues for interactive devices can emerge. Certain material choices can draw focus to temporality, transformation and experience in such devices.

We found paper as a material particularly interesting because of it can be fragile, tearable and degradable, all qualities that subvert the sense of permanence. However, most interactive paper projects push focus to the electronic components, with the paper as support material rather than an essential material with its own active capabilities. HCI research on flexible displays often reflects some affordances of paper [20], but the ability to tear, crumple, burn or biodegrade are typically neglected. While many if not all paper based electronics projects have explored the affordances of paper to some extent [21 - 24], even projects that integrate electronics during the papermaking process do not necessarily use the electrical properties of the paper itself [11]. It is also worth noting that, as late as 2010, in a paper researching manipulation and gesture in deformable paper like displays, such devices were asserted as a speculative technology [25]. The methods we introduce in this paper enables artists and designers to fabricate these once speculative displays in a studio with limited resources and demonstrate interactions based on the affordances of paper, responsive EL properties and ephemeral qualities.

## 2.3 Electroluminescent Paper

EL foils are a type of flexible, light emitting surface or display. Commercially produced EL is both flexible and thin, ideal for the backlighting of LCD displays, emergency signage and even in billboard advertisements. As with many smart materials, EL films are engineered to meet specific requirements for application and performance needs. For example, it is manufactured for backlighting of control panels in airplanes or cars. Thus, it has to provide a perfectly homogeneous light surface which will not disturb the pilot or driver. Reduction in electrical and audible noise, power efficiency and durability are also key requirements for such applications.

EL films are constructed from two electrodes sandwiching a dielectric and phosphor layer. When an alternating current is applied to the electrodes, a strong electrical field is created, resulting in light emitted from the phosphor (in our examples *copper doped zinc sulfide* which emits a green blue hue) [26]. Indium Tin Oxide (ITO) coated polymer is commonly used as a transparent electrode to allow this light to escape from the encapsulated phosphor. EL foil can be fabricated

through screen-printing for cost effective mass production and it offers the advantage of flexibility, thinness and low power consumption over incandescent lighting. EL wire is an alternative construction that works with the same principles as EL foil, but in a flexible wire format. The green/blue hue produced by the EL could draw comparison with bioluminescent organisms such as the *Panellus Stipticus* fungi, fireflies and marine microorganisms like *Noctiluca Scintillans*. However, commercially produced EL appears plasticity and highly homogeneous in contrast with these examples from nature.

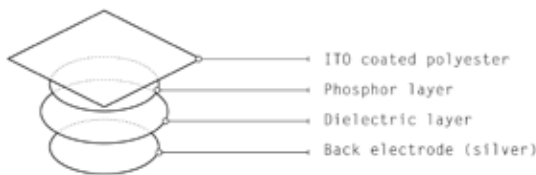


Fig. 1. A composition of commercially available EL paper.

Existing art and design projects use mainly these kinds of commercially available EL products. They are displayed with compositions of unaltered foils like the *Bourrasque* installation [27], cut into shapes as in the *Material Animation* workshop [28], or integrated in other materials and fabric such as *Functional Styling* [29]. Rachel Wingfield of Loop.ph design studio created custom screenprinted EL panels as early as 2002 and again in 2006 for the *History Tablecloth* [30]. Loop.ph also brought EL to an architectural scale by weaving EL wires into spatial structures with several projects such as *Spiratomic Space* [31].

### 3. Design Experiments

After an attempt using off-the-shelf EL, we decided to create our own EL paper from scratch in order to explore new aesthetic and interactive possibilities. In what follows, we describe design and fabrication experiments in which we worked against the homogeneity and plastic look that is characteristic of existing EL products. The results are surfaces that exhibit ephemerality, interactivity, fragility and other unique qualities. In addition to this, we cover two multimodal examples where we enabled motion and sonic capacities of the EL material.

#### 3.1 Etching the Existing

Our attempt to work with commercially available EL foils was initiated by an invitation to develop a concept for a long term EL art installation. After having explored different bending and cutting methods, we focused on laser engraving. This method allowed us to customise the EL foil with various textures or graphical elements. Using a laser cutter we etched away the rear electrode to permanently deactivate certain areas of the EL foil with minimal visual artefacts on the front surface. The result was a surface that reveals patterns and shapes only when activated (Fig. 2). The pattern we created was motivated by our aesthetic goal of developing a water-like surface. We wrote a script for *Reaction Diffusion* based patterning to engrave into the surface, as the organic and fluid qualities of such designs closely aligned with our goal. Through this approach it was possible in one step to etch patterns while laser cutting areas in the EL sheet, thus quickly fabricating both complex structures and surface patterning. However, with this approach, the surface would always retain its plastic appearance. We realised that we can depart from such artificial characteristics in commercially available EL only through a more in depth, hands-on approach.

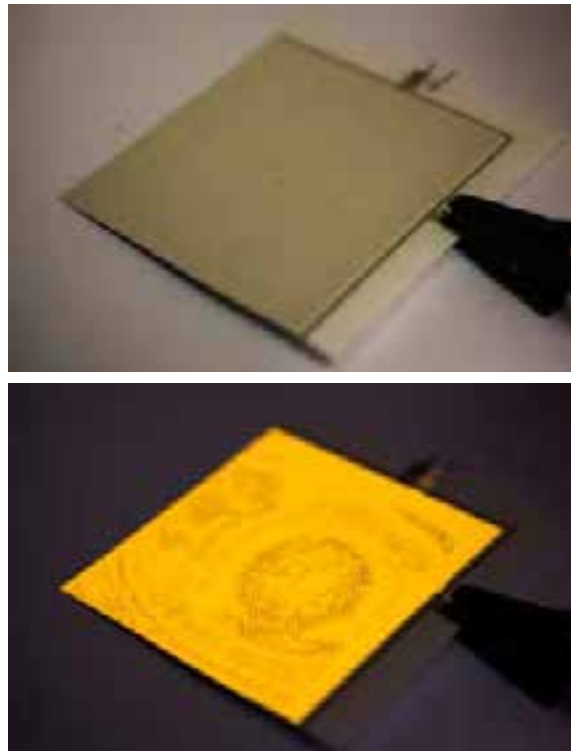


Fig. 2. EL foil with a Reaction Diffusion pattern etched on the rear electrode.

### 3.2 Reproducing industrial fabrication process

Our next step was to understand commercial fabrication processes and simplify them enough to be able to do it ourselves. In the *Actuated Matter workshop* [32], we collaborated with Loop.ph spatial laboratory, learning from their experience with screen-printing EL. We followed a methodical handcrafting process, which resulted in a luminous surface with an unexpectedly organic appearance (Fig. 3). Although the patterns were designed on computer and their stencils printed, the process allowed us to directly engage with the material during the screen-printing phase. Through irregularities in the hand printing process, we were able to get away from the homogeneity of the conventional EL. However, we were not able to address the plastic-like appearance with this approach.



Fig. 3. Screen-printing EL on ITO coated polymer during the Actuated Matter workshop.

### 3.3 De-plastifying

The plastic appearance comes from by the ITO coated polymer, the key component which provides a substrate and transparent conductivity required for EL. Thus, we set to explore the possibility of substituting the ITO with substrates like conventional paper. This introduced the need to experiment with alternative transparent

conductive materials. Using paper as a substrate for EL devices has been proposed in the past [33], but never as an aesthetic exploration or in a way that would be accessible to designers. Our initial experiments to resolve this used diluted silver ink and carbon black powder, which both resulted in working EL displays on paper. In both cases the conductive material was not transparent, but the irregular coating had enough breaks and discontinuity to allow light to permeate through the opaque material. On both accounts the illumination was poor to the point of being barely visible. More enticing results were achieved by screen-printing silver ink with a matrix of 'pores' to allow the light to pass through (Fig. 4). The phosphor illuminated underneath the silver electrode, but because of the phosphor's translucency a thin ring of light could escape from beneath the edges of the silver. Even though the total luminance is limited to the edges of the silver print, this approach allows effective printing of EL graphical elements and patterns on a paper substrate.

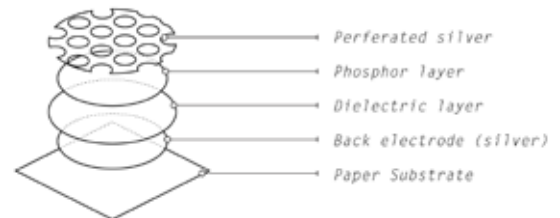


Fig. 4. EL printed on paper with perforated silver ink.

Eventually we tested a PEDOT based transparent conductive ink (gwent C2100629D1) which produced the strongest luminance from our EL paper tests and was significantly easier to handle and print than silver ink. This ink has faster drying and curing time than silver ink, which sped up our fabrication process significantly, opening up new opportunities for experimentation. In contrast to the commercial produced EL foils,

these screen-printed surfaces retained all the material qualities of paper and exhibited intriguing imperfections and irregularities from the fabrication process (Fig. 5). Unlike other display technologies commonly referred to as electronic paper, EL paper truly allows for an exploration of affordances inherent to paper such as creasing, crumpling or tearing (Fig. 6). This opens up numerous new possibilities for interaction, some of which have been further explored in *PrintScreen* [34], which was inspired by our approach with EL paper and made use of our information and guidance.

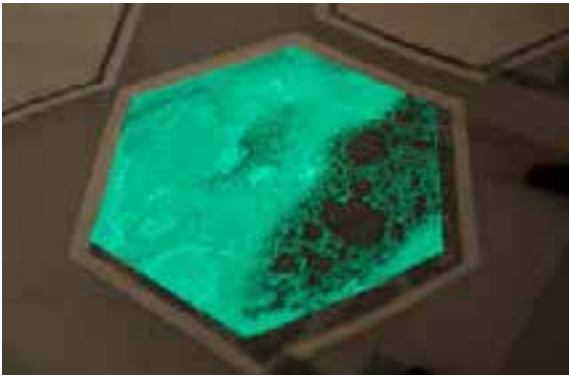


Fig. 5. EL printed with PEDOT based transparent conductive ink.



Fig. 6. Tearing the EL paper

### 3.4 Folding

With the new techniques covered in the previous section, we were able to create a foldable EL surface from a paper substrate (Fig. 7). We first developed a foldable structure based on a simple interconnected hexagonal arrangements in Grasshopper for Rhino 3D, a generative design tool. Folded structures are typically highly geometric, but the form we developed allowed for a more subtle, organic like modulations through its algorithmic generation. We fabricated the folded design with a flatbed plotter to pre-crease and cut the

structure in preparation for printing. Five layers of print were applied to the paper, including back electrodes and traces, two layers of dielectric, phosphor, PEDOT ink and finally silver ink at the contact points between the paper and hardware. Simple snap fastener studs were used for interfacing between the paper and insulated wires for connection to the power supply. From here the structure was folded into its final form and illuminated with a sequenced animation using a custom built controller. The illuminated parts of the structure were resistant to a degree of folding, bending and contortion (see video at <http://vimeo.com/84845032>).

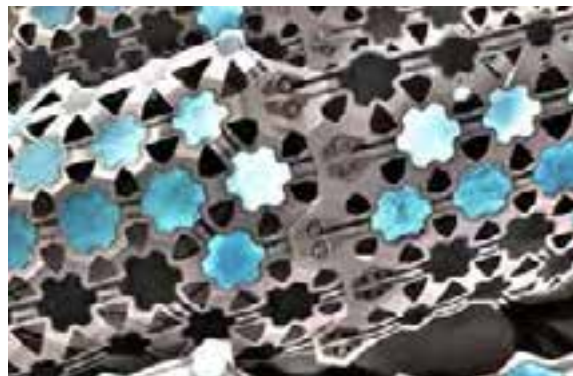


Fig. 7. EL surface printed on folded paper.

Our next challenge was to enable painting with luminous matter. By pre-printing the back electrode, dielectric and phosphor layers through screen-printing on paper, we hand-painted the transparent PEDOT ink directly onto the phosphor layer. This enabled us to quickly try out ideas and to explore the dynamic free-hand technique for generating luminous surfaces.

### 3.5 Paper as an Active Material

We further iterated the hand painting approach to produce an EL material where the paper itself is both the substrate and the dielectric material. This means that we reduced the layers that must be painted from five to three: back electrode, phosphor and front electrode. Uniformity in the dielectric layer is essential to avoid short circuits and poor EL performance. Since our approach uses the homogeneous thickness of the paper the remaining layers can be less precise. This allows the possibility of hand painting the entire surface, removing the complexity and time constraints of screen-printing. Through this approach the paper becomes an active part of the EL; it is no longer just a substrate material but an integral part of the EL



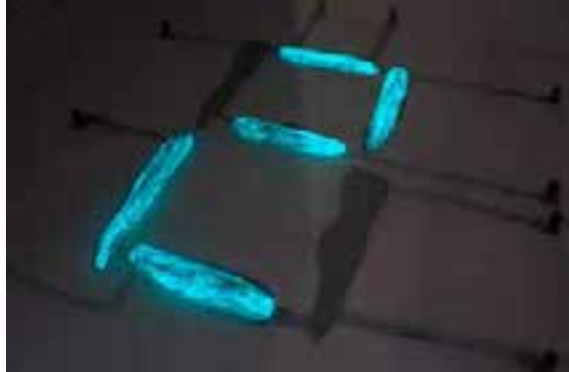


Fig. 8. Hand-painted numerical display, which “breathes” in a rhythmic fashion. A collaboration with product designer Robert Wettstein.



properties. We used tracing paper, which allowed viewability from both sides because of its translucency and for the unexpected effect of thin paper irradiating light (Fig. 8). This new technique allowed us to quickly involve designers without previous experience with EL in a creation process.

### 3.6 Painting Light with Water

As an ephemeral interaction experiment, we tested the use of water as an interface and as a transparent electrode (Fig. 9). Related interfaces using liquids include the *Soap Bubble* [35], where bubbles are the ephemeral material forming the interface between human and computer. In our case, however, the water is forming an interface between human and the material phenomena, avoiding any digital computation between interaction and visual response. Unlike printed or painted EL paper, the water electrode introduced a dynamic element to the lighting experience. The manipulation of fluid over the surface produced surprisingly animated and playful results. We moved the water, and therefore the appearance of light, by manipulating the paper through tilting and bending, dripping water via syringes and using a heat gun to move and evaporate the droplets. As the droplets of water connected and disconnected, new patterns of light began to flow and propagate (Fig. 10). Thus, we could interact directly with the affordances and agency of water, paper, electricity and light.

Although this was one of the last experiments we did, we were filled with surprise and fascination as the light acquired a liquid appearance and behaviour (see video <http://vimeo.com/104921022>).

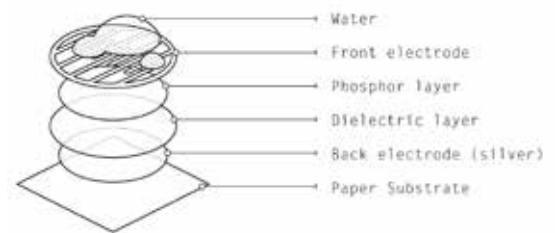


Fig. 9. EL construction using water as a responsive electrode.

### 3.7 Sounding Light

By taking a hands on approach to fabricating and experimenting with materials we are open to surprising and unexpected results. In one such example we accidentally discovered the possibility producing both light and sound when touching the EL surface (see video <https://vimeo.com/60236646>). After preparing a sheet of EL on paper, but before applying the last conductive layer, we placed a piece of ITO coated polymer over the phosphor and applied voltage. We were surprised to find that not only would the EL illuminate in response to pressure on the polymer, but a loud tone was also

Fig. 10. Video stills showing the process of creating illuminated areas by dripping and blowing droplets around the surface.



produced. This high frequency tone can be modulated by touching the surface.

The sound was the result of electroacoustic transduction. By separating the two electrodes an electromagnetic field results, vibrating the EL film in the same frequency as the alternating current from the EL driver. The driver used (ENZ E040 601X) is rated to output between 340-810Hz, which is incidentally and audible frequency range. The driver does not have a fixed frequency; it is free-swinging dependent upon the total capacitance of the attached EL film. The following formula expresses the output frequency, where L is the inductance at the driver and C is the capacitance of the screen [36].

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

When the module was pressed, the top electrode come into contact with the phosphor forming the capacitor. The more the surface was touched the greater the illumination and capacitance, resulting in reduced frequency i.e a lower pitch. The outcome was an eerie high pitch tone reminiscent of a theremin in its fluid modulation of sound.

All EL devices produce a subtle tone which can be heard when placed close to the ear. The alternating current produces an elastic deformation in the the dielectric at the frequency of the current oscillations [37]. EL devices designed specifically for the capability of generating

sound were first proposed in 1989 [38]. However, the device was not touch responsive and it produced sound through a composite of piezoelectric ceramics and EL, rather than using the EL device itself to produce tone. In this example the ITO coated polymer was re-introduced, which we had previously avoided because of its undesirable qualities. Finding an approach which combines interactive capabilities of this device, with the material qualities of a purely paper based construction would be an exciting line of enquiry for further development.

### 3.8 Stretching Light

One of the most surprising experiments came from combining this work with another strand of our research, electroactive polymers (EAP) mentioned above, which deform when high voltage is applied (up to 5000v). In our process of constructing soft-frame EAPs, the stretched elastomer is applied to a compliant frame, which must oppose the force of the elastomers constriction but wield sufficiently to allow movement (see <http://www.enactiveenvironments.com/enabling/tutorials-2/>). The stretched surface is then manually impregnated on both sides with carbon black powder, forming two conductive electrodes separated by the dielectric elastomer. When voltage is applied the elastomer is constricted between the electrodes, relaxing the tension in the elastomer. Unlike the mechanical movement of most conventional actuators, EAPs have a fluid organic quality.

Using the same approach as in the “Paper as an Active Material” example, we painted a functioning EL surface on to the stretched dielectric elastomer (see video

Fig. 11. EL surface hand-painted on to a dielectric elastomer.



Fig. 12. Touch responsive, sounding EL surface.



<http://vimeo.com/76430662>). This simple experiment showed a potential for the combination of EAP and EL into one single material, a luminous surface that changes its form based on electrical activation. Such a material could potentially be used as a digital display in product design and architecture as it opens up rich possibilities for creative exploration of this soft, moving, transparent material.

#### 4. Conclusion

Existing projects in interaction design are dominantly based on combining, composing or weaving of ready-made electronic components - techniques which do not allow an exploration of active and responsive properties of matter. In this paper, we presented novel techniques for working with such matter in the case of EL paper. We explored its unique aesthetic and ephemeral qualities by developing a number of novel materials and unique fabrication procedures. We reduced the process of creating EL paper from hours to minutes, further shifting the process away from the commercial fabrication to that of instantaneous handcrafting and exploration of EL paper. We described new possibilities for interactivity, creating audiovisual feedback to touch and modulating light through water. We also showed the possibility of integrating shape changing and luminescent behaviour into a single material. These examples demonstrate the power of our approach to engender novel creative practices and to engage designers with the aesthetics of ephemerality and responsiveness.

Our research revealed unexpected aesthetic potentials of EL materials. We embraced the benefit of relinquishing some control of the outcome, letting the materials show us their unexpected properties and guide our aesthetic explorations. We probed different physical assemblages and chemical conditions in order to alter material appearance and behaviour. We focused on properties and processes that are inherently present in such materials. Our approach was to activate such aesthetic qualities hidden in the material - thus the term *Active Materials*. This often led us to work with aspects that might be considered undesirable in some performance oriented applications, yet provided intriguing possibilities for creative contexts.

However, our aesthetic explorations would not have been possible without the knowledge gained

from scientific resources and experts whose work is performance oriented. Dr. Emil Enz, who introduced us to commercial EL production was at first dubious of our methods, but as he saw the results he recognised new applications based on non-uniform EL for more natural lighting and interactive possibilities. This shows a potential for collaboration with material scientist and engineers: novel materials can feed into design research and, vice versa, design experiments can stimulate the development of novel materials.

This feedback hints at the potential for applications resulting from research presented in this paper, although we focused primarily on processes and materials themselves. By working with material transformation one is continuously pulled to investigate various possibilities, rather than to freeze processes into a fixed form or interaction model. For this reason our results did not take the shape of final products, commercial applications and larger scale pieces. We see this as our next challenge. We aim to embed the different techniques presented here into concrete projects involving users. Particularly important are the ephemeral aspects of EL paper and ways of integrating their aesthetics in everyday life and exploring their interconnectivity with the environment (for example, exposing an EL paper to rain and let it draw light surfaces with its drops).

The evaluation of our experiments was naturally embedded in the research process as we discussed and made decisions on what kinds of aesthetic effects are worth following. We did not follow a structured perceptual evaluation, but let the process evolve naturally as we acquired an intimate aesthetic knowledge of materials. We did however involve other designers and students in our work. The documentation of our experiments allowed us to reproduce the findings and to share them through our online platform and in hands-on workshops [39]. By inventing novel fabrication processes, we were able to transfer this knowledge from research labs into the hands of designers who provided valuable inputs in the form of direct feedback. Our future steps include the development of evaluation methods to understand the affective and aesthetic impact of a specific material on both designers and users.



## Acknowledgements

We would like to extend our thanks ENZ Electronics and Lumitec, Ulano, Looph.ph Spatial Laboratory and Design Departement of Zurich University of the Arts for assistance with materials, advice and funding.

## References

1. Nijholt, A., Giusti, L., Minuto, A. & Marti, P.: Smart material interfaces: "a material step to the future". Proceedings of the 1st Workshop on Smart Material Interfaces: A Material Step to the Future. Article No. 1 (2012)
2. Koehly, R., Curtil, D. & Wanderley, M.: Paper FSRs and Latex/Fabric Traction Sensors: Methods for the Development of Home-Made Touch Sensors. Proceedings of the International Conference on New Interfaces for Musical Expression (NIME). pp. 230-233 (2006)
3. Goulthorpe, M. and the dECOi office: Aegis Hyposurface (2001). Available from: <http://hyposurface.org> (accessed 1 May 2015)
4. Oosterhuis, K. & Bilorio, N.: Interactions with proactive architectural spaces: The muscle project. Communications of the ACM - Organic user interfaces. pp. 70-78 (2008)
5. Backlund, S., Gyllenswärd, M., Gustafsson, A., Ilstedt Hjelm, S., Mazé, R. & Redström, J.: Static! The aesthetics of energy in everyday things. In Proceedings of Design Research Society Wonderground International Conference (2007)
6. Menges, A.: HygroScope – Meteorosensitive Morphology. Project Catalogue of the 32nd Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA). pp. 21-24 (2012)
7. Kim Sung, D.: Bloom (2012). Available from: <http://dosu-arch.com/bloom.html> (accessed 1 May 2015)
8. Kirschner, R., Yunchul, K., Domnitch, E., Gelfand, D. & Jacobs, A.: CONTINUUM exhibition, Liquid Things research project, Available from: [http://www.liquidthings.net/?page\\_id=1635](http://www.liquidthings.net/?page_id=1635) (accessed 1 May 2015)
9. Kirschner, R.: Materialwissen in Handbuch Künstlerische Forschung, Ed. J. Badura et al., Diaphanes (2015)
10. Coelho, M., Sadi, S., Maes, P., Oxman, N., & Berzowska, J.: Transitive materials: towards an integrated approach to material technology. The International Conference on Ubiquitous Computing. pp. 493–563 (2007)
11. Coelho, M., Hall, L., Berzowska, J. & P Maes, P.: Pulp-based computing: a framework for building computers out of paper. CHI'09 Extended Abstracts on Human Factors in Computing Systems, 3527-3528 (2009)
12. Bergström, J., Clark, B., Frigo, A., Mazé, R., Redström, J. & Vallgård, A.: Becoming Materials: Material forms and forms of practice. Digital Creativity, 21. pp. 155-172 (2010)
13. Vallgård, A.: PLANKS: a computational composite. Proceedings of the 5th Nordic Conference on Human–Computer Interaction. pp. 569–574 (2008)
14. Rossi, D., Augustynowicz, E., Georgakopoulou, S. & Sixt, S.: ShapeShift (2010). Available from: <http://caad-eap.blogspot.ch/> (accessed 1 May 2015)
15. Ingold, T.: Making: Anthropology, Archaeology, Art and Architecture. Routledge, London. (2013)
16. Blevins, E.: Sustainable interaction design: invention & disposal, renewal & reuse. In Proceedings of the SIGCHI conference on Human factors in computing systems. pp. 503–512 (2007)
17. Odom, W., Pierce, J., Stolterman, E., & Blevins, E.: Understanding why we preserve some things and discard others in the context of interaction design. Proceedings of the 27th international conference on Human factors in computing systems - CHI '09. pp. 1053-1062 (2009)
18. Greengard, S.: Vanishing electronics. Communications of the ACM. vol. 56 no. 5. p. 20 (2013)
19. Döring, T., Sylvester, A., & Schmidt, A.: A Design Space for Ephemeral User Interfaces. Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction, pp. 75-82 (2013)
20. Lahey, B., Girouard, A., Burleson, W. & Vertegaal, R.: PaperPhone: understanding the use of bend gestures in mobile devices with flexible electronic paper displays. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 1303-1312 (2011)
21. Qi, J. & Buechley, L.: Sketching in Circuits: Designing and Building Electronics on Paper. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 1713–1721 (2014)
22. Shorter, M., & McGhee, J.: Enhancing Everyday: Paper Interactions with Paper Circuits. Proceedings of the 2014 conference on Designing interactive systems. pp. 39–42 (2014).
23. Zhu, K.: A Framework for Interactive Paper-craft System. Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems. pp. 1411–1416 (2012)
24. Siegel, A., Phillips, S., Dickey, M., Lu, N., Suo Z. & Whitesides, G.: Foldable printed circuit boards on paper substrates. Advanced Functional Materials 20.1. pp. 28-35 (2010)
25. Lee, S., Kim, S. & Lee, K.: How Users Manipulate Deformable Displays as Input Devices. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 1647–1656 (2010)
26. Degenhardt, H.: Principles and applications of electroluminescence. Naturwissenschaften December 1976, Volume 63, Issue 12. pp. 544-549 (1976)

27. Cocksedge, P.: Bourrasque. (2011) Available from: <http://www.paulcocksedgestudio.com> (accessed 1 May 2015)
28. CAAD, ETH Zurich. Material Animation (2011). Available from: <http://materiability.com/material-animation/> (accessed 1 May 2015)
29. Persson, A. & Worbin, L.: Functional Styling - Exploring a Textile Design Space. *Duck Journal for Research in Textiles and textile Design* .1 (2010)
30. Gaver, W., Bowers, J., Boucher, A., Law, A., Pennington, S., & Villar, N.: The history tablecloth: illuminating domestic activity. In *Proceedings of the 6th conference on Designing Interactive systems*. pp. 199-208 (2006)
31. Wingfield, R. & Gmachl, M.: Spiratomic Space (2010). Available from: <http://loop.ph/portfolio/spiratomic-space/> (accessed 1 May 2015)
32. Enactive Environments research group, Department of Interaction Design, ZHdK. Actuated Matter (2011). Available from: <http://www.enactiveenvironments.com/sharing/actuated-matter/> (accessed 1 May 2015)
33. Kim, J. Y., Park, S. H., Jeong, T., Bae, M. J., Song, S., Lee, J. & Yu, S.: Paper as a substrate for inorganic powder electroluminescence devices. *Electron Devices, IEEE Transactions* 57. pp. 1470-1474 (2010)
34. S. Olberding, M. Wessely, J. Steimle.: PrintScreen: Fabricating Highly Customizable Thin-film Touch-Displays. *ACM User Interface Software and Technology Symposium*. pp. 281-290 (2014)
35. Sylvester, A., Döring, T., & Schmidt, A.: Liquids , Smoke and Soap Bubbles – Reflections on Materials for Ephemeral User Interfaces. *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction*. pp. 269–270 (2010).
36. Meade, R. & Diffenderfer, R.: *Foundations of Electronics: Circuits and Devices*. Cengage Learning. p. 675 (2003)
37. Gillich, H. *Experimente mit Elektrolumineszenz: alles über elektrolumineszierende Leuchtfolien, Leuchtbänder und Leuchtschnüre*. Franzis Verlag GmbH. p. 90 (2003)
38. Minami, T., T. Miyata, K. Kitamura, H. Nanto, and S. Takata.: Sound emitting thin film electroluminescent devices using piezoelectric ceramics as insulating layer. In *Electroluminescence*. pp. 310-313 (1989)
39. Available from: <http://www.enactiveenvironments.com/category/sharing/>(accessed 1 May 2015)

**Patrizia Marti**

University of Siena, Department of Social, Political and Cognitive Science, Siena, Italy,  
and Eindhoven University of Technology, Designing Qualities in Interaction Group,  
Department of Industrial Design, Eindhoven, The Netherlands  
patrizia.marti@unisi.it

# Poetry in design

**Abstract**

This paper describes an attempt to use poetry in design as an access door to experience cultural elements and embed them in the design of meaningful aesthetic interactions. Not only do poems tell a story, but their language and the way they play with the subtleties of that language also tell us a lot about cultural values, feelings, beliefs and judgments. This approach is exemplified by reporting on an educational activity carried out in the “Cultural Sensitivity” module of the Master’s Degree Program in Industrial Design at Eindhoven University of Technology (TU/e). By illustrating and discussing actual implemented students’ projects, a conceptual framework for employing poetry in design is provided.

**Keywords**

Poetry, Aesthetics of Interaction, Showcases, Interaction Design.

**1 Introduction**

This paper is a contribution to the field of Aesthetics of Interaction. It focuses on exploring methodologies for experiencing cultural elements and transforming them so as to endow design with new aesthetic significance. The field of Aesthetics of Interaction has come to maturity in recent years. It consolidates the idea that, in response to a change in the use of interactive technologies, traditional HCI concepts of usability,

efficiency, productivity must be enriched with other values such as curiosity, intimacy, beauty, emotion and affection [1].

Fogarty et al. [2] regard the notion of aesthetics as a result of the properties of form as perceived visually, as the use of attractive materials, and as “an added bonus” pertaining to the object per se isolated from the context of use. Other researchers consider aesthetics as having socio-cultural connotations, as a result of human appropriation of the object, a socio-historical appreciation of different components (materials, forms) and properties that do not inherently pertain to the object itself [3].

Wright et al. [4] recognise the active role of the user, who brings as much to the interaction as the designer does. The focus on sense-making and the acknowledgement that it concerns not just the cognitive but also the sensual and emotional threads of experience provides a means for interpreting interaction as aesthetic engagement.

From a similar viewpoint, Löwgren [5] stresses the need for holistic, interpretive approaches to dealing with aesthetics in interaction design. Wallace et. al. [6] explore the notion of enchantment by arguing that beauty can play a fundamental role in facilitating our experience with digital technologies. Hummels [7] argues that designers should strive to offer rich and authentic contexts for experience, rather than just beautiful products.

Djajadiningrat et al. [8] introduce the concept of beauty in use, to highlight that products that look aesthetically pleasing from a traditional industrial design point of view may frustrate users who start interacting with them. Unlike that part of the design community that reasons from usability towards aesthetics, to minimize the negative impact that poor usability can have on perceived aesthetics, Djajadiningrat et al. [8] start with designing aesthetic interactions to improve usability, with the aim of tempting people to engage in interaction, but also encouraging them to persevere in interacting. To this aim they identify different factors that play a role in aesthetics of interaction, including interaction patterns, richness of motor actions and freedom of interaction.

This paper addresses aesthetics from a similar stream of thought, illustrating a methodological approach to designing aesthetic interaction using poetry as a driving force.

We first provide an overview of research on poetry in design. We then describe our experience working with poetry to grasp cultural subtleties and turn them into actual designs. We will exemplify our approach through showcases of implementations of projects by students who attended the “Cultural Sensitivity” module held in the Master’s Degree Program in Industrial Design at TU/e.

Starting with analysis of poems in different languages, the design process evolves from abstract themes to the sensory realm of experienceability, going from the abstract to the concrete, and therefore developing design expertise. Abstract poetic concepts are turned into concrete poetic product design through incremental implementation phases: experiencing poems, translating poems into different languages, developing mood boards, conceptualizing the abstract, and making/fabrication showing how meaning and form in poetry are transferred and integrated into design.

## 2 Related work

Poets and artists both possess the abilities of thoughtfulness and observation, through which they transform existing imageries into a novel language of meaning and emotions.

Tu [9, p. 28] suggests that poetry is a world of beauty in imagination by which a poet uses words to create authentic experiences.

Poets play with language in order to get to the magic

of life and the human experience. Their poems allow us to see how people think and act in all sorts of environments, what they feel and how they behave. They are source of knowledge and inspiration about life. Recently, some researchers and design practitioners have started to reflect on the relationship between poetry and design and the actual use of poetry in design. Beatty et al. [10] interviewed poets about their creative practices and conducted a thematic analysis comparing these practices to key findings concerning the nature of design expertise. The results of the study revealed similarities between poetry and design, related to the use of “sources of inspiration”; the involvement of “primary generators” or initial concepts to constrain the space of possibilities [11], and the interplay of problem and its potential solution, which “co-evolve”. Some interviewed argued that much of the difficulty surrounding the process of poetry composition derives from the inherently ill-defined nature of the task. Rittel et al. [12] named ill-defined problems as “wicked problems”, to mean something that is not docile, amenable or meek to handle. Wicked problems require a highly iterative and incremental revision process. This makes design and poetry highly conjectural in nature, exploratory and incremental.

Kolko [13] recognises a unique role of poetry in sensing, seeing, and feeling the world. *“A poetic interaction is one that resonates immediately but yet continues to inform later - it is one that causes reflection and that relies heavily on a state of emotional awareness. Additionally, a poetic interaction is one that is nearly always subtle yet mindful”* [13, p. 76].

For Kolko [13], a product that affords poetic interaction has three main features: attention to sensory details and a high degree of visual and material refinement; honesty, that is integrity to the business vision, to materials and to people; mindfulness, in the sense that poetic interaction demands attention in the same way in which poetry requires effort in reading and creating the lyrics. Kolko’s main contribution is to have provided an initial abstract definition of poetic interaction, even if not exemplified by actual designs derived from poetry. Moli et al., [14] adopted a more operational approach by developing a model that illustrates the process for extracting cultural elements from poetry and converting them into a design. They illustrate their methodology articulated in actual implementation steps. The overall process is inspired by a number of features of Chinese

poetry and is mainly focused on visual design and representation of 3D products.

A different standpoint was taken by Lin et al. [15], who defined poetic interaction design as design conveying an image with an ambiguous expression, causing flashbacks originating from a person's experiences. For Lin et al. [15], uncertainty and ambiguity are the key to conveying a poetic image in interaction, and the possibility of transferring a poetic image depends on participants' inherent ability of gestalt. Poetic interaction therefore implies the designer's ability to create an implicit expression that invites users to interpret it with common sense or with their own experiences. This stimulates sense-making, reflection and participation.

As it is possible to guess from the literature mentioned above, research into poetic interaction is still in its dawn. Some practitioners recognise the potential of using poetry as the next step beyond the aesthetics of interaction. Some of them reflect on the use of poetry in design from a theoretical viewpoint, while others strive to define operational guidelines for realizing poetic interactions.

This paper is a theoretical and methodological contribution to the field of aesthetics of interaction. The approach uses poetry as a tool for experiencing cultural elements and embedding them in the design of meaningful aesthetic interactions with concrete products.

### 3 Cultural sensitivity

At present, we are still in the process of investigating and refining both the conceptual framework and the methodological approach to stimulating cultural sensitivity in aesthetic interaction design through the exploration of poetry. Besides our own design work and research in the field [16, 17], the approach has been adopted as inspiration and input for synthesis in related student design projects.

In what follows we present showcases of the "Cultural Sensitivity" module, co-lectured by Patrizia Marti and Ward van der Houwen. Based on the student's craftsmanship and their different cultural and educational backgrounds, the showcases opened up a reflection on cultural values, differences and subtleties of interaction.

The students' learning activity held "Making" in its core. The students were encouraged, through cycles of reflection-on-action, to develop their personal

understanding of poetry, to transform it into design probes, and to present the final designed artefacts to classmates, inviting them to bodily engagement and reflection.

The vision of the module is closely connected with reflective practice [18] and craftsmanship, where knowledge is acquired through the exercise of craft-inspired learning practices throughout design and fabrication processes [19].

The module started with a master class on "reading and writing poetry" by the famous Dutch poet Jan Glas, who writes poems in Gronings dialect: a lingua franca to all participants characterized by a typical accent and vocabulary, which differ strongly from other Low Saxon dialects. He was invited to kick off the module and to perform his own poems. Glas explained that his approach to poetry was mainly a conversion of a feeling or a mental image into words, which in turn left the reader room for interpretation and expression. He used words with nuanced meanings to allow the reader's imagination to run wild and form a feeling, meaning or image independently. He highlighted the active role of the reader in experiencing and making sense of the poem. Students were exposed to an intense investigation of poetry to address the sensuousness of the perceptual experience and the value-related message of the poems at hand. In order to appropriate the meaning of the poems, they were invited to translate the poems into their own language. Dutch students translated from the original Groningen dialect into Dutch, while foreign students translated an English version of the poems into their own languages.

Translation was the first step in a double transformation process: from one language into another (the student's mother tongue) and from that into design. It was a craft activity in which the translator had to develop the skills not only to "transport" words from one language to another, but also to be carried away in a deep, meaningful relationship with the text.

The translation was performed twice: the first time on Glas's poems with the purpose of familiarising students with different styles of translating, and the second time on poems that the students selected on their own as the most promising with respect to the topic of the module. The main source used by the students to select poems was <http://poetryinternationalweb.net/>, a literary organisation that delivers quality poetry worldwide, encouraging translation.

Students had to recite the selected poems many times, with the aim of incrementally developing their sensitivity and sense-making. The poems shared common themes and values, depending on the topic of the module. Students extracted values from the poems and translated them into mood boards which, in turn, were used as the basis for designing probes. The exploration of design probes was used to build a working prototype.

#### 4 Showcases

Below we present four showcases. The first two resulted from a one-week module whose topic was “Everyday activities and objects”. The third and fourth showcase were developed in a previous edition whose topic was the sensory experience of touch and taste.

##### 4.1 Mirror

Mirror is a social networking platform that proposes a new form of digital communication. The project was developed by T. Luu, K. Scheltenaar, S. Mouthaan and A. Jense. Students selected three contemporary poems as a source of inspiration: “Mirror” by Sylvia Plath, “Writing A Curriculum Vitae” by Wislawa Szymborska, and “Interpretations” by Mourid Barghout. The poems shared common themes and values. They were about expressing personal meanings interpreting a situation from different viewpoints. They focused on taking multiple points of view and multiple perspectives to experience life in all its richness, and to express them with a subtle articulation of language. Among the three poems, the students focused on Mirror by Sylvia Plath. The following is an excerpt:

*I am silver and exact. I have no preconceptions.  
Whatever I see I swallow immediately  
Just as it is, unmisted by love or dislike.  
I am not cruel, only truthful---  
The eye of a little god, four-cornered.  
Most of the time I meditate on the opposite wall.  
It is pink, with speckles. I have looked at it so long  
I think it is a part of my heart. But it flickers.*

The poem was translated by each member of the group into Dutch, since all the students were Dutch. The translations were all quite different. They were compared and analysed to get a shared meaning. In the poem, a mirror presents itself and its owner. The mirror first describes itself as an object, “silver and

exact” with a four-cornered eye. The object is therefore humanized: it swallows what it sees and reflects that image back without any alteration. The owner needs the mirror to provide her with an objective, unadulterated reflection of self, even though it is often discomfiting. Sometimes the mirror looks across the empty room and meditates on the pink speckled wall across from it. After the analysis and conceptualization of poems, students identified values and translated them into moodboards (Fig. 1), which in turn were the basis for design probes.



Fig. 1. Moodboards: images of self (top); a mirror that does not reflect reality (bottom).

The poem is about images, reflection on self and viewpoints. Students reflected on the image that people create of themselves when using social media. Analysis of the poems made the students aware of the limited expressivity of today’s social media. Functional non-aesthetic principles are used in social networks, particularly those that rely on documenting the minutiae of real-life. Today’s social media networks convey a limited iconic dialect using emoticons. This impoverishes language, eliminates any form of difference and infantilises expressivity.

The final prototype consisted of a rich typing system to make a conversation expressive. It used pressure on the keyboard and the duration, speed and pace of typing

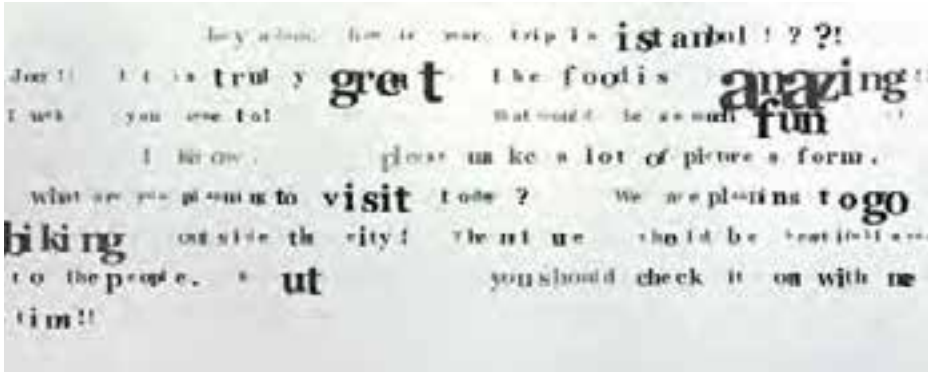


Fig. 2. A conversation on Mirror

as input to vary the typography of the conversation. Pauses in typing were reflected in the final text. All these elements were expressed in the chat, resulting in a landscape of letters and words with clear aesthetic qualities (Fig. 2).

The end result was a meaningful visual translation of contents that conveyed not just the meaning of words and phrases, but also the expressivity of typing, the pace of thinking and the emphasis put on certain words, which were displayed with a bigger font when typed slowly but firmly. The process of information design included not simply the text space. The special organisation of elements within it made sense and it was perceived as a contribution to the meaning of the whole reading and writing experience. Mirror aimed to provide a continuum between expressivity and movement, creating the context for a physical modality for generating meaning. A person could use the platform to express meaning beyond words and was, in turn, influenced by the platform itself. The objective was to provoke reflection among people about the way individuals express themselves through social networks. The platform can be tried out at the following link: <http://www.trieuvy.nl/mirror/>

#### 4.2 Tapestry

Tapestry is an interactive curtain that accompanies the experience of waking up in the morning, harmonising the qualities of the indoor and outdoor environment with the morning ritual of awakening. The project was developed by T. Raijmakers, J. van der Meij, and J. Dabekaussen. Students selected two poems: “This Morning” by Esther Morgan, and “Zo schept ze stilte” (“So it creates silence”) by Jan Glas.

The following is an excerpt from “This Morning”, the poem that was selected by the students to guide the design process.

*I watched like one bedridden for a long time  
on their first journey back into the world  
who finds it enough to be going on with:  
the way the sunlight brought each possession in turn  
to its attention and made of it a small still life:*

As in the previous project, the translations differed in style and language. Differences were compared and used to stimulate sense-making.

In the poem, the narrator feels ‘bedridden’ and puts himself in a position of renewal. The sunlight embraces objects, making them worthy of notice. The students developed a video moodboard, showing how morning light can modify perception of objects under different circumstances. From the moodboard they derived the challenge of the project, which was to design an artefact that could offer a rich experience of awaking, making the world worth rediscovering every day. By focusing on the daily habit of a morning ritual and using the bedroom as context, students developed probes inspired by the way the sunlight illuminates objects. The probes simulated the sun coming and going, and set a spotlight on different objects, giving these mundane things a mesmerizing effect.

Material exploration was carried out to appreciate the effect of light going through different surfaces and materials. As a final prototype (Fig. 3), students developed a sensorized dynamic curtain that could play with sunlight. The end result was a relatively complex projection that aimed to provide a mesmerizing, mindful feeling while triggering curiosity about the outside world.



Fig. 3. Final prototype

While curtains nowadays are opened straightforward on the vertical or horizontal plane, this curtain opened up gradually, fragmenting in interplay with indoor and outdoor light conditions. This afforded a sensory, emotionally charged and awesome experience.

#### 4.3 Invisible touch

This project was developed by D. Peverelli, M. Brinkema, M. Rademakers, and D. Oogjes. The assignment consisted in analysing poems focusing on the sensory experience of touch, and through this coming up with a poetic probe for interaction.

The following poems were selected: “View with a grain of sand”, by Wislawa Szymborska; “Het Water” (The Water), by J. Bernlef; 605, by Emily Dickinson.

Unlike the previous project, all three poems were used equally in the design process. In the following, we report an excerpt from 605, by Emily Dickinson, to give a flavour of the insights derived from a special kind of touch played by a spider described in the poem.

*The Spider holds a Silver Ball  
In unperceived Hands  
And dancing softly to Himself  
His Yarn of Pearl -- unwinds --*

*He plies from Nought to Nought  
In unsubstantial Trade  
Supplants our Tapestries with His  
In half the period*

Two concepts arose from reading and translating the three poems: intangibility (touching without touching), and humanization of objects (giving human qualities to objects or materials that are inhuman). After experimenting with different materials and the



interactions that people can have with them, students were fascinated by soap bubbles and their similarities with the qualities described in the poems.

Analyzing the poems resulted in a moodboard containing an exploration of suitable interactions with different materials and surfaces. While material touch was afforded by different surfaces, the immaterial or invisible touch, which is intangible, was afforded by the behaviour of “untouched” objects (e.g. bubbles). For instance, blowing a bubble makes it animated, with its own behaviour, dictated not only by the intensity of breath, but also by environmental conditions (Fig. 4). The behaviour of the bubble, in its unpredictability, shows agentivity. The bubble resembles a life-like character.



Fig. 4. Exploring interactions with soap bubbles



The final prototype was an interactive wall, an artistic installation composed of interactive “bubbles” inflated with air (Fig. 5). The amount of inflation was determined by the presence of people touching them. Different behaviours of the bubbles were designed: the docile bubble followed the touching hand, the escaping bubble deflated in presence of the hand, the erratic bubble made unpredictable choreographies inflating and deflating to tease the hand. The soft material used for the installation created a poetic, aesthetically engaging and fun interaction.



Fig. 5. Final prototype of interactive wall

#### 4.4 Get close

This project was developed by A. van Ranst, L. Hermans and S. Yamada. The assignment consisted in analysing poems focusing on the sensory experience of taste. The following poems were selected: *The Onion*, by Wislawa Szymborska; *Boomgaard (orchard)*, by Bart Moeyaert, *Mephistopheles Epicureus*, by Albert Verwey, and *Dishes of Summer*, by Ritsuko Hoshino. All the poems were about the experience of taste. The students focused on “*The Onion*” by Wislawa Szymborska, an ironic and beautifully written piece describing how an onion is different from most things insofar. The following is an excerpt.

*the onion, now that's something else  
its innards don't exist  
nothing but pure onionhood  
fills this devout onionist  
oniony on the inside  
onionesque it appears  
it follows its own daimonion  
without our human tears  
our skin is just a coverup  
for the land where none dare to go  
an internal inferno  
the anathema of anatomy  
in an onion there's only onion  
from its top to it's toe*

The poem is about pureness, admiration, desire to be perfect, to be “onionesque”. The onion is perfect; its heart is nothing else than pure onionhood. Szymborska describes an onion with words that contain the word onion: onionhood, onionist, oniony, onionesque, daimonion, and onionoid. The use of these descriptive words, while playful and poetic because of the assonance of the *on* or *un* sound, does not help us better understand what an onion is – it only shows us that an onion is different from other things.

The students composed their moodboards from cutout video animations on the poem presented at the Choreographic Captures competition in Munich 2012. The essence of the moodboard was that the onion is perfect but perfection doesn't exist on its own. The same stands for taste. It is a layered experience that is shared with all senses. The combination of the layers makes it perfect, not just one layer.

Inspired by the poem and the moodboard, students explored different layered objects, focusing on flipbooks. The designed probes were a series of flip

Fig. 6. Flipbook prototype



books with geometric pictures that gradually varied from one page to the next, so that when the pages were turned rapidly, the pictures appeared to animate by simulating motion or other changes. The final prototype was a menu designed as a flipbook with slightly different images of the same dish. When the pages were turned rapidly, the smell wafted around (Fig. 6). The person could even lick her fingers after browsing the flipbook and experience the taste of the dish. The experience of taste resulted from a complex sensory combination that engaged all the senses in search of the perfect taste.

## 5 Discussion and conclusive remarks

In this paper we described our research on poetry-inspired design. The objective of this research is to stimulate sensitivity toward cultural subtleties of interaction, and to endow design through the lens of poetry with new aesthetic significance.

Poetry is a differentiator, and a true alternative to merely functional design. It is not a commodity, but something that does make us reflect on what we do and how. Poetry enables an indirect language, in which what speaks is not the established meaning but rather a new order of sense and expression. Moreover, the meaning of a poem does not dissipate when expressed. It is made lively, persistent and significant by those who experience it. The more a poem is read, the deeper is the meaning, subjected to new interpretations. Poetry is about thoughtfulness and observation, and the human experience described in the language of poetry is never destined for banality. The showcases described above showed that poetry could provide a framework to create rich, sensory, beautiful, engaging and mindful interactions through design. A common aspect of the showcases was the embodiment of sensing, acting and feeling. This was partly afforded by the aesthetics of material and the way it was used. For instance, in *Mirror*, expressiveness was embodied in the way people typed on the keyboard; the act of writing and the expressiveness of the gesture were not separated. In *Invisible Touch*, the quality of the experience was partly enabled by the materials and partly by the active (humanized) behaviour of the object. The person and the artefact perceived each other, so that the two engaged in active dialogue.

*Get Close* offered a good example of an ill-defined problem, in which the comprehension of the problem and its potential solution co-evolved in the design

process, informing each other. The concept of perfection based on a layered sensory experience opened up space for probing and stimulating an original design.

Overall, the “Cultural sensitivity” module was both an educational activity and an instance of research through design, a designerly way of doing research, in which prototypes, iterations and future visions were integral parts of the research method. With this research, we aim to provide a theoretical and methodological contribution to the field of Aesthetics of Interaction, exploring poetry as a source of inspiration and a tool for synthesis.

## Acknowledgements

I would like to thank Ward van der Houwen, poet and co-lecturer of Cultural Sensitivity. Special thanks to Jan Glas for being a precious source of inspiration for our students.

## References

1. C. Overbeeke. The aesthetics of the impossible. Inaugural lecture. Eindhoven Technical University Library (2007).
2. Fogarty, J., Forlizzi, J., Hudson, S. E. Aesthetic information collages: Generating decorative displays that contain information. In *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology* (pp. 141-150). New York: ACM (2001).
3. Petersen, M. G., Iversen, O. S., Krogh, P. G., Ludvigsen, M. Aesthetic interaction: A pragmatist's aesthetics of interactive systems. In *Proceedings of the 5th Conference on Designing Interactive Systems* (pp. 269-276). New York: ACM (2004).
4. Wright, P., Wallace, J., and McCarthy, J. Aesthetics and experience-centered design. *ACM Trans. Comput.-Hum. Interact.* 15, 4, Article 18 (2008).
5. Löwgren, J. Five things I believe about the aesthetics of interaction design. Position paper for Dagstuhl seminar on the study of visual aesthetics in HCI (2008).
6. Wallace, J. Press, M. All this useless beauty: The case for craft practice in design for a digital age. *Design Studies* (2004).
7. Hummels, C. *Gestural Design Tools: Prototypes, Experiments and Scenarios*. Unpublished Doctoral Dissertation, Delft University of Technology, Delft, the Netherlands (2000).
8. Djajadiningrat, T., Wensveen, S., Frens, J., Overbeeke, K. Tangible products: Redressing the balance between appearance and action. *Personal and Ubiquitous Computing*, 8, 294–309, (2004).

9. Tu, K. C. Defining poetry and critiquing poetry. Taipei: Taiwan University Press (2010).
10. Beatty, E. L., Ball, L. J. Investigating exceptional poets to inform an understanding of the relationship between poetry and design, Proceedings of the Second Conference on Creativity and Innovation in Design, October 19-21, Eindhoven, Netherlands (2011).
11. Darke, J. The primary generator and the design process. *Design Studies*, 1, 36-44 (1979).
12. Rittel, H., Webber, M. Dilemmas in a General Theory of Planning, *Policy Sciences*, 4, Elsevier, 155-169, (1973).
13. Kolko, J. Thoughts on Interaction design (2nd edition). Morgan Kaufmann, MA:USA (2013).
14. Moli Yeh, H., Chiu Wei, C., Rungtai L., Employing Poetry Culture for Creative Design With Six-standpoints. Proceedings of Design Research Society 2014, DRS 2014: Design's Big Debates. Umeå, Sweden, June 16-19 (2014).
15. Lin, Y.-C., Chang, H.-M., & Liang, R.-H. (2011). Designing Poetic Interaction in Space. In J. Jacko (Ed.), *Human-Computer Interaction. Towards Mobile and Intelligent Interaction Environments SE - 63* (Vol. 6763, pp. 559–568). Springer Berlin Heidelberg. doi:10.1007/978-3-642-21616-9\_63
16. Marti, P. The Subtle Body. Eindhoven Technical University Library, ISBN: 978-90-386-3714-3. (2014). Available at: <http://alexandria.tue.nl/extra2/rees/marti2014.pdf>
17. Marti, P. In praise of beauty and enchantment: setting the scenery of respectful design. Proceedings of the International Conference on Multimedia, Interaction, Design and Innovation, MIDI 2014, 24-25 June, Warsaw, Poland. Pp 1-6, ISBN: 978-1-4503-2779-4 doi>10.1145/2643572.2643574. (2014).
18. Schön, D. The Reflective practitioner. New York: Basic Books (1983).
19. Sennett, R. The Craftsman. London, Penguin Books (2008).

# Design for Attachment: an explorative search for product qualities that enhance our emotional bond with digital products

## Abstract

This paper describes an explorative search for elements of attachment: qualities that support a stronger emotional bond between user and digital product. Based on a reflection of attachment literature we conclude that digital products require a different approach towards attachment, namely one that focuses on both the physical artifact and the digital content. We hypothesize that the digital products should continuously adapt to the user affecting all product aspects: appearance, interaction, functionality and content.

In order to reach these goals, our research takes an explorative research-through-design approach with a focus on analysis through making. We start with an exploration phase, where we perform a series of case studies: small design iterations on different types of digital products (mp3 players, cameras and e-readers). The concepts from the case studies are coded and clustered into a first set of elements of attachment. In the implementation phase, these elements are used in the design of a new mobile phone concept: FLEX. In the evaluation phase, we evaluate FLEX on its translation of the elements and its ability to support attachment through expert review sessions. From evaluation we define a refined set of elements of attachment.

The elements that we present are *'Knowing each other'*, *'Creating focus'*, *'Sharing memories'* and *'Reflecting identity'*.

They can be used as inspiration and guidance in different phases of the design process.

## Keywords

Design for Attachment; product attachment; concept phone; FLEX; elements of attachment; research-through-design.

## 1 Introduction

"We need things consumed, burned up, worn out, replaced and discarded at an ever-increasing rate." [1] This famous critique from retail analyst Victor Lebow about the American consumption society dates from 1955, but it still seems relevant. Think about the average life of your mobile phone, mp3 player or digital camera, for example. Quick replacement rates result in short product lifespans that have major consequences for the waste problem, especially with digital products [2]. A possible solution could be to design for attachment: by making people care for their (digital) products, we hopefully can increase product lifespan while enhancing user experience.

In digital products product attachment seems to be of a different nature than it was in earlier products. We believe that this is caused by in the increasing divide between interactive artifact and digital content. The relation between the artifact and its content used to be tied to the same rules: if the product got damaged or

lost, the information would be lost (think for example of text messages in early mobile phones). This is no longer the case as digital information can be freely transferred. Digital content has become an entity of value in and of itself, which has become subject to research [e.g. 3]. However, in this paper, we wish to re-focus on attachment to the digital products themselves, in order to increase product lifespans.

In what follows we first dive into product attachment literature to seek guidance for product design. As we find that attachment with digital products might be best supported through adaptation over time to the individual user, we set out to define a new set of elements to enhance attachment with *adaptive* digital products. The aim of these elements is to support the designers of such products in the future. In our journey, we take an explorative research-through-design approach [19]. We split the process into three main phases: *exploration*, *implementation*, and *evaluation*. In the *exploration* phase, three explorative design cases on different types of digital products (camera's, e-readers, and mp3 players) form the basis for a first set of elements. In the *implementation* phase, we use this first set of elements in the design of a new mobile phone concept. In *evaluation*, we evaluate the phone concept on its translation of the elements and we evaluate the elements on their use in the design process. We conclude this paper with a discussion of this new direction in design for attachment.

### 1.1 Product attachment

Product attachment has been researched throughout different disciplines. It concerns the relationship a consumer experiences with a specific product [4, 5, 6, 7], and is related to irreplaceability [8]. "Attachment tends to develop over time as a result of recurring interactions between an individual and the product" [5, p. 641]. These recurring interactions result in profound and sustained experience of meaning [6], which define the relationship between user and product. The experience of meaning include, e.g., feelings of confidence, independence, achievement, security, friendship, or control [6]. Following this course, we see attachment as a relationship between user and digital product that is defined by recurring interactions creating personal experience of meaning, which results in irreplaceability of that product.

This experience of meaning resulting from recurring interaction is explained through a process of *self-extension* [6, 9, 10]: our possessions contribute to our identity and reflect that identity back to us. Zimmerman [10] presents seven framing constructs for self-extension, which are *role engagement*, *control*, *affiliation*, *providing ability*, *longterm goals* and *rituals*. All these constructs have a clear overlap with factors that are known to influence product attachment. *Self-expression* for example (similar to Zimmerman's [10] affiliation and role engagement) is known to have an effect on product attachment: "Products with personality associations similar to the personality of the owner allow him/her to show the world who he/she is. Consequently, the product gains symbolic meaning to the owner, due to which the owner becomes more attached to the products." [11, p.10]. The influence of *memories* (similar to rituals) has also been researched intensively [e.g., 5, 8, 9]. Schifferstein and Zwartkruis-Pelgrim even call "a strategy based on the accumulation of memories" the most promising direction for designers to stimulate increasing attachment on the long term [8, p. 8]. Lastly the stimulation of forming *future goals* influences people's connection to possessions [4]. Apart from the self-extension constructs, there are other aspects that influence attachment. Perceived pleasure [5] or *enjoyability* [5, 12, 13] has a positive influence and *surprise* is again known to increase enjoyability [14]. Also the degree of *mental effort* that people invest to gain control and a feeling of ability in a product is positively related to the experienced emotional bond with a product [4].

### 1.2 Focus on adaptive digital products

The role of the different constructs that influences attachment changes over time. Mugge et al. [5] found an inverse U-shape relation between duration of ownership and attachment: after a stable first year attachment decreases but after twenty years it is highest. According to this research, attachment is first most associated with enjoyability but after time the qualities pertaining to memories become key. We see possibilities in extending the positive factors from the beginning of the relationship as well as bringing the long-term triggers forward through adaptive digital products. Moreover, adaptive digital products can change along with users changing facets of the self and can adapt their way of supporting identity, which could increase

the opportunities for self-extension. Therefore, in this study, we focus on adaptive digital products.

**Related adaptive design directions.** We are not the first one to focus designing on adaptive products to support the relationship between user and product. We discuss the three most well known directions and in order to specify our focus further.

*Customization.* In customization, patterns of customer needs lead to a set of personal choices within product families [15]. Think for example of NIKEiD [16], where sneakers can be customized based on predefined choices. Customization makes products more personal, which certainly has an effect on their enjoyability, but there is no transformation of the product over time and use. The adaptation happens only at purchase, which means that there is no elongation of surprise and enjoyment. Moreover, the adaptation is based on target groups instead of individual users, which diminishes the connection to the facets of users individual identities.

*Personalization.* Personalization does have a continuous adaptation based on the individual user [17]. For example, Google's search engine [18] learns from previous search actions and continuously adjusts result accordingly. So as for its adaptation, personalization seems very suitable for attachment. However, personalization is mostly software-based, which makes the adaptation transferrable and not product specific.

*Graceful aging.* The adaptation of graceful or dignified aging products [13] is, in contrast to personalization, product specific. It focuses on aesthetically pleasing wear and tear of materials that make products look unique. This effect is often named when people mention their favorite products (think for example of a leather bag that becomes more beautiful with every scratch). The adaptation in these products is continuous and based on the individual user but only focused on appearance. Especially in digital products we need a broader effect on multiple product aspects, including at least the interaction and digital content.

**Direction & contributions.** Concluding from this review, we propose a new direction in design for attachment with digital products. We aim at digital products that adapt continuously to the individual user, affecting all product aspects: appearance, interaction, functionality and digital content. In general, this paper has two main contributions: we define elements that

can support designers of adaptive digital products and we present a mobile phone concept to illustrate and evaluate our direction.

## 2 Exploration

We started this project with a designerly exploration of product elements that could enhance the bond between user and adaptive digital product. We performed three case studies three different digital product groups: cameras, MP3 players and e-readers. We chose these products because they are prime examples of products that we trade in easily for a new version. Moreover, they are also all products that function as a shell for external, interchangeable data. Lastly, all of these examples have analogue predecessors (analogue cameras, books and music carriers like vinyl or cd's) that have the potential to form an emotional bond with their owners.

To gain inspiration for the design case studies, we held a focus group where we asked five people to bring a product they would never throw away and to explain the reasons for this irreplaceability. We also performed a social media enquiry on the meaning of different relationships, i.e. the difference between acquaintances and friends. The resulting anecdotes and examples formed the input for the case studies on cameras, MP3 players and e-readers. Each case study took two weeks and followed a similar process. We started with one or two group brainstorms involving three to five master students with a background in Design. The goal of each brainstorm was to come up with more personal and more 'attachable' versions of the digital product we were designing for (MP3 players, cameras, or e-readers). The brainstorm was followed by a weeklong individual ideation session. We captured the most promising ideas into low fidelity prototypes made of paper, cardboard, and scrap materials. An example of results from the case study on cameras can be seen in figure 1.

**Analysis.** The resulting camera, mp3 and e-reader concepts were used in an inductive thematic analysis [20]. Each concept was evaluated and compared to constructs deriving from attachment research [e.g. 4, 5, 8, 9, 10, 11, 14] through extensive discussions between the two authors of this paper.

Each concept was labeled with codes (see figure 1), which were clustered again, resulting in nine themes (*shared experiences, memory recollection, showing content, physical digital content, personal interaction,*



Fig. 1. The prototypes resulting from the camera case study and the coding of these prototypes.

*layered functionality, effort, patterns and intimacy*). To condense our themes in a more workable set, we mapped the nine themes on one of the four aspects of digital products that they influence most: interaction, functionality, appearance, or history. The four resulting clusters were given names and descriptions, of which this set of four elements of attachment is the result:

- *Knowing each other*. This element (resulting from the theme *personal interaction*) is based on the idea of growing familiarization of interaction. In time mutual adjustments between user and product make the interaction personalized.

- *Creating expertise*. Through this element (resulting from the cluster *layered functionality & effort*), the product supports more specific and goal oriented functionality over time, by enhancing often-used features and forgetting about lesser-used functionality.
- *Expressing identity*. This element (resulting from *showing content & physical digital content*) changes appearance of the product to express the connection between user and product towards others.
- *Sharing memories*. This element (from *shared experiences & memory recollection*) triggers recollection of shared experiences between user and product, which leave their mark on the product.

Fig. 2. A selection of explorations in the development of the phone concept.





Fig. 3. FLEX with (A) a flexible rim and (B) hardware components around (C) the screen.

### 3 Implementation

In this phase, we used the set of elements in the design process in order to design an adaptive digital product that matches our direction. We decided to take smart phones as the product group for this implementation. Phones form a clear example of digital products that are indispensable but that are rarely irreplaceable [21]. The most important reason for replacement has very little to do with the functional life of the phone, but mainly depends on the contract length with a service provider [22]. These characteristics make the phone an interesting case for design for attachment.

We took again an explorative approach with a focus on making, and the aim to start with a broad range of concepts (see figure 2). The set of elements was used in different parts of this process. In idea generation, we used the elements to structure a group brainstorm session with five design students. The three-hour brainstorm was split up into four phases, and in each phase one specific element was introduced and used to redesign the mobile phone. During the selection of a final concept, we used the elements as requirements, and we compared each concept on the opportunities they offered on each requirement. During concept development, the elements were used as guidelines and for regular check-ups to see if development went in the right direction.

#### 3.1 FLEX: The mobile phone concept

The result of the design process is the mobile phone concept FLEX (figure 3). In FLEX, specific in- and output components (camera, LED, speaker, microphone, GPS, and keyboard; figure 3B) are located at the border of the screen (figure 3C). A flexible rim is placed around the components (figure 3A). By pushing the rim surrounding the components in or out, one can explore the functionality related to that component.

By gently flexing the rim of the phone around one of the components, the applications that are relevant for that component appear. So by flexing the speaker for example, applications like *Spotify*, *Soundcloud*, and *myRadio*, are presented. The applications appear in order of relevance: the more they are used, the sooner they appear and the larger the icons. If quick access is required, the rim can be pushed in one resolute movement, which will directly open the most-used application for that component. Different in and output components can be combined. For example, by pushing the speaker and microphone simultaneously, the phone application will show (see figure 3). This rim behavior is expected to result in short cuts and personalized interaction, and forms an example of how the element '*Knowing each other*' can be translated.

In FLEX, applications are not actively stored on the phone. Instead, the phone gives seamless access to the 'App Store' within the user interface. This means that there is a continuous invitation to explore new types of applications and new types of functionality based on the current state of the hardware, your preferences and community recommendations. This offers the flexibility and ability to specialize in functionality, and forms a translation of the element '*Creating Expertise*'. The flexible rim is made of a silicone outside with a highly viscous liquid core. The core slowly moves to the sides in the places that are used a great many times, which deforms the rim in those areas. The deformed locations in the rim are thinner, so rim becomes more flexible around the often-used components, leading to more comfortable usage (this represents the element '*Knowing each other*' again). With time, through the deformations in the rim the phone will show use patterns to the user and to others, which links to '*Expressing identity*' and '*Sharing memories*'.



Aside from the translation of the elements, FLEX represents our direction towards designing for attachment (see section 1.2). It is adaptive to the individual user's actions and usage. The adaptation is open-ended and continuous and affects the phone in appearance (in the rim), in interaction (through the rim's flexibility and ordering), and in functionality and digital content (in the available applications and new recommendations).

## 4 Evaluation

The evaluation phase has three main aims: (1) to see whether FLEX could trigger attachment, (2) to evaluate the translation of the elements in FLEX, and (3) to refine the four elements of attachment.

### 4.1 Setup

Since the FLEX prototype is not fully functional we made use of an expert panel for the evaluation. Experts can understand the underlying ideas and potential despite of prototype limitations, foresee problems, and elaborate on opportunities [24].

The expert panel consisted of eight senior design researchers with different expertise, including system design, business design, and user-centered design. The differences in expertise highlight different implications of the design of FLEX, of the elements, and of design for attachment, such as usability, user experience, business cases, and technical implications.

Each review session lasted for 30 minutes, and existed of two parts. In the first part, we introduced the phone concept without mentioning our aim to design for attachment, in order to get unbiased opinions on the value of FLEX. FLEX was presented by means of an animated movie and a prototype, existing of a 3D printed model equipped with flex sensors, connected to a Flash [24] interface on a laptop to function as the phone's screen. Material samples were available to show the deformation of the rim from use patterns. In a semi-structured interview we asked the experts about the value of the concept, its usability, the interaction, and the overall experience.

In the second part of the session, we explained our aim to design for attachment with adaptive digital products through an animated movie. We introduced the four elements of attachment through cards, and we briefly explained what we meant with them. We did

not explain the translation of the elements in FLEX, or their translation in product aspects in general. In a semi-structured interview we asked the experts about their opinion on whether they thought the elements would support attachment, on the completeness of the elements, on whether they recognized the elements in the phone and if so, in what way, and about the value of the elements for designers.

The setup was tested in a pilot with a master student. All sessions were filmed and transcribed.

We performed a thematic analysis [20] on selected quotes from the transcriptions. We categorized quotes on subjects related to the different parts of the evaluation: the phone concept and the interaction, the four elements, their translation into the phone, and the value of the elements for designers.

### 4.2 Findings

In the following section, we discuss the main results by using quotes of the experts. We briefly discuss the evaluation of FLEX as a mobile phone concept, after which we elaborate on the elements and their translation into FLEX.

**The mobile phone concept.** Overall, the experts appreciated the new way of interacting with the phone. The value of FLEX is especially seen in navigation, since it helps to avoid hierarchal and confusing menu-structures: *"It [the rim] becomes a sort of tangible frequently-used app selection that I can access fast and easy."* The central placement of the hardware components is seen as an interesting way to create understanding of the phone's functionality and abilities that should invite the user to explore new functionalities. Similarly, the recommendation of relevant applications was cheered upon, as long as reliability of the recommendation system is secured. The physical interaction with the flexible rim was evaluated positive, as well as the aging qualities: *"I love the traces of use"*. So, apart from some implications that need to be resolved in further development, FLEX was seen as an interesting phone concept.

**The elements.** The background of the project, and the reasons to focus on a new direction in design for attachment with a large focus on adaptive systems, was understood and met with enthusiasm by all experts. The

elements were generally appreciated but were received with some insecurity about their completeness. Because of the complexity of the matter, there was hesitation to accept a list of only four elements to describe the effect. However, no missing elements could be named.

*Knowing each other.* The feeling of attachment through familiarization, as seen in 'Knowing each other' was easy to relate to. Most experts could easily find an example from their own cherished products: "I feel in the way of playing [my contrabass], how we make each other sound better. I feel a steering from it that makes me intone with the instrument." In FLEX, this element was also recognized and appreciated: the ordering of the applications in the interface and the changing flexibility of the rim were seen as good examples.

*Sharing memories.* All experts recognized 'Sharing memories' as part of attachment. "My running shoes from the first marathon, souvenirs from the first holiday with my wife... You cherish the products that are connected to the peak moments in your life." It was recognized by 6 out of 8 experts in FLEX: "This is one of the few devices I know that tries to hold on to moments physically through the rim, which I really like", even though it was mentioned that the implementation could be stronger.

*Expressing identity.* This element is meant to contribute mostly to self-extension, where our possessions contribute to our identity and reflect that identity back to us. However, by some of the experts, the identity-expression was perceived as 'pretending to be someone you are not': "Identity... maybe that is a generation thing. I mean, I am who I am." People want to distance themselves from this interpretation, which led to a negative assessment. The people that recognized the more reflective qualities did underwrite it as a possible element of attachment and also saw this element reflected in the phone, especially in the use patterns that show in the material as a result of recurring interactions. However, questions were raised on what is actually being expressed: "with [FLEX] I cannot really see what kind of applications you use. Say that you use your camera intensively. That might mean that you are a photographer, or a moviemaker, or a Skyper. [...] In current phones [...] I can see how you handle your phone; whether you are careful with it or not. That might be even nicer". So it might be that the style interacting (how you bend the rim, where you store your phone) is more interesting to

show than the subject of interaction. It is expected that the phone has this type of expressivity in the material already (strong, direct movements give different deformations than exploratory, soft bending), but this quality could be enhanced more. Overall, strong clues point towards the value of 'Expressing identity', but we decided to rephrase it to move away from 'pretending', and to highlight the reflective qualities. The new name for this element is 'Reflecting identity'.

*Creating expertise.* With this element, worries were expressed about the implementation: "In a design this element needs to be implemented very subtly in order to make it feel as a natural guidance." Experts also foresee an issue with the static nature of hardware: in order to reach expertise a product needs to have features that offer enough room for growth.

Otherwise the user's skills might outgrow the system's ability to adapt too soon. These are valid and valuable remarks. However, we feel that they have to do with the naming of the element: the word expertise is very strong. We are aiming at more subtle development of functionality that is often used. In FLEX this element is represented by the recommendations for certain applications, which become more detailed for the components that are used often and more general for the ones that are hardly used. Since this aspect of the phone was received with great enthusiasm and since it is underwritten in literature (in, e.g., providing ability [10] and self empowerment [21]) we decided to hold on to the element but renamed it to the more subtle 'Creating focus'.

## 5 Discussion

**The elements of attachment.** Our final set of elements of attachment exists of 'Knowing each other', 'Creating focus', 'Sharing memories', and 'Reflecting identity'. Through their connection to the various constructs of attachment theory we have indicators that the elements support attachment between user and digital product. We do expect that individual users might value some elements higher than others. This shows in the variation in answers in the review sessions, and is also found in literature [21, 25].

**FLEX as an example.** Whether FLEX supports attachment is difficult to conclude as longitudinal evaluations in use were not possible in the current state of development. However, the translation of the

elements in the phone was overall recognized well and the resulting product features were appreciated. Therefore, we suspect that FLEX does have the potential to support attachment. The concept can serve as an inspiring example of how the elements can be translated into digital product aspects.

**The need for a multi-facet adaptation.** Our direction for increased attachment with digital products involved a continuous adaptation of the product to the individual user. We envisioned multi-faceted adaptation on physical object, interaction and digital content. In FLEX, the digital content is mainly represented by the functionality (the applications of the phone). As a result of the multi-facet aspect, the adaptation applies to both emotional and utilitarian properties like interaction and functionality. In attachment research, product utility is often not perceived as a precondition for product attachment [e.g., 8]. However, we believe, in line with Meschtscherjakov et al. [21], that it is necessary to also focus on the functional aspects for attachment in the type of digital products we researched. Even though we can think of scenarios where people have strong attachment to non-functional mobile phones (the authors also save their old phones as a memory cue), it will still get replaced for a new one that fulfills our utilitarian needs. Therefore, in digital products indispensability (relating to utilitarian needs) and irreplaceability (relating to emotional needs) should go hand in hand. Therefore, we believe that attachment requires multi-facet adaptation, taking next to the emotional, also the utilitarian properties of the phone into account.

**Approach & Limitations.** In this project we took a research-through-design approach with a large focus on analysis through making, in order to (1) create elements to support attachment with adaptive digital products and (2) ground the elements in an example. The explorative approach allowed us to investigate different implementations and translations of the elements through the case studies before making decisions for FLEX. However, the elements themselves and the implementation of the elements in FLEX are not yet validated. In order to do so we advice further development of FLEX, to evaluate longitudinally whether FLEX actually supports attachment and if the elements hold up.

Throughout our process, we involved users, design students, and senior design experts in, e.g., focus groups, creative sessions, and the discussed review sessions. However, FLEX is currently our only design. Even though the elements of attachment are based on explorations of different types of digital products, we currently only have one implementation. Therefore, we must be cautious when generalizing our findings. We would like to invite other designers to use the elements and to build up a larger variety of examples of adaptive digital products that can support attachment.

## 6 Conclusions

Even though the set of elements of attachment are not yet validated longitudinally, they build upon constructs and models that are known from literature [e.g., 4, 5, 8, 9, 10, 11, 14]. The elements are linked to aspects of digital products (interaction, functionality, appearance, and history) and focus on the adaptation. The elements are suitable as inspiration in various phases of the design process. We especially experienced their value in the idea generation, concept development, and for reflection. In these activities the elements can be used more loosely: as inspiration, reflection tools, and as a way to set challenges; rather than as hard requirements. The mobile phone concept that we presented, FLEX, forms an example of how the elements can be translated into aspects of digital products and of how elements can be combined.

## 7 Acknowledgements

Our thanks go to prof.dr.ir. Aarnout Brombacher, prof. dr.ir. Lou Feijs, dr. Matthias Funk, dr.ir. Bart Hengeveld, dr. Jacques Terken, dr. Oscar Tomico, dr.ir. Stephan Wensveen and dr. Lu Yuan for their constructive criticism during the review sessions. We also would like to thank the participants of the focus groups and brainstormings. We are indebted to the anonymous reviewers whose comments improved this paper.

## 8 References

1. Lebow, V. Price Competition in 1955. *Journal of Retailing*, Spring, (1955), 5-10.
2. Hoornweg, D., Bhada-Tata, P. What a Waste: A Global Review of Solid Waste Management. Worldbank (2012) <https://openknowledge.worldbank.org/handle/10986/17388>
3. Odom, W., Zimmerman, J. and Forlizzi, J. Virtual Possessions. *Proc. DIS 2010*, (2010), 368–371.

4. Csikszentmihalyi, M. & Rochberg-Halton, E. The meaning of things; domestic symbols and the self. Cambridge University Press (1981).
5. Mugge, R., Schoormans, J. and Schifferstein, H. Emotional bonding with personalized products. *Journal of Engineering Design*, 20,5, (2009), 467-476
6. Savaş, Ö. A perspective on the person-product relationship: attachment and detachment. Doctoral Dissertation, T. Orta Doğu Teknik Üniversitesi, (2002).
7. Kleine, S.S., and Baker, S.M. An Integrative Review of Material Possession Attachment. *Academy of Marketing Science Review*, (2004), 1-35.
8. Schifferstein, H., Zwartkruis-Pelgrim, E. Consumer-Product Attachment: Measurement and Design Implications. *International Journal of Design*, 2, 3, (2008), 1-13.
9. Belk, R.W. Possessions and the Extended Self. *Journal of Consumer Research* 15, 2 (1988), 139-168.
10. Zimmerman, J. Designing for the Self: Making products that Help People Become the Person they Desire to Be. CHI 2009, ACM Press (2009).
11. Govers, P.C.M. and Mugge, R. I love my Jeep, because it is Tough like me: The effect of Product Personality Congruence on Product Attachment. *Proc. International conference on Design and Emotion* (2004).
12. Hinte, E. van. Eternally Yours: Visions on Product Endurance. 010 Publishers, (1997).
13. Muis, H. Aging with dignity. In: Verbeek, P. and Slob, A. *User Behaviour & Technology Development: Shaping Sustainable Relations between consumers and Technologies*. *Eco-Efficiency in Industry and Science* 20, Springer (2006), 283
14. Vanhamme, J. and Snelders, D. What if you surprise your customers... Will they be more satisfied? *Advances in Consumer Research*, 30, 1, (2003), 48-53.
15. Jiao, J., Simpson, T.W. and Siddique, Z. Product Family Design and Platform-based Product Development: A State-of-the-art Review. *Journal of Intelligent Manufacturing* 18, 1, (2007), 5-29.
16. NIKEiD Customized Shoes. [http://www.nike.com/us/en\\_us/c/nikeid/](http://www.nike.com/us/en_us/c/nikeid/).
17. Tseng, M.M., Jiao, R.J., Wang, C. Design for mass personalization. *CIRP Annals – manufacturing technology* 59, (2010) 175-178.
18. Google search engine. <http://www.google.com/>.
19. Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., and Wensveen, S.A.G. *Design Research through Practice; From the Lab, Field, and Showroom*. Elsevier (2012).
20. Braun, V. and Clarke, V. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, (2006), 77-101.
21. Meschtscherjakov, A., Wilfinger, D., Tscheligi, M. Mobile Attachment – Causes and Consequences for Emotional Bonding with Mobile Phones. *Proc. CHI 2014*, ACM Press, (2014), 2317-2326.
22. Huang, E. and Truong, K. Breaking the Disposable Technology Paradigm: Opportunities for Sustainable Interaction Design for Mobile Phones. *Proc. CHI 2008*, ACM Press (2008).
23. Stienstra, J.T., Overbeeke, C.J., Wensveen, S.A.G. There is more to a single touch: mapping the continuous to the discrete. *CHI 2011*, ACM Press (2011).
24. Adobe Flash Professional CC. <http://www.adobe.com/products/flash.html>.
25. Bowlby, J. *Attachment and Loss, Vol. 1: Attachment*. Basic Books, New York, (1969)

# Dynamic and imperfect as emerging material experiences. A case study

## Abstract

It is generally acknowledged that the materials have a crucial role in the process that shapes meanings and sensorial and emotional interactions. The choice of materials and processes actually affect the user-object interactions and they often contribute to give to the products these features that are mediators of the quality of the interaction itself. In the paper, the concept of emerging materials experiences is used to describe the panorama of possibilities for the designer to design interactive and longer lasting products.

The paper presents an initial theoretical part that focuses on dynamic material experience and imperfect material experience. Here, examples are given of materials that can provide this kind of experiences. In the second part, the Sui Bag is illustrated as an example of object designed to enhance dynamic and imperfect materials experiences to provide meaningful interactions between users and artefacts.

## Keywords

Materials experience, smart materials, leather, dynamic, imperfection

## 1 Introduction

In the contemporary panorama of designed objects, we can easily notice changes in some features that affect the whole appearance of the objects themselves. In many cases, they are interactive and smart, sensorially

interesting and surprising and more often it is also possible to find personalized and craft produced objects. Taking into account a change in paradigm relating to the aesthetics of contemporary objects, we can affirm that they could belong to the *paradigm of knowledge economy* [1]. The main characteristics of this paradigm are: customization, designer's knowledge about new technologies and open-innovation processes, and people's creative approach towards their objects. Indeed, nowadays it is difficult for almost all companies to attract people's attention and differentiate themselves in a crowded landscape of similar artefacts. In this context, it is clear that designers need to consider products as means to establish emotional and meaningful interactions with users, being design "as an activity that essentially shapes meanings by conceiving product features as mediators" [2].

The design community and the scholars in the field of materials for design have already stressed the central role of materials in shaping meanings, sensorial and emotional interactions [3-9]. The choice of the right material and process actually affect the user-object interaction [10], [11], and often contributes to give to products the features that are mediators of the quality of the interaction itself.

Significant theoretical contributions to the topic of material interaction come from the interaction design discipline, and particularly from the HCI community. In fact, in this domain the scholars started to consider

not only the functional properties of materials, but also their power as signifiers [12]. This *material turn* [13] puts a particular emphasis on the methodological importance of closeness to the materials-at-hand [14] and on underlining the importance of actively working with materials. Thanks to the material interaction, it is possible to activate “a knowledge generating process inseparably intertwined with, and enabled by, a material discovery process” [15].

How people interact with products determines and affects their experiences and potentially improves the interaction [16]. In the same way, users can experience the materials embedded in the products and be influenced in their behaviours and life. For these reasons, the concept of *materials experience* describes the experiences that people have with, and through, the materials embedded in a product [17], [18]. This definition acknowledges and emphasizes that, through shaping what we feel, think and do, materials have the power to foster meaningful experiences [19]. In order to design meaningful material experience, the designer needs to consider four different levels. The first one is the sensorial level (i.e. the aesthetics of materials) that is the experience that originates from perceiving and noticing material sensorial information by senses. Then, the designer has to reflect on what the material may represents, its meanings (interpretative level) and on how the material makes the user feel in terms of emotions (affective level). Finally, it is necessary for the designer to include also “the active role of materials on shaping our ways of doing and ultimately, practice (performative level)” [20].

The general aim of this paper is expanding and strengthening the concept of materials experience in the context of interaction design, showing how emerging material experiences can be able to inspire the development of innovative artefacts. The two emerging material experiences considered in this paper are dynamism and imperfection. Both are nowadays considered very promising material experiences in terms of creating meaningful interactions and, as a consequence, user’s attachment to the product. Although very different, dynamism and imperfection share a changing and evolving nature able to break the monotony of the idealized “perfect” and “static” relationship usually established between user and artefact. The paper then focuses on the meaningful interactions aroused by these two emerging material

experiences – dynamism and imperfection – when applied to the design of a bag.

## 2 Emerging material experiences

Scholars in the field of materials for design [19] have identified some key issues affecting material choices made by designers and then influencing also the experiences with materials embedded in products. The most important contemporary issues identified are: technology and sustainability. These are the two main issues driving almost everything in the present society and are strongly related one to the other. It is thus difficult to build a framework in which everything is isolated and well defined because these two concepts are deeply interpenetrated. Furthermore, the two issues are expressed in many shades of emerging material experiences. Here, we choose to focus on two emerging materials experiences that in our opinion are the most interesting and promising: the dynamic material and the imperfect material.

### 2.1 Dynamic materials experience

Dynamic is defined as “something pertaining to or characterized by energy or effective action; vigorously active or forceful; energetic; ... something marked by continuous activity or change; something related to variation”.<sup>1</sup>

Tacking into account the above definition, it is easy to realize that there are a lot of shades of meaning for the concept of *dynamic* and following them we could find several categories and subcategories of dynamic materials. For example, dynamic is the material that is able to grow, as the materials made from agricultural bio-products and mushroom mycelium by Ecovactive<sup>2</sup> or the mushroom materials developed by Studio Eric Klarenbeek<sup>3</sup>. Another case about materials that dynamically grows are the bacterial materials developed by Suzanne Lee, founders of BioCouture<sup>4</sup>, the first bio-creative design consultancy, focused on the exploration how organisms like bacteria, yeast, fungi and algae could be harnessed to produce fabrics. Other examples are: the Gravity Stool by Jan van der Wiel<sup>5</sup> shaped with the use of magnets and Gord by Jerry Mejia<sup>6</sup>, a bottle made of the wood of a Gourd fruit that grows inside the mould.

Dynamic can also be the active design gesture as performed by Front Design group when they designed the Sketch furniture collection<sup>7</sup>. The Swedish group

developed a method to materialise free hand sketches. Dynamic are also the surfaces that perform new or surprising function like the Katedra table by Desnahemisfera<sup>8</sup>, that is able to charge your phone just by touching the table, or the self-cleaning surfaces with hydrophobic nanotechnology finishing by Aamir Patel<sup>9</sup>. After this quick list of examples, we want to focus on those particular materials that are dynamic and changeable thanks to their inner properties, the smart materials. In our contemporary realm, two parallel worlds coexist: the physical world and the digital one. The physical world is tangible, static and touchable by senses. The digital world is the intangible space of data and information, characterized by dynamism and transience [21]. Thanks to technological developments and advancements in material science, there are materials able to mediate between these two worlds transforming the object from static to dynamic entities [22]. Among them, there are the *smart materials*, generically defined as highly engineered materials that respond intelligently to their environment [23]. These materials “have changeable properties and are able to reversibly change their shape or colour in response to physical and/or chemical influence, e.g. light, temperature or the application of electrical field” [24]. Smart materials are called smart because of their ability of sensing the environment and at the same time transforming themselves in a controlled way. These materials are fundamentally different from traditional materials since they are dynamic and active [25]. Recognising these distinctive qualities, the smart materials have the possibility to generate *smart materials interfaces* promoting a new way of interacting with the user. They can create a new form of physical interaction based on new affordances and communication language. Unique material qualities applied to everyday objects play a big role in the people’s social and procedural practices because they can become useful to build affective and emotional interactions. [26-28]. As Addington [23] stated, smart materials are providing the material foundation for the design of open-ended objects and spaces that are reconfigurable and can dynamically respond to use or context. To all this, we shall add another important observation about time. In fact, smart materials can change their identities over time. To highlight the dynamism of smart materials over time, some scholars in HCI defined them as *becoming materials* [29]. Becoming because they are

fundamentally temporal and have the ability to assume multiple states of expression that can be repeatedly and minutely controlled over time [29]. As Bergstrom et al. [29] affirmed, the world of materials where the designer chooses the right combinations of features to concretize the intended experience, can be described in terms of being (what is the material?), doing (what does it do?) [30] and also becoming. As evidence of the fact that smart materials are a central issue in the context of product design, it is useful to mention that the European community in the last years founded important projects related to this theme<sup>10</sup>.

As explained above, smart materials enable an expanding range of aesthetic expressions and user experiences and introduce new possibility for designing the material as a whole as well as programming material performance or behaviour over time.

Since it is hard to find samples of smart materials available on the market, these materials enable practices related to the world of craft and DIY. It is an approach of experimental design that involves prototypes and inventions. The samples produced in the experimenting design with smart materials are meant to explore aspects of the expressiveness of materials and become a basis for communicating ideas and experiences [29]. Here we mention Catarina Mota’s research activity that brought her to found Open Materials<sup>11</sup>, a research group dedicated to open investigation and experimentation with DIY production methods and uses of materials. One of the aims of this community is to encourage discourse and experimentation with the broadest range of possible materials and processes. They would like it to become a large, collectively generated data-base of DIY information on smart materials [31].

## 2.2 Imperfect materials experience

Imperfection is defined as “the quality or state of being imperfect. Imperfect is something flawed, defective, or incomplete; not perfect”<sup>12</sup>.

Western culture has always seemed interested in perfection, in the regularity and clean lines that the development of science and technology have made possible. In fact, we could say that technological development has been led and driven by a trend toward perfection [32]. Today, it seems that we are getting bored with the aesthetics of perfection as a synonymous of mass production. On the contrary, we start to feel the need to reintroduce anomalies, defects and

imperfections, all elements that can evoke the human presence, traces of human being. The added value brought by imperfection, defects, and traces is a way of expressing workaday reality and creating innovation. By bending imperfection to our will, intensifying them and imbuing them with aesthetic value, a new image can emerge [33]. In terms of sustainability, giving value to the imperfect condition leads to a reconsideration of the relationship that we have with everyday objects “...because imperfections can be endearing and help to create a bond with the user” [34]. The concept of imperfection in products may arise from a wide range of physical features and between them one of the most important are the materials that products are made of. The essential concept is, as Giaccardi stated [35] “materials are not simply what objects are made of. They invite, suggest, facilitate, and collaborate with the unfolding of our activities and respond to these activities by aging, changing their appearance”. As people interact with objects, material surfaces inevitably lose their initial qualities and manifest traces in form of alterations, signs, defects and imperfections. There are materials that degrade only and other that conversely mature. This positive term of *mature* is reserved to natural and organic materials as, wood, leather, stone and so on. So, we can say that the ability to receive traces is not the same for all the materials and in general, for natural material it is easier to support traces due to time and use. Imperfections, defects, traces are related to concepts like: aging, patina and maturation of materials [40-42].

Certain materials more than others have the ability to manifest the interactions through evidences and traces created by the use and/or the passage of time. In fact, time and usage can create another set of surfaces [36]. In this sense, traces on material become as texture for communication and interaction and, in this perspective, several studies in HCI focused on investigating the possibility of product designer to conceive objects made of materials able to valorise and accept traces as an important feature in materials experience [37-39].

After the theoretical description of the emerging materials experiences, defined as a key issue affecting the designer's material choices for the creation of user experiences [19], the paper describes a case study: the project of the Sui Bag.

### 3 The Sui Bag as a case study

The Sui Bag project was developed as a Master thesis in Fashion Design at Politecnico di Milano School of Design [45]. The starting point was the creation of a female bag as a sack in which it would be possible to place part of your home, creating a little world to be brought always close to yourself. A personal object accompanying the owner in daily life and with which to establish an affective and lasting relationship.

The first object of investigation was the concept of aging and lasting over time and thus, the possibility for this artefact, even thanks to materials, to accept irreversible alterations, evidences, traces and imperfections due to the user's interaction and to the passage of time. One of the aims of the project was the creation of a material experience that would allow the artefact to change over time, trying to design this effect with the awareness of the incapability of controlling and predicting it as a whole. The material experience was characterized by the valorisation of imperfections through the choice of materials able of qualitatively accepting traces so to enable a slow and continuous mutation of the artefact itself. In paragraph 3.2 we will see in detail the materials applied to formalize this concept and to translate it in design solutions for the bag.

The first step of the design process was to study the modality of relationship and interaction between users and bags through direct observation and photographic survey. This first step produced observations that led us to design actions determining the formal solutions (Fig. 1). During this phase focused on shapes solutions, further studies on the change of the material experience over time were carried out and the design choice on the use of other materials that have the ability to change over time, but in a more rapid and reversible manner, was implemented.

It was therefore decided that one portion of the bag was to be representative of a more dynamic material experience as opposed to an imperfect material experience that is slow and irreversible. In both cases, we speak about “traces” as an alteration of an initial ideal state of the material surface. The final design solution of the bag, however, will be able to receive both traces and patina of interactions over time and dynamic traces able to support interactive messages. In paragraph 3.3 we will see in detail the materials and processes used to give shape to this concept and integrate it in the bag.





Fig. 1. Boards showing the relationship between the studies on the user-bag interactions and the design of formal solutions in progress

In general, the purpose guiding the design of the Sui bag was the will to create a correlation between the materials promoting the slow accumulation of traces and the materials that can be quickly and temporarily traced. In a single artefact two emerging material experiences are included, defining different ways of interaction with matter that mediate the experience of the final product.

### 3.1 Description

The Sui Bag is composed by two containers of different material and size. The smaller container is placed inside the larger one (Fig. 2).

### 3.2 External bag - imperfection

The external part of Sui Bag is designed to be made of vegetable tanned leather. Leather is a natural material derived from animal skin, usually from cattle, which is converted in a resistant material with improved properties through the tanning process. "In design, fashion and applied arts, leather is valued for its unique visual and tactile properties, as well as for simultaneously being a flexible and sturdy material. Leather used in design today makes references both to

primitive and nomadic aesthetics, but also to expensive and luxurious items, such as leather accessories produced by exclusive fashion brands, in comparison to 'cheap', mass-produced, fake skin items" [46].

The tanning process was developed in the ancient time and it has been used for centuries as a means to render animal skin a durable and versatile material. It prevents inevitable decay and putrefaction and increases the flexibility and workability of the materials. The modern tanning process allows for a greater degree of uniformity, but despite this, scars, veins and growth marks present in the raw animal skin will be in some way visible in the processed leather. The shade and grain of the leather will also vary across the hide due to variations in the pore structure of the animal skin. Often these unique markings are regarded as desirable, and thanks to them we can state that leather is timeless material, able to receive traces of imperfections and make them acceptable<sup>13</sup>.

**Vegetable tanned leather.** Vegetable tanning is a craft traditional process that transforms the raw hides into a material that will resist over time thanks to a slow manufacturing process using wooden drums, with

Fig. 2. Drawing and schema of Sui bag composition.



lower societal and environmental impact. This process uses tannins and other ingredients found in vegetable matter, such as tree bark prepared in bark mills, wood, leaves, fruits and roots. Among the various tanning methods, the vegetable tanning is still the most classical, traditional, recognisable, natural, environmental-friendly process giving leather unique characteristics<sup>14</sup>. The leather is supple and brown in colour, with the exact shade depending on the mix of chemicals and the colour of the skin. For this project, the designer chose the vegetable-tanned leather because it is expected to keep the traces of human interactions over time and it seems that it becomes older without ruining. This material enables the bag to become a kind of intimate diary able to tell about owner's memories and gestures. The natural ageing does not compromise its resistance and gives it a vintage look with warm colour shades showing evidence of being a natural product. No leather looks like any others; its peculiar unique characteristics offer a wide range of possible interpretations in shape and design. The designer preferred leather with clear and natural colour to enhance the imperfections laying up to the surface (Fig. 3).



Fig. 3. Samples of vegetable tanned leather used in the Sui Bag

The last important thing to say about the vegetable tanned leather is that it is a kind of leather very suitable to be carved or stamped. The technological properties of the material are fundamental for its transformation and also to give more possibility to express the wanted materials experience.

**Manufacturing process.** The vegetable tanned leather was processed with two technologies to boost the effects desired for the creation of meaningful

interactions. Firstly, a big texture was embossed on the material surface. The embossing is a technique in which raised or recessed images and patterns are created on the surface of a product through the application of heat and pressure. It is considered a process that changes the appearance of the material, adding a three-dimensional effect.



Fig. 4. The aluminium matrix and some samples to study the texture on leather.

The Sui Bag is characterized by the big embossed texture on its leather surface. The texture present a pattern that recalls the design of the internal part that includes a photochromic thread with a specific stitch that will be described later on. To obtain the texture, an aluminium matrix was realized for embossing the material. After several tests and samples studies (Fig. 4), the designer decided to realize an irregular texture on the external surface of the bag and texturize only the parts most exposed and predisposed to collect traces and evidences of time and use.

The second process used to realize the Sui Bag was the laser cutting. It is a type of subtractive manufacturing that cuts a digital design file into a piece of sheet

material, also leather. The positive characteristics of this process are the versatility and the possibility to have free and complex cuts. The cuts on the leather of the external part of the bag enable a direct communication between the two components and permit to show and compare the two diverse material experiences (Fig. 5).



Fig. 5. The cuts realized by laser technology to connect the internal and the external part

### 3.3 Internal bag - dynamism

The internal part of the Sui Bag presents a more dynamic material experience, although changeable and temporary, thanks to the use of photochromic (or *chromogenic*) materials, i.e. smart materials able to change their optical properties. The group includes electrochromic, thermochromic and photochromic materials. Photochromic materials are sensible to the UV rays and can change reversibly their colour on the basis of the intensity of light. Generally these materials are uncoloured and become coloured (soft nuances, not full colour) when the UV light enables the changes on the molecular structure of the material<sup>15</sup>.

When the light is switched off, the colour disappears and the material comes back to its original version. It is also possible to realize the changeable effects mixing the photochromic colours with basic colours like pigments, inks, or paints. The most famous application of these materials are the photochromic glasses lenses and windows.

These materials have been available for about 10-15 years but the cited examples apart; they have never found large applications and have not been exploited in product design yet, despite their qualities and

advantages. One of this advantage is that they can become effective tools to increase the function, aesthetics, and performance of objects or means of communication, saving energy compared to traditional systems. The colour change can also affect the emotional dimension, ensuring a surprise effect [47]. In the context of product design, the trend to proceed increasingly towards choices and solutions that involve more direct and immersive communication and interaction between the user and the product is evident. The research for a real exchange of communicative intelligence that chromogenic materials allow, through their change of colour, shows different communication options: for instance, it is possible to send messages to users showing how to use the object or what is happening to it [22]. "Because of all this, chromogenic materials offer a radical change in the ways of designing, perceiving, understanding objects and media, of interacting with the real world which surrounds us: a more immediate way, similar to the natural and biological logic and the human mind" [48]. There are several examples of products representing this communication and interaction process allowed by these dynamic materials: Wall-covering by Solenne Morigeaud<sup>16</sup>; light sensitive wallpaper by Front Design<sup>17</sup>; colour changing textile by Kathy Schicker<sup>18</sup>. For the Sui Bag the designer chose colour-changing threads in order to guarantee the dynamic change of colour and determine a kind of contrast with the traditional material, the leather, of the external casing that changes much more slowly. The threads used are produced by SolarActive International<sup>19</sup>, California-based company specialised in products development characterized by UV colour change technology (Fig. 6).



Fig. 6. Colour changing threads by SolarActive



Fig. 7. Examples of colours combinations and patterns studies with the colour-changing threads

**Manufacturing Process.** The internal bag is made of a crochet with photochromic thread through a machining. The stitch chosen after several tests (Fig. 7) is called "pave stitch", able to provide a marked texture (Fig. 8) that was taken up in the three-dimensional pattern on the external part of the bag made of leather (Fig. 5). The aim was to obtain an evident three-dimensional pattern adapt to play with light and enhance the colour of the thread with the dynamics of light and shadow. Several tests of matching colours and studies of pattern were carried out, and the solution presented here are not the arrival point but a proposal to study and implement the desired effect with an example. So many other colour combinations, textures and patterns are possible. Thus, bag here presented is a work in progress (Fig. 9).

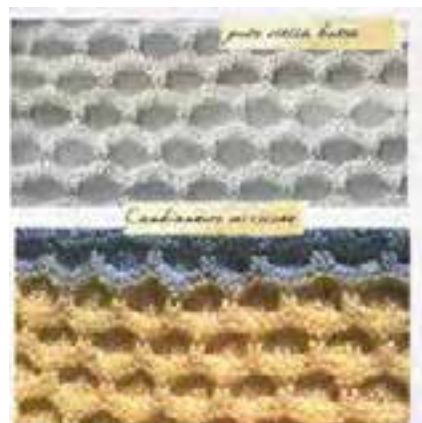


Fig. 8. The stitch chosen is the "pave stitch", able of providing a marked texture.

#### 4 Conclusions

The paper focused on the emerging material experiences explaining how it is possible to design meaningful interactions with products through a study on materials and manufacturing processes. The change of paradigm that affects the functional and aesthetical approach to artefacts pushes the designer to consider design solutions that enable a more "dynamic" and "imperfect" material experiences. Technology has strongly affected the world of products, but today, thanks to the great developments in the fields of technologies and materials, we can assist to the addition of another layer of information. This layer can be obtained exploiting both the properties of advanced materials and the characterization of the traditional ones.

The emerging materials experiences described in the paper are also coherent with the Weiser's and Brown's concept of *calm technology*, as "that which informs but doesn't demand our focus or attention" [49].

Coherently with this concept, the interaction between the artefact and its materials with the user is designed to occur in the user's periphery rather than constantly at the centre of his/her attention. Information from the materials, and in general from the object, smoothly shifts to the user's attention when needed, otherwise stays calmly in the user's periphery.

The Sui Bag is a good example on how to design tacking into account materials and manufacturing processes for creating meaningful interactions between user and artefact. The materials used to create the Sui Bag





Fig. 9. The Sui Bag, the solution “in progress”

enable meaningful interactions thanks to their intrinsic properties and also thanks to the designer’s idea to put them in relation, highlighting the common points about change, mutation and alteration.

## 5 Acknowledgments

The Sui Bag described in this paper is the result of a design investigation by Giulia Maria Francesca Ardenghi, brilliant and skilled fashion designer from Politecnico di Milano. Sui Bag is a project developed thanks to her strong passion for fashion accessories and the theoretical themes of imperfect and mutant materials. We want to thank also Chiara Morellini, designer, for supporting and facilitating the development of the project.

## References

- Gardien, P., Djajadiningrat, T., Hummels, C., & Brombacher, A.: Changing your hammer: The implications of paradigmatic innovation for design practice. *Int. J. Des.* 8 (2), 119-139 (2014).
- De Medeiros, W.G.: Meaningful interaction with products. *Des. Issues* 3, vol.30, 16-28 (2014)
- Ashby, M. F., & Johnson, K.: *Materials and design: The art and science of material selection in product design*. Oxford: Butterworth-Heinemann (2002).
- Doordan, D.: On Materials. *Des. Issues*, vol.19, n.4, pp.4-8 (2003).
- Rognoli, V. The expressive-sensorial atlas for materials of design [Doctoral dissertation]. Milano, Italy: Politecnico di Milano (2004).
- Zuo, H., Hope, T., Castle, P., Jones, M.: An investigation into the sensory properties of materials. In: *Proceedings of The 2nd International Conference on Affective Human Factors Design* (London, 2001).
- Karana E., Hekkert P., Kandachar, P.: Meanings of materials through sensorial properties and manufacturing processes. *Materials and Design*, 30(7), pp. 2778-2784 (2009).
- Pedgley, O. (2009). Influence of stakeholders on industrial design materials and manufacturing selection. *International Journal of Design*, 3(1), 1-15.
- Crippa G., Rognoli V., Levi M.: Materials and emotions: A study on the relations between materials and emotions in industrial products. In: *Proceeding of Design and Emotion Conference*, eds. Jamie Brasset et al., (Central Saint Martins College of Arts & Design, London, 2012).
- Karana, E., Hekkert, P. (2010). User-material-product interrelationships in attributing meanings. *International Journal of Design*, 4(3), 43-52.
- Rognoli V., Salvia G., Levi M.: The aesthetic of interaction with materials for design: the bioplastics' identity. In: *DPPI '11 Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces*. Article No. 33, ACM Press, New York (2011).
- Regier H.: Giving Materials a voice. In: *TEI'07. Proceedings of the 1st international conference on Tangible and embedded interaction*, pp. 125-126. ACM, New York (2007).
- Robles E, Wiberg M.: Texturing the “material turn” in interaction design. In: *Proceedings of TEI2011—international conference on tangible and embedded interaction*, pp. 137–144 ACM Press, New York (2010).
- Schon D. A.: *The reflective practitioner: how professionals think in action*. Basic Books, NewYork (1983).
- Wiberg M.: Methodology for materiality: interaction design research through a material lens. *Pers Ubiquit Comput.* 18, 625–636 (2014)
- Jensen J. L.: Designing for Profound Experiences. *Design Issues*, vol. 30, n.3, pp. 39-52 (2014).
- Karana E., Hekkert P., Kandachar, P.: Materials experience:

- descriptive categories in material appraisals. In: Proceedings of International Conference on Tools and Methods in Competitive Engineering, ed. Imre Horvath and Zoltan Rusak (Delft University of Technology Press, 2008): 399-412.
18. Karana E., Pedgley O., Rognoli V.: Introduction to Materials Experience. In: E. Karana, O. Pedgley, O., & V. Rognoli (Eds.) *Materials Experience: Fundamentals of Materials and Design* (pp. xxv–xxxiii). Butterworth-Heinemann: Elsevier, UK (2014).
  19. Karana E., Pedgley O., Rognoli V. (2015). On Materials Experience. *Design Issues*, Vol. 31, N. 3 Summer 2015, pp.16-28.
  20. Giaccardi E., Karana E.: *Foundation of Materials Experience: An Approach for HCI*. ACM Press, New York (2015).
  21. Van Campenhout, L. D. E., Frens, J. W., Overbeeke, C. J., Standaert, A., & Peremans, H.: Physical interaction in a dematerialized world. *International Journal of Design*, 7(1), 1-18 (2013).
  22. Colombo S., Rampino L.: Information embodiment: how products communicate through dynamic sensory features. In: DPPI 2013, Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces, pp.211-220, ACM Press, New York, 2013.
  23. Addington, M. and Schodek, D.: *Smart Materials and Technologies in Architecture*. Architectural Press. 2004
  24. Ritter, A.: *Smart Materials in Architecture, Interior Architecture and Design*. Birkhäuser, 2007.
  25. Kretzer M., Minuto A., Nijholt A.: Smart Material Interfaces: "another step to a material future". In: ICMI'13, proceedings of the 15th ACM on International conference on multi-modal interaction, pp. 611-612, ACM Press, New York (2013)
  26. Wakita A., Shibutani M., Tsuji K.: Emotional Smart Materials. In: J.A. Jacko (Ed.): *Human-Computer Interaction, Part III, HCI 2009, LNCS 5612*, pp. 802–805, 2009. Springer-Verlag Berlin Heidelberg 2009
  27. Vyas D., Poelman W., Nijholt A., De Bruijn A.: Smart material interfaces: a new form of physical interaction. In: CHI '12 Extended Abstracts on Human Factors in Computing Systems, pp.1721-1726, ACM Press, New York (2012).
  28. Minuto A., Pittarello F., Nijholt A.: New materials = new expressive powers: smart material interfaces and arts, an interactive experience made possible thanks to smart materials. In: AVI'14 Proceedings of the 2014 International Working Conference on Advanced Visual Interfaces, pp. 141-144, ACM Press, New York (2014).
  29. Bergström J., Brendon C., Frigo A., Mazé R., Redström J., Vallgård A.: Becoming materials: material forms and forms of practice. *Digital Creativity*, 21(3), 2010, pp.155-172
  30. Manzini E.: *The Materials of Invention*. Cambridge, USA: MIT Press, 1989.
  31. Mota C.: Open Sourcing material. In: Nissilä J., Braybrooke K., Vuorikivi T., (eds). *The Open Book*. Open Knowledge Foundation. pp. 67-71. <http://openbook.okfn.org/#info>
  32. Rognoli, V. and Karana, E. (2013) Towards a new materials aesthetic based on imperfection and graceful ageing. In E. Karana, O. Pedgley, and V. Rognoli (eds) *Materials Experience: Fundamentals of Materials and Design*, Butterworth-Heinemann, Oxford, UK.
  33. Remakers R.: *Less + More, Droog Design in Context*. 010 publisher, Rotterdam, 2002.
  34. van Hinte E. (ed.): *Eternally yours: Visions on Product Endurance*. 010 publisher, Rotterdam, 1997
  35. Giaccardi E.: *Designing the Connected Everyday*. *Interactions*, January+February 2015, pp.27-31, 2015.
  36. Fisher T.H.: What We Touch, Touches us: Materials, Affects, and Affordances. *Design Issues*, vol.20, n.4, pp. 20-31, 2004.
  37. Giaccardi E., Karana E., Robbins H., D'Olivo P.: Growing traces on objects of daily use: a product design perspective for HCI. In: DIS'14. Proceedings of the 2014 conference on Designing interactive systems, pp. 473-482, ACM Press, New York, 2014.
  38. Rosner, D.K., Ikemiya, M., Kim, D., and Koch, K. (2013) Designing with traces. In *Proc. CHI 2013*, ACM Press, 1649-1658.
  39. Ostuzzi F., Salvia G., Rognoli V., Levi M.: The value of imperfection in industrial product. In: DPPI 11. Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces, ACM Press, New York, 2001.
  40. Saito, Y. (2007). *Everyday Aesthetics*. Oxford University Press: New York.
  41. Odom W., Pierce J.: Improving with age: designing enduring interactive products. In: CHI '09 Extended Abstracts on Human Factors in Computing Systems, pp. 3793-3798, ACM Press, New York, 2009.
  42. Rosner D., Taylor A. S.: Binding and aging. *Journal of Material Culture*, 17(4), pp. 405-424, 2012.
  43. Terzidis K.: The Etymology of Design: Pre-Socratic Perspective. *Design Issue* vol.23, n.4, pp. 69-78, 2007.
  44. Benjamin W.: *Paris, Capital of the Nineteenth Century*. In: *ibid.*, *Reflections: Essays, Aphorisms, Autobiographical Writings*, New York, 1986.
  45. Ardenghi G. M. F.: Imperfect Traces on smart and traditional materials. The project of the Sui bag. Master Thesis in Fashion Design, School of Design of Politecnico di Milano, 2014.
  46. Tsaknaki V., Fernaes Y., Schaub M.: Leather as a material for crafting interactive and physical artifacts. In: DIS'14. Proceedings of the 2014 conference on Designing interactive systems, pp.5-14, ACM Press, New York, 2014.

47. Ludden, G. D. S., Schifferstein, H. N. J., Hekkert, P.: Surprise as a design strategy. *Design Issues*, 24(2), pp 28-38, 2008.
48. Ferrara M., Bengisu M.: *Materials that Change Color*. PolimiSpringerBrief, Milano, 2014.
49. Weiser M., Brown S.: *Designing Calm Technology*. Xerox PARC, 1995.

<sup>1</sup> The New Penguin English Dictionary

<sup>2</sup> [www.ecovatedesign.com/mushroom-materials/](http://www.ecovatedesign.com/mushroom-materials/)

<sup>3</sup> [www.ericklarenbeek.com](http://www.ericklarenbeek.com)

<sup>4</sup> [www.biocouture.co.uk](http://www.biocouture.co.uk)

<sup>5</sup> [www.designboom.com/design/jolan-van-der-wiel-gravity-stool](http://www.designboom.com/design/jolan-van-der-wiel-gravity-stool)

<sup>6</sup> [www.jerrymejia.com](http://www.jerrymejia.com)

<sup>7</sup> [www.frontdesign.se/category.php?id=174&product=515](http://www.frontdesign.se/category.php?id=174&product=515)

<sup>8</sup> <http://design-milk.com/high-tech-desk-charges-phone/>

<sup>9</sup> [www.kickstarter.com/projects/741186545/a-shirt-that-cleans-itself?ref=recently\\_launched](http://www.kickstarter.com/projects/741186545/a-shirt-that-cleans-itself?ref=recently_launched)

<sup>10</sup> The first one is DAMADEI – Design and Advanced Materials As a Driver of European In-novation ([www.damadei.eu](http://www.damadei.eu)) - that seeks to raise awareness among designers and to provide them with the appropriate experience on how to take advantage of these huge opportunities regarding advanced materials. In this way, design will be able to unlock its full potential as a driver of innovation. Another one is still in progress and is titled Light Touch Matter Project ([www.light-touch-matters-project.eu](http://www.light-touch-matters-project.eu)) in which designers and material researchers joined forces to develop a completely new generation of smart materials that can sense touch and respond with luminescence. The base technologies are novel piezo plastics and flexible or-ganic light-emitting diodes (OLEDs). Being thin, flexible and formable, these 'light touch materials' promise to revolutionize product design by integrating luminescence and touch in such a way that eventually the product becomes the interface.

<sup>11</sup> <http://openmaterials.org>

<sup>12</sup> The New Penguin English Dictionary

<sup>13</sup> From: <http://makeworks.co.uk/guides/guide-to-leather>

<sup>14</sup> <http://www.pellealvegetale.it/>

<sup>15</sup> For more technical insights about photochromic materials see: Ferrara and Bengisu (2014) [49]; Addington and Schodek (2004) [23]; Ritter (2007) [24].

<sup>16</sup> [www.solennemorigeaud.fr/wallcovering.html](http://www.solennemorigeaud.fr/wallcovering.html)

<sup>17</sup> [www.frontdesign.se](http://www.frontdesign.se)

<sup>18</sup> [www.kathyschicker.com/#/light-reactive-textiles/4530739355](http://www.kathyschicker.com/#/light-reactive-textiles/4530739355)

<sup>19</sup> [www.solaractiveintl.com](http://www.solaractiveintl.com)

# Towards the maturation of design: From smart to wise products

## **Abstract**

Recent years have shown the introduction of several types of smart products. These products gather data about user behaviour and try to determine an optimal response, in order to make the user's life easier. However, some smart products also lead to user behaviour that is undesirable. Hence, we would like to introduce a new design paradigm aiming for wise products that make the user's life better. These products allow the user to be in control of his own life, they are empathic, and they know multiple ways to evoke desirable behaviour. Besides awareness of the user's current situation, wise products are connected to a knowledge source that helps them decide on the appropriate behaviour, and they possess a repertoire of possible actions that may be customized to momentary demands. The aim is for wise products to contribute to the user's and society's subjective well being. We discuss several examples of how people experience wisdom in products and in the way they interact. In addition, we describe implications for the design process.

## **Keywords**

Wisdom, smartness, design paradigm, well-being, interaction design, product design

## **1 Introduction**

Since computing devices have become smaller in size, computing elements have become part of many

everyday products. Common examples are smartphones and tablet computers, but also dedicated products like smart thermostats, refrigerators, ovens, and medical devices that we carry on our bodies. Environments can become smart, now that GPS and sensory networks can track our whereabouts across locations. In addition, new materials and technologies allow new forms of communication.

Smartness is a common term to state that some sort of intelligence is embedded in interactive products (e.g., phones, refrigerators, health-trackers) in order to make our lives easier. For products to attain this smartness, we may need to provide our system preferences requiring explicit user actions, or the products may just automatically gather data about our preferences and behaviours, without us even being aware of it. We benefit from smart products, because they are autonomous in initiating certain actions and thereby reduce our workload. However, some smart products lead to user behaviour that is undesirable. For instance, the smartphone has provided ubiquitous access to the Internet, which has resulted in people's addiction to Facebook, Instagram, and other social media, while neglecting face-to-face contacts and interfering with work and study demands. Other smart products, such as alarm clocks and thermostats calculate an optimal response based on past behaviour, but do not take into account a person's momentary biological state (e.g., illness or fatigue) and thus seem to take over control



of a person's life. As a result, interactions with smart products can feel intrusive, may demand immediate change in behaviour, radiate authority by outsmarting a person, and exhibit an obvious sense of righteousness. Therefore, we would like to introduce an alternative paradigm for designing a new generation of products that have an empowering, inspiring, encouraging, and soothing role in people's lives: wise products. Our starting point is that while smart products make our lives easier, wise product should make our lives better. In this paper, we set the scene for this new paradigm by presenting the basic constituents of wisdom and how they can translate into product properties. While we acknowledge that wise products are inherently interactive products, our methodology is based on theoretical explorations and on the first impressions of design students into this new topic in the field of product development. Hence, the studies are exploratory in nature and the tools are traditional and familiar to the design context (e.g., mind maps, mood boards, sketching).

Throughout the introduction of this paper, we will contrast wise with smart products. First, we indicate how smartness and wisdom differ in the context of human life. Second, we describe the value of wise and smart products, by explaining how they affect people's lives and in what way they contribute to their well-being. Subsequently, we explain the differences in the underlying properties of smart and wise products, we review consequences in terms of the way people interact with the different types of products, and we indicate how the products are connected in networks and product ecologies. In addition, we provide examples of how people experience wisdom in products, by providing student descriptions of products that can potentially be wise. Finally, we discuss implications for design, by describing several ways in which products can communicate wisdom through their physical properties, interactions and behaviour.

## 2 The difference between smartness and wisdom in daily life

The Oxford dictionary definition of smart indicates two subconcepts: being *quick* and having *intelligence*. That is, smartness pertains to quick-witted intelligence provided momentarily as a response to an external stimulus. In contrast, wisdom pertains to *experience*,

*knowledge*, and *good judgment*. Hence, wisdom relies on the interpretation of multiple, repetitive, or longitudinal life experiences.

Wisdom requires the accumulation of knowledge, based on life experiences [e.g., 1]. A person's decisions and behaviour are based on what one knows and how one chooses to act. Hence, whether a decision or action is wise or not, depends on the knowledge and assumptions on which it is based. Wisdom involves changing the balance between acting and reflecting [2]. Knowledge accumulated should not just be derived from textbooks, but from real-life experiences, in particular the ones that are somehow challenging. Knowledge should not be limited to factual knowledge about human nature, lifelong development, interpersonal relationships, social norms, and ways to promote wellbeing of the self and others. It also concerns procedural knowledge about strategies and heuristics for dealing with the meaning and conduct of life, such as heuristics for giving advice, ways to handle life conflicts and life decisions, and knowledge about alternative strategies if things do not work out as expected. As a consequence, the archetypal image for wisdom is an old woman or man, who has accumulated many life experiences [3].

Wise people know how to communicate their opinion. A wise person can cope with positive and negative emotions, including uncertainty. They understand their emotions, and do not allow themselves to sabotage their good judgement. By experiencing events in real-life, a person obtains awareness about the context in which an event happens (social, economic, cultural), and develops a feeling for nuance. A person gets a feeling for the complexity of issues, develops moral sensibility and is able to predict the consequences of solutions. Wise people may support multiple perspectives, allow for compromise, and recognize the limits of their knowledge.

Baltes and Staudinger [4] define wisdom as "an expert knowledge system concerning the fundamental pragmatics of life. These include knowledge and judgment about the meaning and conduct of life and the orchestration of human development toward excellence while attending conjointly to personal and collective well-being." These authors use five criteria to evaluate

the wisdom in people's responses: (1) rich factual knowledge, (2) rich procedural knowledge, (3) lifespan contextualism, (4) relativism of values and life priorities, and (5) recognition and management of uncertainty. According to Baltes and Staudinger [1] smartness only implies the first of these criteria: Rich factual knowledge. Hence, wise products are likely to show a different behaviour than smart products.

Ardelt [5] makes a comparison between intellectual knowledge and wisdom-related knowledge based on how the knowledge is obtained, what it is used for, and what its effects are on the person. Intellectual knowledge derives from scientific and theoretical approaches that try to quantify facts and describe them. The main aim is to strive for certainty, regularity, and predictability in order to estimate and plan future events. Intellectual knowledge is often detached from personal involvement, because daily events need to be abstracted in order to discover a specific phenomenon behind them. Such knowledge can be acquired through books or listening to lectures. In contrast, gathering wisdom-related knowledge requires personal involvement. The aim is to obtain a deeper understanding of phenomena and to discover the significance of events. This type of knowledge is broad and integrated. It requires an openness to all types of experiences, including negative ones. Wisdom-related knowledge helps one to deal with the unexpected and the unknown. Instead of wondering *how to do* things, wisdom-related knowledge helps one to decide *whether you should do* things.

### **3 The difference between wise and smart products: product properties, interactions, user impact, and connectedness**

Early definitions of smart products included descriptors as *electronic*, *high-tech*, or *intelligent* [6, 7]. Rijdsdijk and Hultink [8] defined smart/intelligent products as products containing information technology in the form of micro-chips, software and sensors that are able to collect, process, and produce information. The smartness of the early smart products served mainly a utilitarian function: through user input or data collection and with limited capacity of data interpretation, smart products served a specific need, which was to complement human mental and physical faculties in order to make humans smart and efficient

[9]. Smartness was initially considered as an added attribute to the existing product categories. For example, an autonomous lawnmower differed from a regular lawnmower, because it had the ability to function independently of the user. However, with the advancement of technology, smart products became a separate product category with complex IT systems and embedded multifunctionality, in order to support users with complex mental tasks (e.g., smartphones, navigation devices, PDAs).

In the current decade with high connectivity (Wi-Fi, Bluetooth, GPS, Internet of Things) and easy data collection through mobile devices and wearable technology, products may acquire additional roles, for instance to monitor and provide feedback on people's physical, mental, and social health (e.g., Nike+, Fitbit, AIRO). If this development continues, products may start to take over the role of fitness coaches and mental coaches, having a direct impact on the user's subjective well-being. Because people have become accustomed to sharing parts of their lives through social media and more wearable technologies become available, more data on everyday life patterns become available and can be used to understand and support people at society, group, or individual level.

So, at what point does a smart system become wise? Wisdom and smartness both operate on the basis of knowledge systems. According to Baltes and Staudinger [4], smartness and wisdom both rely on rich factual knowledge. But in addition to that, wisdom makes use of rich knowledge of procedures and regulations, it evaluates situations in the context of everyday life experiences in the past and the present, and it can predict consequences for the future. Furthermore, wisdom takes into account the relativity of values and life priorities, and it recognizes and is able to handle uncertainty. So, whereas smartness relies heavily on intellectual knowledge, wisdom relies on the accumulation of many everyday life experiences and includes personal reflection on emotional events [1, 5]. So, if we look again at the six dimensions that Rijdsdijk et al. [10] identified for smart products, it seems that some of these dimensions might already suggest a wise product, depending on how exactly the product operates. The dimensions of autonomy and the ability to learn both apply to smart and wise products. If the

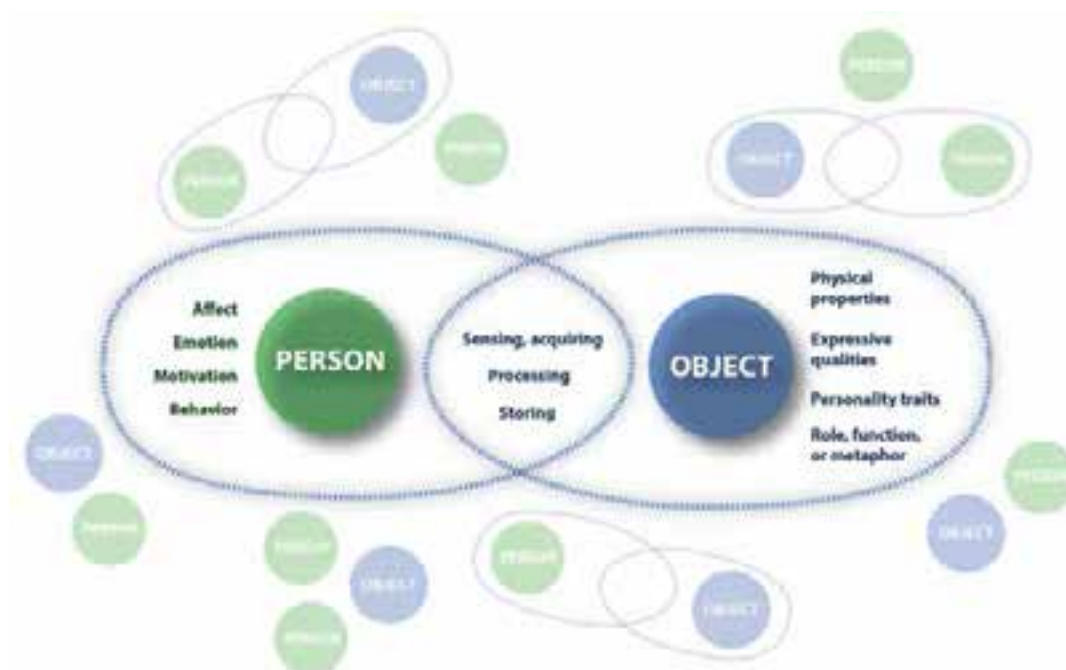
ability to cooperate with other products is used to gather basic behavioural data, the product is smart, but if the data come from multiple sources and give in-depth insight in a person's life, then the product may act wisely. Similarly, the dimensions of reactivity probably refers to basic stimulus-response patterns that applies to smart products, but if the interaction becomes more human-like and the product exhibits a specific personality, this opens up possibilities for more complex and sophisticated types of product behaviour. Wisdom has a large impact on the style of interacting with the product. Wise products foster more subtle, intimate and empathic connections with the technologies surrounding us. Technically, interactive screens could be replaced by smart materials with which users can interact in a multisensory way, in order to enhance the intuitiveness of interactions. As wisdom enables a natural integration of technology in people's lives, it also promotes more meaningful interactions with products. Instead of taking over control or producing an increasing number of notifications and alerts, a wise product should really connect to its user, hence fostering a feeling of well-being. Possibly, a wise system can grow with a person, so that after some time it knows best what is good for them. Instead of having a fixed expert system, the product could make use of

new developments in machine learning that facilitate long-term learning.

Also, wise objects are perceived as empathic, they know what questions to ask and they have the technology to get the information they need. In addition, they should know how to communicate a certain message. They are aware of the situational context in which they operate: The physical environment, but also a person's emotional and mental state and history, his routine daily practices, any sudden events that may have occurred and the feelings that may have caused. Wise objects can foresee the consequences of their actions, they know when (not) to say things, and they know what is the best way to deliver a message. Based on the situational data, a user may be assigned to a certain profile, which activates a specific interaction pattern according to which the product can respond. The interaction patterns may involve various expressions of personalities: Sometimes the product may act annoying, sometimes it can be very loving and caring, if that is necessary.

In order to describe the characteristics and effects of smart and wise products, we use the general framework in Figure 1 that distinguishes between different types of aspects in the person-object interaction. First of

Fig. 1. Conceptual framework of user-product interactions for smart and wise products.



all, if we look at the properties of objects, we can describe physical properties (e.g., material, instrumental properties), expressive qualities (e.g., looking sincere or moving calmly), the personality traits conveyed by the product (e.g., confidence, patience or maturity), and the roles it gets in people's lives (e.g., taking care) with the corresponding metaphors (e.g., it acts like a father). The properties we distinguish for the object may either be due to the characteristics of the static object or they may be perceived during dynamic interactions with the object. Therefore, we see them here as resulting from either the object itself or the object's behaviour during manipulation.

Second, smart and wise products need to gather information. Therefore, they need to sense their environment and acquire data, they need to process this information, and store the information for future use, just like users do. Third, the product has a certain effect on the person who interacts with it. After sensing and processing the product's behaviour during the interaction, the person may experience some affect (i.e., feel good or bad), may experience emotions (e.g., feel happy, surprised, relaxed), may become motivated to act, and may engage in specific actions.

#### **4 The characteristics of wise products according to design students**

To explore the new concept of wise products and to obtain a better understanding of people's preliminary conceptions of what wise product could be like, we conducted two studies with industrial design students at master level at Delft University of Technology. The first study investigated possible conceptual frameworks for wise products in order to determine such products' roles and functions in users' daily lives. The second study explored the physical and, to a certain extent, interactive properties of wise products. Both studies were exploratory in nature and their results were merely inspirational for the conceptualization of wise products.

In the *first study*, 15 industrial design students were asked to write an essay on how they envisioned the concept of wise products as opposed to smart products. Students first explored the definition of wisdom and then reflected on the discovered properties of wisdom-related knowledge and experiences and their fit to future product concepts.

In the *second study*, 61 industrial design students were asked to analyse the personality of a daily product of their own choice (e.g., sportive watches, professional bikes) and the physical and interactive properties that facilitated meaning attribution to this trait. In addition, students redesigned their selected product so that its physical properties and personality traits represented wisdom (e.g., wise watch, wise bike). By transforming the existing personality traits and product properties into 'wise products', students were able to reflect on the essential features of wisdom. Students were free in expressing their ideas in any form they preferred (e.g., mindmaps, moodboards, sketches). The aim was to see the immediate response of designers to the conceptual development of wise products. Results of these studies are presented in the following paragraphs.

#### **Study 1 – Conceptualization of wise products**

The defined object properties in Figure 1 will be used to summarize students' conceptualizations of wise products. First of all, students described the wise products' *technical qualities* as containing big data sets of information about users (their habits, emotional tendencies, daily practices). Data collection occurs through monitoring user experiences of daily events (e.g., driving, running, making coffee) through sensing and IT technologies (e.g., activity sensors, accelerometers, voice activators). This data collection is needed for the wise product to understand the working principles of the user's daily life. The product becomes knowledgeable of the user's life in an idiosyncratic way. Such knowledge also allows the product to predict the user's next step and perhaps adjust or develop strategies to support them better. Furthermore, data collection through observation not only uncovers daily practices but also emotional experiences or expressions. Hence, the wise products' user awareness will be their distinguishable technological asset, even though the technological constructions of wise products are essentially based on smart products.

The *expressive qualities* of wise products mostly involve empathy, humility, and sometimes sympathy. All these qualities imply a strong emotional content, especially in comparison to smart product qualities. Students indicate that it is essential for wise products to understand and predict user emotions, and to help users cope with them. This enables users to take

important decisions without being adversely affected by their momentary emotions. Thus, assisting emotion regulation comes across as one of the fundamental functionalities of wise products. Furthermore, humility was said to encourage a dialogue between the wise product and the user. Because humans are social creatures who tend to deal with daily struggles by sharing them and by reflecting on them, a humble and empathic product supports such a dialogue and encourages users to build a relationship with it.

Consequently, the *personality traits* of wise products were suggested as being fatherly, caring, kind, concerned, communicative, humble, moral, comforting, assuring, and altruistic. These personality traits also facilitate the *function and role* of wise products as supporting users in their lives in order to incentivize a better quality of life. Other supportive roles were described as encouraging, motivating, and empowering. Wise products were suggested to be present and active in users' lives when experiencing difficulties. Such difficulties could range from maintaining a physically active life style (e.g., finding motivation to exercise, keeping a balanced diet, being able to wake up early) to dealing with mental problems (e.g., miscommunication among partners, being stressed out) and even with life changing events (e.g., recovering from cancer). These important life events can often be characterized by the elicitation of intense emotional reactions (e.g., feeling overexcited or sad) or of mixed emotions (e.g., feeling happy and guilty simultaneously due to conflicts encountered). In such situations, people need to find a good balance between rationality and emotionality. The *functions* of wise products are defined based on two behavioural tendencies in difficult situations. First, people find it hard to recognize their bodily feelings and sensations, and lose contact with their intuition. Second, people find it difficult to foresee the consequences of their actions. Initial ideas for wise product functionality include evoking self-awareness on mental, physical, and emotional levels and facilitating reflective processes in order to reappraise an emotionally charged situation.

The effect of wise products on the user is proposed to be mainly for the long-term. It involves training users and making them gain new and healthy habits that support subjective well-being. Consequently, users are motivated to satisfy their intrinsic needs and

reach intrinsic goals (e.g., valuing friendship, gaining self-confidence) rather than extrinsic ones (e.g., earning more money, winning a prize). As a result of their interactions and experiences with wise products, people can have an increased feeling of self-awareness, a broader perspective on the events surrounding them, become more sensitive to their and others' feelings and emotions, and attribute new meanings to daily events. Nonetheless, when wise products are still learning about the user, also some short-term reactions may be expected. After all, wise products are described as products that aim to interact with the user. During their interaction with the user, wise products will need to draw the user's attention to a message they want to deliver or ask for reactions in return by creating short-term effects.

Students also explored product ideas while investigating the concept of wise products. One of these ideas tackled the experience of being stressed while driving. In this idea, the car's steering wheel is embedded with sensors to measure the driver's stress level, it is connected to his agenda and other communication applications, and the car knows his daily driving routine. If the driver is too stressed, the car blocks all notifications and incoming calls, allowing a more relaxed driving experience by prioritizing safety. Another idea tackled obesity. This student designed plates that change colour according to the caloric content of the food on it. The aim is to trigger the user to reflect on healthy eating habits. Another student designed an app for cancer patients to manage their lives mindfully during recovery. Apparently, cancer patients feel vulnerable after leaving hospital, because they no longer have daily access to medical and expert support. This app provides tips to feel confident about their recovery, embedded in an interface that supports realism, compassion, and altruism. All these design ideas tackle a critical situation where a little wisdom is welcome.

## **Study 2 – Physical properties and personality traits of wise products**

But how will people perceive that an object is wise and that they can trust that it has the best intentions? Students' strategies for embodying ideas for wise products often involved a metaphor and mapping the properties of the metaphor onto the product. The *metaphors* found apt for wisdom included 'mother, father, grandmother, coach, Yoda (from Star Wars),

Einstein, Buddha, God, and the universe'. The majority of these metaphors involve human characters that serve as role models or that have a positive influence on one's life. In relation to the metaphors, students described the personality traits for wise products as 'patient, dedicated, understanding, serene, divine, elegant, subtle, cautious, caring, altruistic, appropriate, having manners, accurate, sensible, clever, sharp-sighted, trustworthy, feminine, well-informed, knowledgeable, sophisticated, able to foresee things, and reflective'. The *expressive qualities* of wise products included 'calm, quiet, subtle, mature, detached, serious, balanced, and regular'. As expected, these personality traits and expressive qualities imply a virtuous person who values the future consequences of their actions as well as an intelligent person who is aware of his/her past and current surroundings. In addition, many of the metaphors and one of the personality traits indicate a feminine characteristic for wise products.

Furthermore, students described the *physical properties* of wise products in detail. The *form* of wise products are 'well-balanced, stable, heavy at the bottom, present, upward, round, non-geometrical (as in organic), and centred'. The *material composition* of wise products refers mostly to natural materials that can age over time or show the effects of aging such as 'wood with wrinkles, dark wood with nerves, metal, leather, and marble'. The *texture* could be 'worn, seasoned, and not smooth'. *Colour* combinations include darker shades of warm and natural colours 'brown, red, pink, violet, beige', and also pure and full colours such as 'black and white'. Students also mentioned the altered *functionality* when they redesigned their existing products to have a wise character. The new functionalities included 'analysing user behaviour', 'observing mood', 'suggesting / offering advice', 'watching out for danger', 'reflective', and 'enabling discoveries'. On an *operational level*, the wise product should be 'quiet, efficient, focused, direct, easy, moving by itself, multi-layered, changing over time, growing up, and logical'.

Table 1. Basic differences between smart and wise products.

		Smart	Wise	Wise interaction characteristics
Why	<b>Design intention</b>	Striving for a predefined optimum	Setting the stage for reflection and action	Feels open, curious, and supportive
Who	<b>Personality characteristics</b>	Monitoring, controlling, judging	Authentic and supporting	Feels trustworthy since awareness is shared and negotiated. Product is perceived as making suggestions rather than demanding.
How	<b>Interaction</b>	Rigid / digital	Fluid / flexible, subtle	Feels like the product embodiment and materiality is authentically connected to its behaviour
	<b>Role</b>	Assistant	Coach	Has an adaptive attitude in order to induce awareness and reflective user behaviour
What	<b>Presence</b>	Ubiquitous / obtrusive	Occasional and timely	Tactfully tackles sensitive and critical situations
When and where	<b>Connectedness</b>	Predefined individual knowledge	Wisdom of the crowd	Perceived as knowing more general knowledge
	<b>Development</b>	Fixed knowledge base	Evolving system architecture	Perceived as naturally developing connection

## 5 Implications for design

Now let us see how the distinction between smart and wise products affects the design process and the way in which people will interact with the products. In Table 1 we make a distinction between different aspects of the product design, according to the six basic questions why, who, how, what, when, and where?

The *why* defines the reasons for existence of the product design. Typically, smart products strive to achieve some predefined optimum state, from which designers can deduce settings for preferences or behavioural markers. In contrast, wise designs will set a stage for reflection and action, in order to strive for the user's long-term well-being. They are designed with open-endedness in mind.

The *who* in this case refers to the characteristics of the product personality. Wise products do not just monitor us (Big Brother), but acknowledge our presence and allow us to disclose ourselves through negotiation (as in two-way communication). Although wise products assess our behaviour, they do not judge or condemn us. Instead, a constructive dialogue between the user and the wise product evokes a more trustworthy and sincere interaction. Within such a dialogue the wise product takes on a suggestive role rather than a demanding one as in smart products.

The *how* refers to the way in which the product interacts with the user. In smart products, communication may rely on an algorithm with a rigid digital format with specified material interactions. Wise products, however, use more subtle ways of communicating. They evaluate the circumstances first and reflect on the actions that need to be taken. The outcome of this decision process may give rise to varying expressions and behaviours: they can tease us, ignore us or confront us. The wise product selects the type of behaviour that is most likely to promote desirable changes in user behaviour. These behaviour changes include evoking awareness of oneself or inducing a reflective process.

The *what* refers to the physical properties of the objects. Although the physical properties may not differ that much between smart and wise products, we may experience a difference in perceived presence:

smart products have a ubiquitous presence in our lives and present themselves rather obtrusively in daily situations. The presence of wise products, however, is only noticeable when the situation is critical and asks for sensitivity, for example, when people undergo difficulties or cannot cope with emotional stress.

The *when and where* refer to the context in which the product and its user operate, and the way in which they are connected to other objects and people. Smart products know more than us, because they have more sensors and data, and they try to optimize their behaviour pattern over time. However, wise products go a step further: Wise products have awareness of the context in which they operate: they know the history, they know the trends, but they are also aware of momentarily relevant events, so that they can respond to how a user is likely to feel at that moment. Because a wise system accumulates knowledge over time, the products evolve and grow with users.

## 6 Conclusions and future directions

Although smart and wise products have much in common in terms of constructive elements, they differ in the way they interact with users and the resulting effect on behaviour change. Wise products are particularly suitable in situations where users' well-being is at stake, which requires changes in behaviours and attitudes. Designing wise products requires an understanding of complex situated experiences and rituals, and their embedding in social practises [11, 12]. In addition, it requires knowledge on how design features connect to character and personality [13] and how subtlety in interaction can enrich the action repertoire by its sound, materiality and product behaviour [14]. We expect that insights obtained in the field of persuasive technology will be extremely useful in this respect [15].

Currently, we investigate this new design paradigm by reflecting on the design process, design outcomes and design skills. For wise products to become a viable future option, there is much to be learned from psychology, sociology, ICT, and interaction design. Furthermore, there are many critical issues to be tackled regarding privacy and ethics, because of the way in which wisdom is created through connected objects that observe human practices and seek for behavioural patterns [16].

**As a next step, we will conduct embodied explorations to define the behavioural, expressive and interactive qualities of wise products and look for action-reaction coupling, context dependency and complex system behaviour. We will also study benefits of wisdom in daily circumstances by observing behaviour change in users with prototypes specially built to act wise. These studies will utilize and assess the knowledge in Table 1. To conclude, we are positive about the potential effects that wise products can have on user's well-being and their role in society. Interacting with wise people generally induces wisdom for a person. Hence, we think that interacting with wise products will also be beneficial, because it makes people wiser. And if people will act wiser, society is likely to benefit, which makes the world a bit more beautiful.**

## References

1. Baltes, P.B., Smith, J.: The fascination of wisdom: Its nature, ontogeny, and function. *Perspectives on Psychological Science* 3, 56–64 (2008)
2. Birren, J.E., Fisher, L.M.: The elements of wisdom: Overview and integration. In: Sternberg, R.J. (ed.) *Wisdom: Its nature, origins, and development*. Cambridge University Press, Cambridge, UK (1990)
3. Clayton, V.P., Birren, J.E.: The development of wisdom across the life-span: A reexamination of an ancient topic. In: Baltes, P.B., Brim, O.G. (eds.) *Life-span development and behaviour*. Academic Press, New York (1980)
4. Baltes, P.B., Staudinger, U.M.: Wisdom: A metaheuristic (pragmatic) to orchestrate mind and virtue toward excellence. *American Psychologist* 55, 122-136 (2000)
5. Ardelt, M.: Intellectual versus wisdom-related knowledge: the case for a different kind of learning in the later years of life. *Educational Gerontology* 26, 771-789 (2000)
6. Den Buurman, R.: User-centered design of smart products. *Ergonomics* 40, 1159-1169 (1997)
7. Feldman, L.P.: Increasing the usability of high-tech products through design research. *Design Management Journal* 5, 27-33 (1995)
8. Rijdsdijk, S.A., Hultink, E.J.: The impact of product smartness on consumer satisfaction through product advantage, compatibility, and complexity. . *Proceedings of the 13th PDMA Research Conference, Orlando* (2002)
9. Norman, D.A.: *Things that make us smart: Defending human attributes in the age of the machine*. Basic Books (1993)
10. Rijdsdijk, S.A., Hultink, E.J., Diamantopoulos, A.: Product intelligence: its conceptualization, measurement and impact on consumer satisfaction. *J. of the Acad. Mark. Sci.* 35, 340-356 (2007)
11. Vermeeren, A.P., van Beusekom, J., Rozendaal, M.C., Giaccardi, E.: Design for complex persuasive experiences: helping parents of hospitalized children take care of themselves. *Proceedings of the 2014 Conference on Designing Interactive Systems*, pp. 335-344. ACM (2014)
12. Giaccardi, E.: Designing the connected everyday. *Interactions* 22, 26-31 (2015)
13. Fokkinga, S.F., Desmet, P.M.A., Hekkert, P., Özcan, E.: From Product to Effect: Towards a human-centered model of product impact. . 6th Design Research Society Conference, Umeå, Sweden (2014)
14. Rozendaal, M.C., Schifferstein, H.N.J.: Pleasantness in bodily experience: a phenomenological inquiry. *International Journal of Design* 4, 55-63 (2010)
15. Fogg, B.J.: *Persuasive technology: Using computers to change what we think and do*. Morgan Kaufmann, San Francisco (2003)
16. Shilton, K.: Four billion little brothers?: Privacy, mobile phones, and ubiquitous data collection. *Communications of the ACM* 52, 48-53 (2009)



# Designerly Handles: Dynamic and Contextualized Enablers for Interaction Designers

## Abstract

In this paper we argue along the lines that the act of designing benefits from an experiential approach that capitalizes on making. Hence, that making in interaction design benefits from being addressed from a designerly perspective when used for the design of intelligent products, systems and services. We elaborate and discuss the design process of two design cases that exemplify how the design for interaction and the design of dynamic product behaviors can be brought to the designers realm of making, grasping and manipulating materiality in context. We suggest and highlight the characteristics of this in-context design approach that enables interaction designers to utilize their pathic skills when exploring and detailing interaction and behavior qualities. The aim of this paper is to introduce dynamic and contextualized enablers and designerly handles as means for interaction designers to work with digital qualities in a designerly manner.

## Keywords

Interaction Design, Tools, Prototyping, Research-through-Design, Design Processes

## 1 Introduction

In this paper we concern ourselves with the question of how to design for interaction and systems with a focus on design tools and materials. Following Schön [1], we see action and reflection as the designer's way

to cope with complexity in the real world [2, 3, 4] and embrace designing as a skillful activity. Yet we observe that, as design faced the challenge of designing for interaction and systems, the design tools and materials changed. To cope with the particulars of shaping the dynamic behaviors of connected products in intelligent systems [5, 6] design tools and materials from other fields of expertise were borrowed (i.e., social sciences and engineering practices like computer sciences) [7, 8]. However, together with these new tools and materials also the values of those particular fields were carried over. While successful in their own field, these values are not always compatible with those of design [7, 8, 9, 10]. Where traditionally the design discipline used design tools and materials that were open for interpretation and that did not prescribe but supported reflection and decision-making, the new ones ask for more definition, rigor and pre-reflection. Moreover, where design acknowledges that no situation is alike and that consequently the design process benefits from a unique and tailored approach, the new design tools and materials are strongly generic in nature.

In this paper, we reconsider the tools that we borrowed from other disciplines, not by refuting them, but by using the tools themselves as a material for design.

Doing so, we tailor them to the unique needs of specific design challenges capitalizing on the *designerly ways* [2, 4] of grasping complexity by introducing the openness for interpretation. In what follows we first introduce the

notion of *pathic* understanding in order to get grip on the mismatch between of the borrowed tools with the needs of design.

We present two design-cases that present a new way of understanding 'tools for interaction design' – dynamic and contextualized design enablers. These enablers we call *designerly handles*. They are specific customized tools that serve to explore (with) the dimensions of the potential design solution. They are a mix of physical, embodied interaction possibilities interwoven with the digital backbone. After elaborating on the designerly handles we discuss the qualities of these enablers and conclude by tying them back to our design-take on *pathic* understanding.

## 2 Design Values, Designerly Tools

In this section we investigate the notion of pathic understanding in the context of design in order to better grasp the mismatch of the design tools that were borrowed from different areas of expertise.

### 2.1 Grasping Complexity Pathically

Designers utilize the making process to get a grip on the complexity of the design context. They accomplish this by *reflection-on-action* and *reflection-in-action* [1], where the latter is not necessarily a cognitive process. Designers get in touch with the design-material itself in direct interaction and are thus enabled to manipulate the form or interaction qualities without the inference of a cognitive reflection; they are able to bypass the cognitive and utilize the tacit, or to be more specific, what van Manen [11] calls their pathic understanding. This term furthers 'tacit knowledge' coined by Polanyi [12], which is used to speak of the not-articulate nature of certain forms of personal knowledge. Whereas tacit knowledge has roots in silence, thus residing in an implicit to explicit dimension, pathic knowledge has roots in 'feeling' and thus contrasts with the cognitive and (dia)gnostic aspects of bodily knowledge. Pathic information is that what resides or resonates in the body, in our relations with others, in the things of our world, and in our very actions. These cannot necessarily be translated back or captured in conceptualizations and theoretical representations [11]. Where Polanyi frames tacit knowledge to be implicit, van Manen frames pathic information as a tacit knowledge to be accessed via bodily skills of doing and feeling contrary to thinking and reflecting.

With accepting pathic knowledge as a form of knowledge that designers and users are able to grasp and work with in interaction; we acknowledge that meaning resides in a bodily relationship with the world not an abstracted, reflective relationship per se. Hence, to us, the pathic skills refer to how we as users and designers, make sense of the world in relational, situational, corporeal and actional manners contrary to primarily gnostic, cognitive, intellectual or technical manners.

A common method for designers to cope with the unknown yet experienced salient qualities is reduction. In other words, to get a grip on the design challenge designers aim to 'label' the hidden, invisible, originary and salient aspects of meaning or qualities in the design or engagement with it, i.e., we name things. These aspects that belong to the pre-reflective phenomena of are brought into visibility or nearness through, for example affinity diagrams, repertory grids and other determination methods. By reducing the users experience with products or systems into a set of 'words', a whole realm of nuances can be lost. In other words, designers have a tendency to bring their pathic knowledge under words in order to communicate and perhaps get a 'grip' on the matter. Instead of turning the pathic knowledge to a 'determinable' realm, we depart from the idea that pathic knowledge and our skills to deal with them are valuable in themselves. We see designers capable of transforming, manipulating, exploring and fiddling with matter (i.e., designing) while staying within the realm utilizing their pathic skills of feeling without turning to their skills of knowing.

### 2.2 Mismatching Design Tools

Traditionally designers use (physical) tools and materials that can be directly manipulated. For example, when sketching or physical modeling, designers utilize their *reflection-on-action* and *reflection-in-action* skills; they engage in a dialog with the material through their hands. To be more specific, during the act of sketching, a line can easily be reinterpreted and redefined. This ambiguity of the sketch or the design model is a valuable resource for design [13] as it allows him to act upon the reflection almost immediately offering ground for new reflection and redefinition. It allows the designer to express and to discover the desired form [14]. When designing for interaction and systems, new design tools and materials for exploration were introduced

to the design practice, borrowed from other academic fields and heavily rely on computers and computation. We identify two problems with these tools and materials: (a) they are often abstract, closed and reductive and (b) they are mostly directed towards a defined prototype rather than to exploration. Below we elaborate.

Firstly, we feel that we need to briefly clarify our understanding of these computer and computational tools and materials. Over three decades ago, the computer was introduced to design, first as a literal replacement of existing tools, technical drawings moved from paper to the computer, but later also as a new tool for the exploration of, for instance, interactive behavior of products, e.g., paper prototyping [15] or augmenting physical models [16, 17, 18]. Lately microcontroller platforms like Arduino, Gadgeteer or Raspberry pi have been very successful as tools for the exploration of interactivity in product design. This influx of computers and computation can be regarded as new *tools*, for example in the form of an Arduino microcontroller board, but can also be regarded as a new *material*, for example computer code is often regarded a design material that can be shaped. These new design tools and materials share that they need discrete and defined input [19] and that they are manipulated indirectly. Thus, they neither allow for ambiguity nor for direct experienceable manipulation. In these tools and materials, interactivity is approached through abstraction with the result that the richness of the physical is filtered by the limitations of the abstract. For example to develop the code to define interactive behavior requires a level of abstraction, structuring and planning, which poorly facilitates *reflection-in-action*. Possible moments for reflection are often shifted to a later stage in the design process. Only then while being able to feel and experience, the designer's *pathic* skills come to play. All these issues are important drawbacks as they poorly encompass the explorative qualities that we seek in our design tools and materials.

Secondly, digital tools tend to facilitate the creation of defined results (i.e., prototypes that have a fixed form and implementation). In most cases, a 3D-printed prototype or uploaded programming code can only accommodate limited exploration. Fluid exploration is limited by the fact that coding, printing as well as redesigning with predefined measures takes time

and this breaks the flow of designing. This limitation contrasts with the previously mentioned sketching and sculpting in which making and validating takes place in the hands of the designer.

These criticisms are partially sidestepped by for example Hartman, Abdulla, Mittal & Klemmer [20] who show a programming by demonstration environment where sensor inputs can be authored and mapped immediately allowing for exploration and *reflection-in-action*. In this paper we present an approach that marries a similar vision to a holistic approach to designing for interaction. Our aim is not to create a generic toolkit as such but to empower a designer to simultaneously explore form and interaction within specific contexts fitting a specific skill-set.

### 2.3 Opportunity

We see an opportunity for digital tools to have a closer fit with the designer's idiosyncratic design process in the sense that they could better accommodate to the designerly way of *reflection-in-action* while exploring form and interaction. What we propose to respond to the criticism that we have outlined above is to develop designerly tools *within* the process of designing. In order to let these custom designerly tools 'speak' to our *pathic* skills, we argue to capitalize on the rich expressive character of the physical while designing for the digital. For this purpose we consider valuable to bring the digital qualities to the physical realm where the designerly skills come to play.

## 3 Design Tool Examples

To accommodate our own design process when designing intelligent products and systems, we decided to develop our own tools that are fitted to the fidelity of the design phase, and that utilize our designers' skill of feeling and grasping. The use of the words tool and platform in our exemplars are slightly misleading. In this paper, we do not refer to the tools and platform to function as generalizable means to accomplish design activities. Instead, we propose custom enablers with designerly handles developed in context. Designerly handles are the specific customized tools that can be used to fiddle with the dimensions the dynamic enablers (i.e., urge, power, flexibility) deal with. In the following we elaborate upon two design projects in which we developed these tools and integrated open-



Fig. 1. Trackpad used to control the behavior of the Sensible Door while people enter. The position, angle and amount of pressure of the fingers influence the character of the haptic feed-back in the door in real time.

endedness. The first example concerns an exploration of the movement of an intelligent door. Different implementations of a trackpad as a designerly handle are explored and described. The second example questions the current chunk based agenda paradigm and explores what the value of a physical manifestation would be. The example describes two distinct ways of how the dynamic qualities of the lever are explored. As these designerly handles and modifications were designed in the process of the particular design projects, we follow the descriptions with a reflection highlighting the characteristics of these tools.

### 3.1 Door Movement Behavior

Our first example concerns the exploration of the movement of a door. In order to design the dynamic movement behavior of an intelligent door [21] a trackpad was used to manipulate the characteristics of the movement. The Sensible Door project aimed to bring back nuanced movements that addresses people's feelings while they interact (i.e., walk through) with the door. While most automated doors function to open and close at the appropriate time, the Sensible Door aims to do so in appropriate manner as well. This means that the door embodies behaviors of opening and

closing. Thereby, the door is capable of swinging gently or gracious, slamming roughly, opening curiously and closing confidently.

#### Exploring dynamic qualities of the door.

While the behavior of the door had to be mapped to the behavior of interactants and the context, the exploration of the nuances was done with the use of a trackpad. The trackpad was chosen as it allows for a variety of expressive input manners, i.e., the hand of the designer can be placed and moved in various manners. The software allowed for the use of real-time trackpad data such as the location, angle, size, and major and minor axis of the fingertips touching the surface (i.e., touchpoints). While designing the behavior of the door, the trackpad was utilized in two distinct manners. The first manner was the employment of the sense data as direct manipulator of the movement of the door. In this case, the location of the first finger was mapped to the openness of the door. The designer in an iterative process controlled for instance when a person approached the door, the movement of the door. The initial mapping that was explored concerned that; while someone would walk up the door fast would have the door opened fast contrary to someone that would walk

up slowly. This easy use of opening and closing the door, and ability to control the expression, was further used to explore whether it was possible to persuade people to move in or out while being near the door by applying simple nudges and gracious swings. As these simple ideas were easily executed, exploring the opportunities of an enriched Sensible Door.

In the second manner we combined the sense data of the Sensible Door with the direct control of the designer in the dimension of expression. After exploring with the direct control, several sensors took over the mapping. A distance sensor and topview camera was used to measure the distance and consequently the pace of approaching. This was mapped to the speed of opening accordingly. Similarly when a person would walk through the door, the door-handle could be pushed or pulled. The Sensible Door could push back or pull the person while going through the door. The mapping of the door's behavior was thus between sensor and actuator whereas the sensor in the first exploration was replaced by the trackpad. The trackpad was used to manipulate the nuances in the already established mapping between sensor and actuator (i.e., the movement of the person and the movement of the door). For example the size of the fingertips while pressing the trackpad influenced the resistance or friction in the mapping. When the person walks through the door, the door opens easily while the trackpad was pushed gently. This indirect manner of utilizing the trackpad in the iterative design process allowed the behavior designer to explore the nuances in the designed mapping in a natural manner. While the person walks through the door, the characteristics could be adjusted in real-time. This informed the designer about qualities in the movement and mapping in the process of designing. It turned out that the designer did not have a full control over the adjustments made to the mapping in a sense that the designer could consciously predict the effects following a cause. The designer, through iterations that were allowed in real-time, got a feeling with and a grip on how the nuanced use of the trackpad influenced the nuanced behaviors of the door. Without conscious reduction, the behavior designer was capable of utilizing its *pathic* designerly skills in the sensitively attuning the behavior of the mappings in the door.

### 3.2 The Physical Meeting Manager

Our second example concerns the exploration of a physical calendar that seeks to manage business people while arranging appointments. Digital calendars, in essence, are built upon the paradigms used in physical calendar booklets. Meetings are subscribed to blocks laid down on grids of days, hours and quartiles. Although technology has evolved, calendars are still build upon the chunk-based paradigm where new communication tools could possibly provide a more continuous experience of time. The Physical Meeting Manager [22] design, in turn, aimed to bring subjective values from our complex social life into the activity of arranging meetings (i.e., considering the occupancy, personal intentions and hierarchical relationship between people build over time). Practically, the design consists of expression-rich physical levers for people that want to set up a meeting. These levers can be used to convey one's intention to a person on the other side. The position of the lever (i.e., in the range between up and down) indicates in how long the meeting will take place.

When the occupancy of the other person increases, moving the lever gets physically challenging in order to set up a meeting (i.e., the resistance and even force increases). Over time, the behavior of the levers utilizes the hierarchical relationship of the people setting up the meeting (i.e., which person is dominant) in the interaction qualities of the lever.

#### Exploring dynamic qualities of the lever.

While designing the levers it became clear that communication through expressive values requires extensive exploration in the subtle differences in dynamic qualities. The mapping of user's occupancy to reactive force in terms of the movement of the levers (i.e., powerful, relaxed, stressed) as well as the fadeout over time needed to lead up to a holistic experience that naturally emerges in interaction. Through reasoning, it can hardly be grasped how the levers should act. A dynamic enabler was required because of the large complexity, to sketch with the designed platform. Exploring the subtle details turned out to be crucial for creating a meaningful experience. For example, a little but too much resistance or force back as reaction to the occupancy of the other person resulted in the feeling that this other person was trying to refuse this meeting or was at least not happy with it.

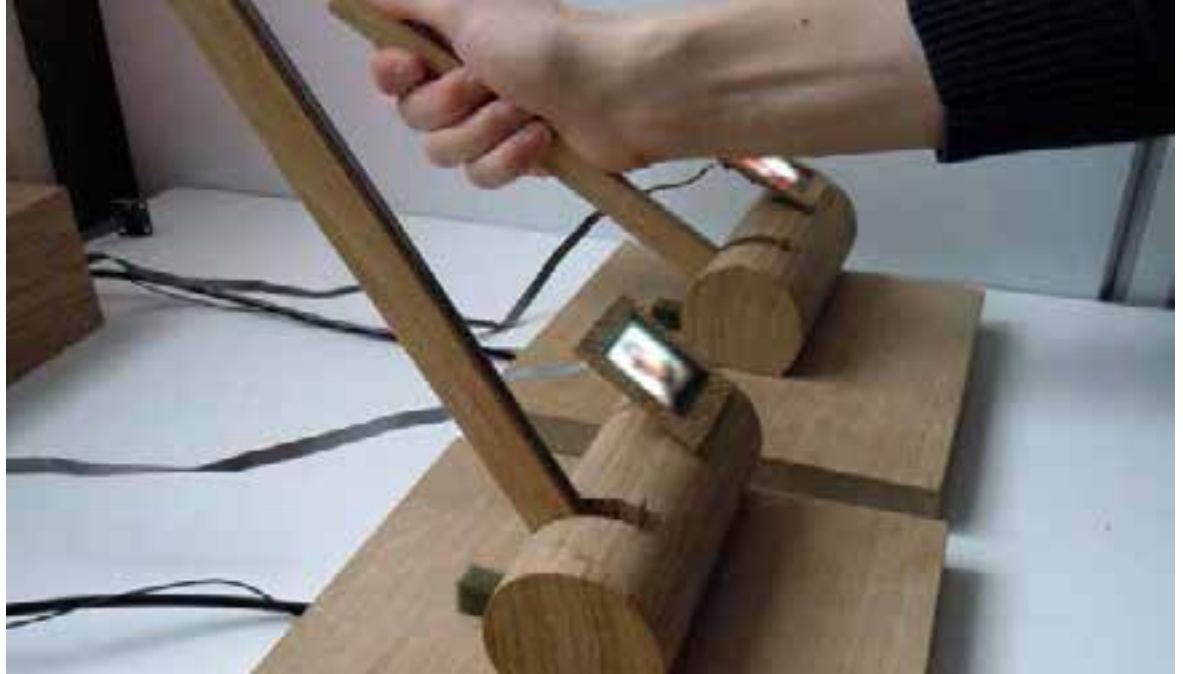


Fig. 2. The Physical Meeting Manager used to arrange a meeting by pressing down the lever. Haptic feedback of the lever conveys the intentions of the other side.

This made us integrate two distinct open-ends in the platform to explore the dynamic qualities.

In the first exploration, the software contained multiple variables (i.e., the amplitude, speed, fade out) that defined the dynamics of the movement of the lever.

Although these variables are easily adjustable in code, it requires a short time to upload the code with the changed variables, which makes the exploration of dynamic qualities time consuming and more analytical (reductive) than *pathic* (utilizing the designer's feel skills). It turned out that it was relatively easy to get a grip on the values of the individual variables, as these variables clearly influence each other. However, this approach assumed that the set variables were the only variables at stake.

Although this exploration into the quality of the movement dynamics was only a small part of the design process of the Physical Meeting Manager, the first iteration highlighted the need for a custom design tool accommodate to explore the richness and freedom of the design space. In a second iteration, we mapped the motion of one lever (input) to the motion of another lever (output). Through this direct coupling, a designerly tool was created to explore the dynamic behavior in a richer and embodied way. Instead of defining the system

parameters by code, the system would collect the variables derived from the designers' movement exerted on the first lever and store them for later use. As this tool allowed both designer and user to express "what feels right" in specific use situations (i.e., pressing with a certain swing while an event requires attention and others to be postponed), the new tool also facilitated in the dialogue between designer and potential end-users in the design process.

### 3.3 Reflection

In these two examples we sketched the need for specific, dynamic and contextualized enablers for interaction design. Dynamic enablers are highly project specific, tailored design tools and platforms that facilitate our designerly skills in interaction design. By using the prototypes as design enablers we regained grip on the digital realm through our pathic skills instead of analytical skills (i.e., a reductive approach). Both examples show commonalities in their focus on dynamic and expressive qualities. They offer designerly handles that utilize openness and immediacy of exploration. It is interesting to note that these two examples do not operate in the same phase of the design process. Where the Sensible Door example operates in an early phase

of the design process where much of the behavior and functionality is still to be defined, the Physical Meeting Manager presents an exploration of conceptual details in a more defined concept.

## 4 Reflection and Insights

After framing the main characteristics of our 'designerly handles' that enable designers to use their *pathic* skills in context when designing for interaction, we elaborate upon the benefits, generalizability and possible pitfalls of our approach. Besides characterizing these designerly handles that function as part of our enablers, we reflect on some particular design skills and attitudes we consider to be valuable for applying it.

### 4.1 Tuning in the Moment

An often used method to tweak or define behaviors and other interactive qualities in product and system design is to adjust the model or programming after each confrontation or validation. In other words, qualities are analyzed and adjustments are made in the source code that will be uploaded to the device to face another confrontation that provides new insights. When we design for interactive behaviors of products and systems, the design process benefits from the possibility to tune the behaviors in the moment. The closer the action (i.e., the designers adjustment) and reaction (i.e., the adjustment applied to the design, ready to be experienced by the designer) are coupled; the easier it gets for a designer to utilize its *pathic* skills of *reflection-in-action* to either explore or nuance the design space.

#### Exploring and nuancing with the handles.

We argue that the design process could benefit from designerly handles that exploit and explore within an open-ended space of possibilities. It is up to the designer to design the constraints and dimensions of the exploration, yet not to fall for the trap of definition and temporal reduction. If a design concerns the expression of a product, the designer could for example define the landscape for exploration in terms of dimensions such as the spontaneousness or fluidness. Instead of defining the particular grade of spontaneousness we recommend it be explored over a certain dimension (i.e., in this case a spontaneuity dimension). To this dimension of exploration, the designer attaches a tool that allows him or her to explore this aspect within context as part of the design process.

#### Designed and contextualized.

Arguably the easiest way to explore a dimension in a specific interaction challenge is to add a rotary or linear potentiometer to the prototype. In our view an expressive handle needs to be as much of a designed entity as the prototype that is used for exploration itself. It needs to be contextualized so that it fits the act and form of exploration. What we mean here is perhaps best illustrated in the physical meeting manager example where a set of two 'handles' was made that allowed for a wizard of oz-type of interaction where one handle acted as input and the other as output. The designer worked together with a second person, one acting on the input the other experiencing the output, tuning intention to experienced expression. All the while the computer that connected input and output handle recorded a compound set of variables, slowly but certainly defining the behavior and in doing so giving the designer an understanding of how the variables together were meaningful to his user.

#### Multi-Dimensionality in handles.

So far we have positioned the dimension of exploration or nuancing as a sole dimension to be integrated in the design tool. However, what the two exemplar cases show, the 'handle' of dimensions could be approached differently. Instead of tuning, fiddling or exploring a single reductive dimension, we argue to integrate multiple dimensions at the same time. We argue for a more holistic approach in which the separate lines are explored at once, through for example stacking or intertwining within the mapping of the dimension to the tool's action-possibilities. This does imply some kind of ambiguity, as it would be difficult to assess what 'action' influences what dimension. Yet, while the stacked or intertwined dimensions offer the opportunity for the designer to explore over 'surfaces or blobs' instead of 'lines', it does enable the designer to explore the multiple dimensions at once in a holistic manner. Furthermore, it does speak to the *pathic* skill of the designer that develops in interaction.

### 4.2 Double Loop of Exploration

Bringing the points that were made in section 4.1 together, we introduce a continuous double loop of exploration. In the process that we envision for exploring the designerly handles becomes part of the process of exploring the design solution, and these two

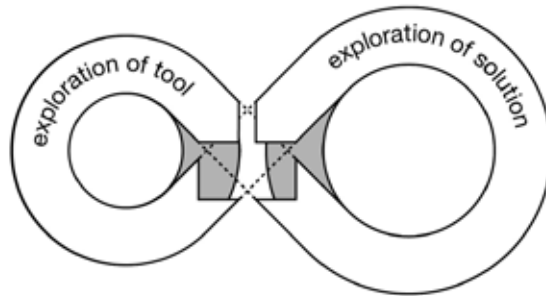


Fig. 3. The Double Loop of Exploration.

explorations will influence each other. In fact, this could be seen as a double loop (or mobius band) that fluently integrates these two different processes of exploration. The understanding of how to solve the design challenge will grow together with the understanding of how to explore it. Crucial to this process is to understand it as a 'looping' process, an iterative process. In this way, the designerly handles are always a reflection of the current state of the design process. Whether it is early in the design process where broad explorative qualities are needed (i.e., The Door Movement Behavior) or later in the process to finetune and explore detailed dynamic qualities (i.e., The Physical Meeting Manager); highly customizable, tailored designerly handles give us the necessary openness that allows us to explore beyond the limits of the generalized tool.

#### 4.3 Benefits for Designing and Generalizability

Where current research in design prototyping tools focuses on reusable and generic tools, we propose designing highly customized and tailored explorative handles to empower the designer in using its *pathic* skills. In physical making, our tools enable us to shape a design on the fly and have a dialogue with the design matter. Making, in the digital realm is currently dominated by building structured software that is disconnected from design context. We strongly believe that what is currently mostly defined as design making in the digital realm is merely the making of what we defined as making Designerly Handles. Making benefits from what these handles empower and facilitate. Through designing highly customized and tailored explorative dynamic enablers with designerly handles, the designer can regain the explorative freedom and ability to reflect and act in action with its skill.

A critical note is that although these custom explorative enablers are specific and therefore not generic enough to be reusable, they are the building parts for the designerly toolkit. While they might be one-offs, they are not a waste of time. The skill that is involved in making them does translate forward. We envision designers that create their own, enablers as part of their practice. A casuistic approach to disseminating these endeavors would be warmly encouraged.

#### 4.4 Consequences for Design Skills

A consequence of what we are proposing is that designers will create very particular repertoires of tools as a result of their double-loop engagements: in a way designers formalize their approach to exploring certain design problems in a sort of 'frame' that carries over to new design problems. This means that not only the chosen approach and chosen tools will be rather idiosyncratic, they also embed the risk of developing blind spots because of the assumptions (i.e., for example the perhaps wrongly chosen dimensions) that crept in, during the process of creating them. We consider that picking the 'right' dimensions is a skill that needs to be developed further.

As the developing toolset is largely individual and designer specific (i.e., it focuses on what the designer can emphasize and benefit from personally), we see the need for a changing skill repertoire for interaction designers. Skills in integrating technology and software are needed to make continuous and on the fly changes to further support exploring in the moment. This in its turn requires a sense of quality, not only to the aesthetics of form, but also to the aesthetics of interaction and behavior. Designers need to develop sensitivity in defining (or not defining) their designerly handles.

#### 4.5 Discussion

One might argue that what we propose is not a very efficient approach to creating tools, as everybody creates their own rather than using a pre-made solution that was programmed once. We feel that what we propose is a much more effective way of opening up the solution domain of the new design challenges. It allows designers to explore very specific and contextualized realms that are bound to suffocate and to be reduced in a generalized approach. As for the lack of efficiency, we feel that this is a necessary tradeoff that values



quality over speed. Yet, at the same time, we feel that the tradeoff is less severe than suggested by the need to make a new tool every time a new design challenge surfaces: the skill in creating custom exploration tools carries forward. The approach can be applied in other design processes, and with some appropriation, the design can be prepared for a more finite version on the basis of the designed dynamic enabler and designerly handle.

## 5 Conclusion

Even though technologies change over time, we posit that designers are at their best when their making-skills come to play. They allow them to explore, nuance and come to terms with the design matter. We foresee that designers in our digital era benefit from a different form of in-context exploration than that the current digital tools now afford. The design process benefits from tools that allow for adjustment and tuning while engaging in *reflection-in-action* sessions; Tools that are essentially open. Designers should thus not simply use the tools provided, but adjust and tailor them in such a way that particular and specific design processes benefit. In this paper, we argue for designers to make these highly customizable and tailored design tools as part of the explorative design process. This allows them to utilize their *pathic* skills while getting grip on the design challenge in different phases. We see these tailored design tools as 'dynamic and contextualized enablers' having 'designerly handles' to address 'dimensions of exploration', enabling manipulation that fits the act and form of exploration. In doing so we open the digital for true, open exploration where designers' *pathic* skills (i.e., they can work directly with the design matter at hand without the need to cognitively reflect upon it) in shaping the behaviors of interactive products come to play.

## References

- Schön, D.A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.
- Cross, N. (2006). *Designerly Ways of Knowing*. London: Springer-Verlag.
- Hummels, C.C.M. & Frens, J.W. (2009). The Reflective Transformative Design Process. In Proc. of CHI2009, (pp. 2655-2658). New York: ACM Press.
- Nelson, H.G. & Stolterman, E. (2012). *The Design Way: Intentional Change in an Unpredictable World*. Cambridge, MA: MIT Press.
- Löwgren, J. & Stolterman, E. (2004). *Thoughtful Interaction Design: A Design Perspective on Information Technology*. Cambridge, MA: MIT Press.
- Frens, J.W. & Overbeeke, C.J. (2009). Setting the Stage for the Design of Highly Interactive Systems. In Proc. of IASDR'09, (pp. 1-10). Seoul, South Korea.
- Rogers, Y. (2004). New Theoretical Approaches for Human-Computer Interaction. In B. Cronin (Vol. Ed.), *Annual Review of Information, Science and Technology: Vol. 38* (pp. 87-143). Medford, NJ: Information Today.
- Stolterman, E. (2008). The Nature of Design Practice and Implications for Interaction Design Research. *International Journal of Design*, 2(1), 55-65.
- Carroll, J.M. (2003). *HCI Models, Theories and Frameworks*. Oxford: Elsevier Publishing.
- Stienstra, J.T. (2015). Embodying Phenomenology in Interaction Design Research. *Interactions*, 22(1), 20-21.
- van Manen, M. (2007). Phenomenology of Practice. *Phenomenology and Practice*, 1(1), 11-30.
- Polanyi, M. (1983). *The Tacit Dimension*. Gloucester: Peter Smith.
- Fish, J. & Scrivener, S. (1990). Amplifying the Mind's Eye: Sketching and Visual Cognition. *Leonardo*, 117-126.
- Sennett, R. (2008). *The Craftsman*. Yale University Press.
- Rettig, M. (1994). Prototyping for Tiny Fingers. *Communications of the ACM*, 37(4), 21-27.
- Avrahami, D. & Hudson, S.E. (2002). Forming Interactivity: a Tool for Rapid Prototyping of Physical Interactive Products. In Proc. of DIS'02. (pp. 141-146). ACM Press.
- Frens, J.W., Djajadiningrat, J.P. & Overbeeke, C.J. (2003). Form, Interaction and Function, an Exploratorium for Interactive Products. In Proc. of 6th ADC, Tsukuba, Japan.
- Greenberg, S. and Fitchett, C. (2001). Phidgets: Easy Development of Physical Interfaces through Physical Widgets. In Proc. of UIST'01 (pp. 209-218). ACM Press.
- Frens, J.W. & Hengeveld B.J. (2013). To Make is to Grasp. In Proc. of IASDR'13, Tokyo, Japan.
- Hartmann, B., Abdulla, L., Mittal, M., & Klemmer, S.R. (2007). Authoring Sensor-based Interactions by Demonstration with Direct Manipulation and Pattern Recognition. In Proc. of CHI'07 (pp. 145-154). ACM Press.
- Stienstra, J.T., Hengeveld, B.J. & Lévy, P.D. (Forthcoming). Exploring Sensible Interaction: Designing the Sensible Door. Accepted for *The Design Journal*.
- Bogers, S.J.A. (2012). *Qualities of Physical and Digital Realms in Interaction*. Master Thesis, Eindhoven University of Technology.

# Enriching the Expressiveness of Products with Life Experiences

## Abstract

Life experiences can inspire designers to create products that resonate with people. Considering the increased appropriation of life experiences into product design to enrich the expressiveness of products, it is crucial to understand people's responses to these products to contribute further knowledge in design research and practice. This study investigated how people associate products with their life experiences so as to assist designers in effectively using life experiences to create original and meaningful products. Card sorting and interview methods were adopted in this study. This study summarized the associative experiences when people interpret the cues presented in products in order to identify the elements in life that can possibly become design inspirations. According to the results, the experience associations induced by products were classified into eight themes: (1) nature, (2) artefact conversion, (3) cultural icon, (4) anthropomorphism, (5) scenario development, (6) operation association, (7) common human behaviour, and (8) zeitgeist.

## Keywords

Life experience, expressiveness, product design, product experience

## 1 Introduction

Generally, the success of a product in the marketplace could be determined by its functional and aesthetic

satisfaction it brings to the user. However, functionality and usability are now taken for granted in products; users expect products to fulfill a deeper level of appreciation. Connections between people and objects are not just limited to product ownership. Users can develop emotional fondness for their possessions by reflecting on the hidden meanings in products. Products are not merely created for practical tasks; and further, they are able to communicate their qualities to users and to establish emotional connections [1]. In this sense, design processes should bring the pragmatic and emotional dimensions of products and interaction to the same level. Users' requirements for products have frequently been compared to Maslow's hierarchy of needs [2]. In response to the change in users' requirements, Jordan [3] proposed the hierarchy of customer's needs based on Maslow's "hierarchy of needs", where functionality lies at the base, usability in the middle, and pleasure at the top. This suggests that emphasis shifts towards the product experiences once issues of functionality and usability have been satisfied. As stated by Van Rompay et. al. [4], not only do designers design products that work well, they also design products that provide people with pleasurable experiences or needed support in their quests for meaningful lives. When thinking about the emotional aspect regarding to the relationship between human and product, designers need to develop an understanding of features in products as mediators that establish meanings

triggering a variety of responses at emotional level. An emotional response is not an automatic response to an object; rather, it is an automatic response to the thoughts that we have associated with the object [5]. In order to evoke emotional responses, designers seek a variety of sources to render products with metaphoric expressions to provide users with sensory and emotional experiences. By translating concepts from these sources into product properties, designers incorporate metaphors into product design to render the meanings and values they want to assign to a product. This design approach invites users to be creative partners in the process of making the meaning of a metaphor [6]. The products loaded with meaningful metaphors can resonate with users' experiences and engage them in the interaction with products. The incorporation of metaphors in product design has been used as a means to convey intended purposes such as communicating the product type and product category to users or to direct users in the use or operation of the product. Increasingly, however, metaphoric products are created for experiential intentions to make users desire them by endowing a product with a symbolic meaning, ideological message, or a fun/witty feature. Such design techniques enrich the product presentation and give meaning to the product for the purpose of increasing consumer acceptance, as well as creating a market for the product. In the pursuit of emotional design, bestowing values and meanings to products that resonate with users can promote the human-object relationship to the reflective level, which refers to the transfer of message, culture and self-image to the meaning of a product. It is observed that various designers appropriate life experiences into product design to trigger a connection between the user's personal experience and the context around the product. Our life experiences are the experiences we have during our lives; life experiences are the accumulation of lived experiences and the understandings and sense we may have made of these experiences [7]. Life experiences play an important part in the establishment meanings of our everyday actions and the world appears to us. In the present paper, life experiences refer to a collection of experiences derived from direct observation or past real-life events and activities, as well as interactions between people, objects and the environment. The emerging appropriation of life experiences in product design

reveals the designer's efforts on drawing on something in our lives to explore the possibilities of design in a more sensitive and reflective approach. The rich collection of this kind of products is the result of the creativity and imagination of the designers and provides design cases worth referencing.

## 2 Life experiences as design inspirations

In design activities, designers use visual references to explore concepts. The image-retrieval activity in design and its cognitive aspects include evocation, analogy-making and concept generation [8]. Visual references serve as a major way of stimulating design creativity, where designers make use of analogies to adapt design features from other fields to their own design problem. In addition to the stereotypes of the product category, designers refer to a broad range of visual references to shape the product form, commonly taking into account other dissimilar products, historic or cultural artifacts, non-products (e.g., nature-related entities, natural phenomena, living things), works of art, and actions [9, 10]. That designers make the appearance of a reference visible in the end product affects users' aesthetic impressions, which relates to the perception of how pleasing the process of regarding an object is [11]. For example, recognizing visual cues of other product types or living things may lead to the perception of unexpected humor and the formation of emotional attachments [12]. Visual references can evoke users' meaningful associations by connecting the product with other entities that are already seen to hold a certain social meaning [13]. By taking an attribute(s) from these references and transferring it to a product, designers generate metaphors to render the values and meanings they want to assign to a product into a physical form. These metaphors may suggest "evocative connections between the [product] and memories from our experience" [14].

Memories from life experiences play an important part in the establishment of a meaningful product. Life experiences involve a collection of experiences derived from direct observation or past real-life events and activities, as well as interaction between people, artifacts and the environment. People rely on their life experience to sense the meanings embodied in products by designers. Thus, the translation of life experiences into cues presented in products helps lead



Figure 1. Ripple lamp designed by Poetic Lab

users to relate to the products and find meaning in the context of product use. The products exhibiting cues of life experiences could remind users of their personal experiences, feelings, knowledge and memory. This is a dialogical process of communication between users and products, allowing the users to endow the products with meaning based on their personal experiences. Through reminding the user of a personal experience and evoking a corresponding emotional response, a unique and meaningful relationship between the user and the product is formed. Numerous designers have drawn on life experiences to diversify the expressiveness of products and created meaningful interactions. Using “Saxophonist Coin Holder” by ArtOri Design as an example, the designer incorporated a scene involving a street performer into the product design to create an expressive context of the product. The “Ripple lamp” designed by Poetic Lab provides another example (see Figure 1.); the lighting collection that imitates the movement of water recalls a familiar experience in a novel way and evokes people’s emotional response. Just as stated by designer Hanhsi Chen, “It’s not about designing a lamp, it’s about the experience and the emotion that is created by this moving light”. Obtaining design inspiration from life experiences and expressing such experiences through the product, results in a product experience that makes

the user feel understood and poetic, engaging with the user on an emotional level. The use of life experiences as design references tends to evoke people’s associations in their personal lives, which in turn may be associated with the familiar and the agreeable, or even makes them smile. A meaningful product experience is created accordingly.

The meanings contained in a product could trigger the user’s imagination. When such visions remind people of things in their lives, they allow people to resonate with and relate to the product, in turn triggering corresponding emotional responses. The translation of life experiences into cues presented in products invites people to draw mental connections between the context of product use and their previous experiences. The products acquiring distinctive meanings and becoming something unique can be achieved. The use of life experiences as design inspirations requires designers to be sensitive on connecting a product with something in our lives. It is crucial to understand how products trigger people to think about their experiences. Thus, this study investigates how people interpret products with cues of life experiences and how they establish their understandings of the cues with their own life experiences. The understanding of people’s perceptions of the products would contribute further knowledge to

the design approach so as to assist designers in looking for design inspiration in life experiences to create original and meaningful products.

### 3 Method

This study conducted exploratory research to probe into the experience associations induced by the products with cues of life experiences. The research methods combined card sorts and in-depth interviews. Card sorting is a categorization task; participants categorize entities externally, which reflects their internal, mental representation of these concepts. Therefore, the card sorting activity can facilitate understanding participants' thinking processes and determining their association evoked by the given cards.

#### Participants.

Twenty-three participants (14 women, 9 men) aged 25–35 years were recruited for this study. A card-sorting activity was conducted with individual participants and in groups, for which the participants were divided into 11 groups: two individual participants; six groups comprising two participants each; and three groups comprising three participants each.

#### Cards for sorting.

A set of product cards was developed to elicit as many categories as possible from participants. We collected products that were endowed with cues to trigger a variety of associations related to life experiences. A total of 245 products were initially selected and printed on a 9cm×12 cm card separately. The cards for sorting were selected through pilot testing using peer review (verification by experts) and member checks (verification by participants) [15]. A group of five experienced product designers were formed to review the 245 images. We discussed the design concepts of the 245 products and eliminated products unsuitable for this research as well as those featuring highly repetitive design concepts. A total of 150 products were identified in the peer review, we then asked each participant to look at the 150 product cards and selected the ones that induce their association of life experiences. The product cards were ranked according to their frequency of selection. The product cards picked by two-thirds of the participants or more (i.e., exceeding 15 times) were used as cards for sorting. The final set of 100 product cards was selected for this study.

#### Process.

Participants were asked to sort these cards into piles based on the experiences with which they associated the products. They were told that there was no limit to the number of piles or the number of cards in a pile. Once they were finished sorting these cards, participants were asked to label each pile using their own words. After the participants finished categorizing the cards, we interviewed and asked them to explain the reason for each categorization and the associated contents with the product cards of each pile. The card sorting and interview lasted approximately 80-100 minutes.

#### Data analysis.

A co-occurrence matrix was created for the card-sort data to encode the frequency with which pairs of cards are placed into the same card sort. This co-occurrence matrix was then analyzed using a standard clustering analysis to combine or separate variables into homogeneous clusters based on the similarities or differences, helping discover a structure in the data. We video and sound recorded the entire card-sort activities and interviews with the participants. The interview contents included the participants' explanations of the experience represented by each group, experience association induced by the product cards, and reasons for categorizing the cards into the group. The contents were summarized into transcripts for analysis. The grounded theory method was performed by reading all of the data repeatedly to achieve immersion and obtain a sense of the whole content. The data were analyzed word by word, and codes were created by first selecting the precise words from the text to capture key thoughts and concepts. We then made labels of these codes, which were sorted into categories based on how different labels were related and linked. Twenty-three categories emerged from 480 labels. The categories were not mutually exclusive but rather had overlap with other categories. These emergent categories were used for organizing and grouping codes into meaningful clusters. Based on the results of card sorting and interview content analysis, we grouped 480 participant card sort labels into 23 categories and 9 themes.

### 4 Results and Discussion

According to the results, the experience associations induced by products can be classified into eight themes:

(1) nature, (2) artefact conversion, (3) cultural icon, (4) anthropomorphism, (5) scenario development, (6) operation association, (7) common human behaviour, and (8) zeitgeist.

### **Nature**

The design concept is to borrow cues from the natural world such as natural landscapes and phenomena, plants, and animals. Once participants got even a slight hint that suggested something related to nature, they could instinctively identify it. Connecting our experiences with the nature with product features, the design approach brings a natural touch or a sense of familiarity to contexts around the products. For instance, No. 004, the pebble carpet made from felt designed by Ronel Jordaan was an imitation of pebbles, and the carpet reminded participants of walking on pebble paths or river stones.

### **Artifact Conversion**

This theme involved converting artifacts into product designs of different categories. Most of the sources of artifacts were commonly seen in daily life. Designers take knowledge from an artifact and put it in another domain or context to create something new. The design borrowing cues from other artifacts excited participants' perceptions of the products and led them to link the products to the referenced artifact in terms of functionality or performance. As the boundary of our physical and digital worlds is blurring, people are getting familiar with the virtual artifacts and understand their signified meanings. This study observed that digital artifacts expand the design inspiration in this theme. For example, No. 009, "my document" by 25TOGO Design, was a clutch bag in the design of a computer folder icon, which enabled the participants to associate the experience of storing files on a computer and indicate the function of the suitcase as to store files.

### **Cultural icon**

A cultural icon is an artifact that is recognized by members of a culture or subculture as representing some aspect of cultural identity. Participants' associations with the products categorized in this theme included religious rituals, customs, and cultural symbols. Participants felt connected to the products or perceived the embedded meaning once they recognized the cultural icons embodied in products. For instance,

No. 244, "Married Mug" designed by CiChi, presented a pair of red cups, the handles of which were designed as the Chinese character 喜 ("joy"). When the two handles were placed together, the Chinese character 囍 ("wedding joy") was formed, reminding the participants of the joy of a wedding and love.

### **Anthropomorphism**

Endowing products with human-like attributes is a prevalent trend in product design. Designers use the anthropomorphic forms, including human appearances, movements, and personalities, to provide users with clues regarding the product's function as well as an association of the product with personal and social significance. People are social entities and have evolved to interpret even the most subtle of indicators and are predisposed to anthropomorphize, and therefore to project human emotions onto everything [16]. For instance, No. 146, "Dress-up Vases" designed by the design studio Nendo, was a set of three flower vases. The vases had their own "collars" and came in different sizes: one heavysset with a straight collar, one slim with a ruffle collar, and one small with a curved collar. The vase body and detail implied the personification of certain signs. In the interviews, the participants reported that the three vases separately resembled a father, mother, and child, suggesting the image of a family.

### **Scenario Development**

In this theme, designers consider the context of using a product as a stage and the product as a prop to engage users in a way that creates an intriguing or meaningful experience. Connecting a well-known tales or circumstances with the context of product use, designers present users a situation that can evoke their memories or associations through the process of using the products. For example, No. 079, "Help! Drain Stopper" by propaganda was a sink plug, which depicted a hand reaching for help like people did when they were in danger of drowning. Placing the plug in a sink enabled the participants to link the image to a situation in which somebody was pleading for help.

### **Operation Association**

Products in this theme exhibit clues to lead people to use or interact with the products based on their past experiences. Designers continue a usage of a common object into another product design to facilitate people

to use the product in an expectable manner, hence bring users a sense of familiarity. For example, the Hono light by Metaphys has the appearance of a real flame inside a tube, which can be ignited by touching it with a magnetic match and extinguished by blowing on it. The light makes users develop a slight sense of attachment to the inorganic and artificial LED. The use of operation association is a design strategy to induce people to interact with a product to perform its function in a pleasurable way. No. 095, “Fitzsu Grand Prix Play-sam Car” by Konstantin Grcic, was a design of a brush in the form of a toy car. The participants reported that this design elicited thoughts of their childhood and playing with toy cars, eliciting a desire in them to use this brush as they did during their childhood.

### Common Human Behavior

This theme involved two categories: human activity and behavioral habit. The two categories refer to the common activities in which humans participate (e.g., sports, recreation, and entertainment) or human behaviors and habits. All of these activities and behaviors are part of a common human experience. For instance, No. 074, “Workaholic Pillow” by a Japanese company, was a design of a nap pillow in the form of an open book, which enabled the participants to associate their experiences of sleeping on a book.

### Zeitgeist

The products classified in this theme captured the zeitgeist of this era and evoked the participants’ thinking of the implied social issues and ideals, comprising categories of social issue, belief and ideology that reflect current society. Zeitgeist is the general intellectual and moral state of a time and is considered as a series of societal preoccupations, including ideals, hopes, and fears [17]. Through the products, current social topics, such as energy conservation, antiwar and environmental consciousness, were conveyed, thereby eliciting users’ reflection on the topics. For example, No. 178, Polar Ice Tray designed by Qualy, depicted a combination of a polar bear and ice cubes, which stimulated the participants to think of the concerns of global warming and thawing icebergs.

## 5 Conclusion

Product design is a force in developing unique and compelling product offerings to differentiate products

from others in the marketplace. The appropriation of life experiences into product design can diversify the expressiveness of products, which are then conveyed to consumers in response to their needs for product differentiation and symbolic meaning. The design approach creates perceptible contexts around products which helps people relate to the products and develop meaningful product experiences. This study summarized the associative experiences when people interpret the meaning embedded in products in order to identify the elements in life that can possibly become design inspirations. Further research into people’s appreciation of life experiences that have been incorporated into products could provide more definitive and conclusive evidence on how the design approach can be used effectively. Whether product designs based on the life experiences of consumers differ in involvement and preference because of gender or personal background requires further investigation. In addition, during the design process, how to generate in-depth and subtle emotional links and meaning can be determined to develop a design language based on such life experiences, which can then be integrated with other fields of research to conduct interdisciplinary research.

### Acknowledgements

This material is based upon work supported by the National Science Council of the Republic of China under grant NSC102-2628-H-011-002-MY2. The authors thank all participants in this study for their invaluable contribution.

### Reference

1. de Medeiros, W. (2014) Meaningful Interaction with Products Design Issues, 30 (3) , 16-18
2. Maslow, A. (1987) Motivation and Personality (3rd edition) New York: Harper and Row
3. Jordan, P. (2000) Designing Pleasurable Products: An Introduction to the New Human Factors. London: Taylor and Francis
4. Van Rompay, T., Hekkert, P., Saakes, D., & Russo, B. (2005). Grounding abstract object characteristics in embodied interactions. *Acta Psychologica*, 119, 315-351
5. Demirbilek, O. and Sener, B. 2001, A design language for products: designing for happiness, in M.G. Helander, H.M. Khalid and M.P. Tham (eds.), *Proceedings of the International Conference on Affective Human Factors Design* (London: ASEAN Academic Press), 19-24.

6. Cupchik, G. C. (2003) The 'interanimation' of worlds: Creative metaphors in art and design. *Design Journal*, 6(2), 14–28.
7. Van Manen, M. (1990). *Researching lived experience: human science for an action sensitive pedagogy*. New York: SUNY Press
8. Bouchard, C., Omhover, J.F., Mougnot, C. and Aoussat, A. (2008) 'TRENDS: a content-based information retrieval system for designers, DCC'08', Third Conference on Design Computing and Cognition, Atlanta, June 21–23.
9. Crilly, N., Maier, A., & Clarkson, P. J. (2008). Representing artefacts as media: Modelling the relationship between designer intent and consumer experience. *International Journal of Design*, 2(3), 15-27
10. Eckert CM, Stacey MK (2000) Sources of inspiration: a language of design. *Design Studies*, 21, 523–538
11. Csikszentmihalyi, M. & Robinson, R. E. (1990). *The Art of Seeing: An interpretation of the aesthetic encounter*. Los Angeles: The J. Paul Getty Museum
12. Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. *Design Studies*, 25(6), 547–577.
13. Postrel, V (2003) *The Substance of Style: How the Rise of Aesthetic Value Is Remaking Commerce, Culture, and Consciousness*, HarperCollins, New York, NY
14. McCoy, M (1984) Defining a New Functionalism in Design Innovation, *The Journal of the Industrial Designers Society of America*, 3(2), 16-19
15. Denzin, N. K., & Lincoln, Y. S. (Eds.). (2000). *Handbook of qualitative research* (2nd ed.). Thousand Oaks: Sage.
16. Norman, D. A. (2004). *Emotional Design: Why We Love (or Hate) Everyday Things*. New York: Basic Books
17. Coates, D. (2003). *Watches Tell More Than Time: Product Design, Information, and the Quest for Elegance*. New York: McGraw-Hill.



# People Research for Eco-system Propositions: a Theoretical Framework towards the Future of Interaction Design

## Abstract

The People Research group, part of Philips Design, plays an important role in the creation of meaningful innovations for Philips by representing the end-user in design processes. The group carries out a people centric design approach with established methodologies that are very helpful in the creation of single (connected) propositions. But these methodologies are challenged with the introduction of eco-systems of interconnected products services and people. The experiences in such an eco-system are more complex to study, require openness for personalization and continuously change over time. Therefore People Research is in need of methodologies that will help to identify, envision, co-create and measure meaningful experiences of eco-systems propositions.

In this paper we present a theoretical framework that supports people researchers and designers in transitioning the so-called people research activities for the future of interaction design. The framework describes four main activities for people research. It suggests how people research activities can be embedded in the design process and it shows how data plays an important role in these activities.

## Keywords

People research, eco-systems, meaningful experiences, design processes, paradigms

## 1 Introduction: Evolving Meaningful Experiences

Philips' mission is to "improve people's lives through meaningful innovation". As societies continuously develop, new social-economic challenges emerge and peoples' values, needs and wishes change accordingly. Thus, what people consider 'meaningful innovation' evolves. Hence, the societal challenges we are faced with today require both new types of systemic innovations and solutions plus new ways of working in both design and people research [1].

One characteristic of these systemic innovations and solutions is the eco-system approach. With eco-systems we refer to interconnected products, services and solutions that grow and adapt with the user to bring new value and meaning [1]. Adaption to the user is enabled through the data they produce by being in the eco-system. Via the usages of the (data gathering) products, services or systems, the eco-system gets to know the user and can adapt to his or her routines, behaviors and preferences. With this data, user experiences become more tailored to the individual. This implies that design and people research cannot longer fully rely on their current or previous methodologies that were intended to *create or stage* meaningful experiences for single (connected) propositions targeted to market segments. The design and people research methodologies of the future have to *enable* meaningful experiences in eco-system

propositions which are target to the individual [1-2]. In this paper, we focus on how our user research and user involvement methods, so-called people research competences, will need to change. How do people research and design enable personalized and evolving meaningful experiences in eco-system propositions? We present a theoretical framework that supports people researchers and designers in transitioning the people research competences for the future of interaction design. We actively use the hypothesized framework in our practice within the People Research group at Philips Design to further detail the model and to investigate the implementations for design practice. By sharing this hypothesis we would like to stimulate debate, exchange perspectives and get a shared understanding in the academic domain of people research for eco-system propositions.

## **2 Moving Paradigms**

To understand how people's concept of 'value' is changing we follow the so-called Paradigm Framework developed by Brand & Rocchi [2]. Following the paradigm shift from the industrial and experience paradigm to the knowledge paradigm, we recognize a change in user expectations and the type of propositions developed. We have moved from delivering a single product to a specific user (industrial paradigm), to delivering targeted experiences for customer segmentations (experience paradigm) and are now challenged to delivering meaningful experiences in eco-systems (knowledge paradigm). In the following section we explain the characteristics of these three paradigms and their implications for design and people research competences.

### **2.1 Problem Solving Products; the Value of Prosperity**

In the nineteen-twenties the industrial paradigm kicked-off when industrialization of societies started. Different from an earlier craftsmanship period, it was the first time products could be mass-produced and consumer goods became affordable to the middle class. Think of the affordable Ford model T that enabled middle class to buy a first automobile.

The sense of owning products which modernized life was important to consumers in this paradigm [2]. Modernizing products was focused on solving problems or bringing new functionalities that helped to make life more efficient. Other classic examples are light bulbs,

fridges and washing machines. Companies, like Philips, who wanted to win customers in the market had to battle with their competitors in price, functionality or quality. The industrial paradigm still exists in some domains like construction and mining equipment or industrial chemicals. Many of these businesses are facing difficulties in saturated and highly competitive markets.

### **2.2 Creation of Targeted Experiences; the Value of Belonging**

In the eighties of the twentieth century the experience paradigm started to role in. Consumers, who fulfilled their prosperity values, were looking for new types of products. Meanwhile as competition for companies was killing, many businesses were searching for new ways to differentiate themselves on the shelf. The experience paradigm was fueled by a changing societal landscape in which the fixed character of social status, politics and religion slowly disappeared. With these changes people looked for new ways of belonging that differed from the fixed communities and identities. Both companies and users were looking for products that offered more than functionality only.

As a response industry started to create new communities that were no longer build on predefined social classes; they were built on lifestyles. In order to belong to a certain lifestyle brands became signifiers to claim and represent someone's aspiration and values. Thus, by buying lifestyle brands, consumers discovered a way to regain a sense of identity. Brands like Nespresso and Nike are examples of the experience paradigm. These brands illustrated a certain lifestyle through media and internet advertisements. In order to express that lifestyle, you as a consumer have to become a customer of their brand.

The experience economy is characterized by the creation of experiences through propositions. Most propositions are single (connected) products with a brand identity. In line with the aspired lifestyle, these products bring a predefined experience on a standalone basis. With standalone we refer to one user-one product interactions.

### **2.3 Enabling Experiences in Eco-systems; the Value of Self-Actualization**

Now society has entered the knowledge paradigm and we find ourselves living in a world of constant and rapid change. Many users do no longer rely on brand

messages only; they create their own opinion, with information of peers, and chose products and services that fit their personal values best. People no longer need brands to signify their identity or lifestyle. Enabled by the digital means people are able to create authentic representations of themselves on their own blogs, web pages and social media platforms [2]. Users expect that the propositions take that same approach; these should deliver evolving, personal experiences.

An example is the mobile phone. Whereas the mobile phones of the early zero's had predefined functionalities, tailored to lifestyle groups, current mobile phones can be personalized through apps, profiles and settings. It is up to the user to decide what experiences the phone should deliver. The experiences through propositions can no longer be created or predefined but the experiences have to be enabled for the user [3]. Thus, the new meaningful experiences should be capable of growing and changing with the user. In turn these interactions with the products and services produce data and content that contributes to shaping what comes next. It is a self-nourishing process [4]. To make that happen, companies have to provide platforms and eco-systems within which users can add their personal touch. Instead of thinking solely in terms of single connected products, designers and people researchers need to start thinking in terms of eco-systems. These eco-systems of interconnected products and services have to offer meaningful, relevant and coherent experiences for users [4].

### **3 Existing Design and People Research Processes**

Each paradigm has its own type of value propositions; prosperity in the industrial paradigm, belonging in the experience paradigm and self-actualization in the knowledge paradigm. As these values change over time so have the people research and design competences. In this section we would like to illustrate how design processes are organized in the industrial and experience paradigm in order to understand what elements require change in the knowledge paradigm.

#### **3.1 Rational Problem-Solving Design Process in the Industrial Paradigm**

With the industrial paradigm came mass-production, a radical departure from the forgoing era which was characterized by craftsmanship and in which every piece

could be tailored to the client. It was the first time products had to be functional for a big audience. This resulted in the birth of the Industrial Design profession: a multifunctional competence which required to tech savviness, an eye for aesthetics, a business minded attitude and an awareness of user needs and dimensions. Designers followed a rational problem-solving design process consisting of the steps analyse, synthesise, simulate and evaluate [5], see figure 1. The designer was the one who took care of the functional factors of a product and who made products fit the body and mind. Ergonomics, human factor studies, standardization and anthropometrics were important subjects to make a functional benefit for end-users. The people research profession did not yet exist; users were not always involved in a project, but if so, it was the designer who studied the ergonomics of its creations.

#### **3.2 People Research Input for Design Processes in the Experience Paradigm**

In the experience paradigm the approach moved from functional to emotional. Products no longer were functional alone: they had to be liked too. Therefore design teams have started to tailor solutions to deliver targeted experiences to customers who share particular lifestyles. In order to study the response of products, people with common characteristics are clustered. This is named consumer or market segmentation [7].

The reflective practice design process for the experience paradigm has more loops, and can be structured in the activities: naming, framing, moving and evaluating [6], see figure 2. The focus of this design process is on the creation of experiences where an inventory of the current situation and experience inform the creation of a new/enhanced experience. The people research process taps into the design process and helps to identify the current experience, to envision the to-be experience and performs qualitative measurements. The qualitative measurement focuses on both clarity of the product and on the enhanced experience the product can bring. The people research competence flourished in the experience paradigm (e.g. experience flows, persona's).

#### **3.3 People Research Competences Change**

It is very important to acknowledge that although new paradigms arise, some skills and competences from earlier paradigms are still relevant today and will be



Fig. 1. The rational problem-solving design process in the industrial paradigm [5].

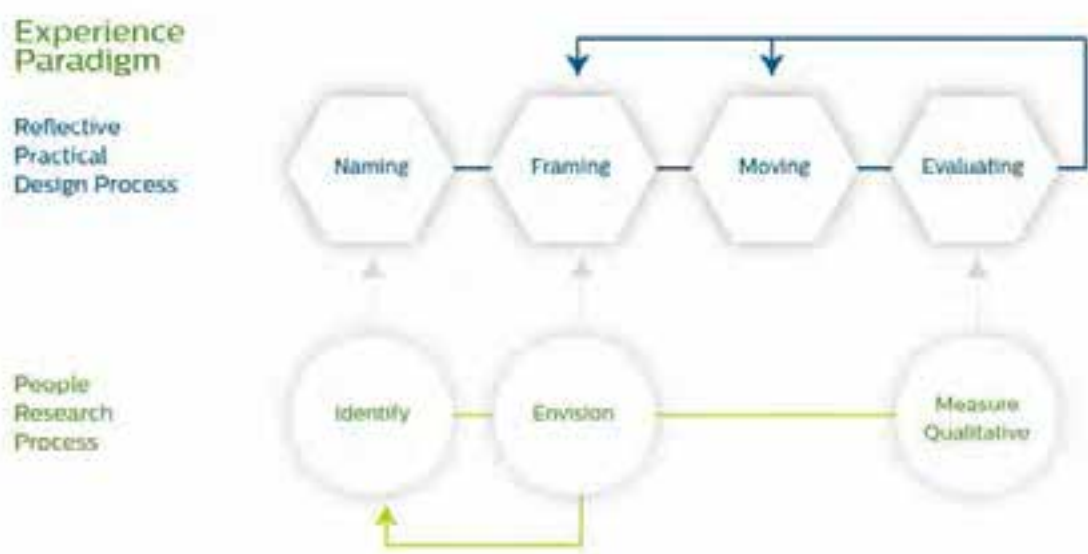


Fig. 2. The reflective practice design process, with people research input, in the experience paradigm [6]

tomorrow. Think of interview techniques, qualitative analyses skills or being able to visually represent insights. All of these will remain at the core of people research to comprehend users' thoughts, to make stories of insights, to inspire and to communicate with other disciplines. There might also be skills or competences that we will take for granted in the new paradigm or which become irrelevant. The question is how do we best apply and use our existing way of working in the new paradigm? What new skills and competences do we have to obtain to ensure valuable user involvement in people research for eco-system propositions?

#### 4 Three Challenges Occurring in the Transition

Looking at the past and existing processes of people research and design, reflected in the theoretically approached sections above, the People Research group of Philips Design foresees that current methodologies

will suffer from three challenges. In the knowledge paradigm experiences will be (1) more complex, (2) open and (3) evolve more continuously than before. These challenges have been abstracted by reflecting on the established way of working and by taking the paradigm model as a reference. Thorough understanding of the changes is needed to be able to define new methodologies for eco-system propositions that deliver meaningful experiences.

##### 4.1 Complexity Needs to be Embraced to Study Total Experiences

In the experience paradigm most innovations are single (connected) products and services. These propositions bring value on a standalone basis. The impact of the single products or service on the user experience is that big that products or services are often studied isolated from other products or services.

In the knowledge paradigm, propositions become more connected and interlinked. Think of enjoying

music through one of several devices, linked with a streaming music service which in turn is linked to your favorite online community. An experience such as this is not created through a single user - single product interaction. Instead it is sum of several encounters at touch points spread throughout when users interact with multiple (non)intelligent objects, services, environments and stakeholders. The increasing complexity of experiences has to be embraced in the new people research methodologies for the knowledge paradigm.

#### **4.2 Openness in Propositions Required to Create Personal Meaningful Experiences**

In the experience paradigm, experiences are staged in relation to a market segment, lifestyle and subculture. The end-user wants to belong to a particular lifestyle and is looking for products, services and brands that fit that collective image. By studying user groups and translating these insights in propositions, companies try to approach end-users with 'average' value propositions. Many decisions are based on a persona with average income, abilities, taste etcetera, resulting in moderate value propositions.

In the unfolding knowledge paradigm we shift from a collective approach to a personal approach; users no longer want to copy a certain group identity but want to create a life uniquely their own [8]. Therefore the end-user is looking for bits and pieces of experiences that fit with his envisioned life. The community is still very important in the knowledge paradigm, but more to reflect and compare, than to copy lifestyles. With this shift, innovations will become more meaningful when they fit the individual's need for self-actualization. To live up to the request for personalized propositions, designers no longer create a staged experience, but they enable an experience through their proposition [4]. Depending on the way the user positions a proposition in his personal eco-system, and the way the proposition learns from the interaction with the user, it is determined how the experience becomes personal and meaningful.

For example, light-companies like Philips in the experience paradigm provide staged experiences with predefined styling, light settings and interactions with the light source. Instead in the knowledge paradigm, users are enabled to create a light experience that fits them best. With an open API and connecting it to their existing eco-system, users can control the lamp in a

way which is most relevant to them. People research methodologies have to respect this openness for personalization to enable companies to create personal meaningful experiences that evolve with the user.

#### **4.3 Continuous Design and Research Development Required**

In simple terms, previously it was very clear what the life cycle of a proposition was: from intention to buy to end of life. Also the development process followed a clear linear approach from first idea to product launch. Nowadays the introduction of new products can be less defined with beta releases, kick starter projects and limited editions. And once introduced, products and services do not have to be as fixed as they were before. Since they are part of an interconnected network of other products, services and people which are changing over time, so are the products and services. It is a dynamic network with updates, added propositions, new connections, new functions, etcetera.

Moreover, multiple players will be active in an eco-system. The user decides which products and services to link. A company like Philips is not the only player in the eco-system and thus the eco-system can grow in many different directions depending on the user without Philips, or any single company, being in charge.

This early introduction of the proposition and the continuous development, growth and change of the eco-system will rapidly impact people's mindset, behaviors, experiences and expectations. Therefore we can no longer stop people research and design affords after the introduction of a proposition; learning and development has to continue to maintain meaningful innovations. The question is how to deal with early introductions, high speed projects and real time, continuous development from a people research perspective.

#### **5 Hypothesis of Theoretical Framework: Transition of People Research and Design Processes**

The three main challenges for people research in the knowledge paradigm require change of the existing methodologies. In this section we would like to describe how we envision the change. We propose a theoretical framework that takes these three challenges into account.

#### **5.1 People Research and Design Embedded**

The hypothesized theoretical model (illustrated in figure 3) proposes a true integration of people research in



Fig. 3. Hypothesized theoretical model with an integrated people research and design process for the knowledge paradigm.

the design process and vice versa. In the knowledge paradigm, these activities can no longer be executed separately due to the complex character of experiences, the fact that we are not longer creating but enabling experiences and the speed by which projects are running, launched and changed.

Previously people research and the design process could be executed in parallel as user insights were enough input for designers to create an experience. Insights could be shared using visual representations of the consumer segment characteristics. And with these representations designers could continue to design the proposition. As the propositions in the knowledge paradigm are not focused on the creation (or predefinition of) experiences anymore but enable users to define their own personal experience, designers need a different understanding of these experiences. This implies that not only the reflection and learning part of the design process require user involvement. Also the creating and making part of the design process need a stronger embedding of the user.

As well as design competences need people research involvement, so do people research activities require design involvement to be of value. With the increased complexity of experiences that arises in eco-systems it is nearly impossible to study an experience apart from a design or proposition. Design activities have to steer the people research activities to gather relevant

information. Thereby the eco-system of propositions becomes a vehicle to study experiences. Design exploration tools can also help to structure insights in the complex experience to be relevant for design, like proposed in the Experience Design Landscape methodology [9].

## 5.2 Four People Research Activities: Identify, Envision, Co-create, Measure

In the hypothesis we envision four main activities of people research that can be executed in all phases of the design process: identify, envision, co-create and measure. Some activities find their basis in the experience paradigm, but all have a slight different connotation or execution in the knowledge paradigm.

**Co-create.** Co-create is a new activity for people research in the hypothesized theoretical framework. It is added since we envision the involvement of users beyond given input, reflecting on ideas or validation of concepts solely. Enabling of experience requires designers to thoroughly understand how people connect the proposition to their eco-system and how that possible evolves over time. Co-creation is not new for the design process but so far not articulated as a people research activity [10]. The role of the people researcher in co-creation is to understand how experiences develop in interaction; how is a

proposition, as part of the eco-system, enabling the user to create a meaningful experience. The co-creation activity is an ongoing activity. Also after a launch, real-time data about usage or insights abstracted from communities can help get a deeper understanding of how experiences evolve.

**Envision.** The envision and co-create activities are closely related in this theoretical model. In the experience paradigm the envisioning phase required scenarios and other means to communicate the envisioned experience. Users could respond to these scenarios by projecting the envisioned experience on their own values. But in the knowledge paradigm designers can no longer predefine the envisioned experience since these will be different for all users. Early prototypes in which data of users is gathered and used will help users to envision new possibilities: the prototype has to truly enable the experience [11]. A prototype in the envision activity can be provocative [12] or a stimuli to explore the boundaries of an experience while a prototype in the co-creation activity is an early version of the final proposition.

**Measure.** The measure activity already existed in the experience paradigm process. This activity aims to validate design concepts with end-users. New to the measure activity in the knowledge paradigm is data gathering through experiential prototypes. With the use of sensors and actuators, prototypes are enabled to gather information about usages, context, cognition and behavior of people. In eco-systems we have the ability to (real-time) make use of all data in the system to study the user and his/her complex experiences. Different from the previous process, measurements can be interesting in multiple stages of the design processes. First it was mostly used to validate the impact of a proposition but now the measured results can be used in an explorative phase, to identify opportunities or to be of inspiration.

**Identify.** The identify activity still focusses on the exploration of current context, looking for inspiration, interesting phenomena and to get an understanding of relevant factors in the experience. New to the identify activity for the knowledge paradigm is to not only look at the qualitative side of current experiences but to involve information of use, context and behavior too

(gathered through identification prototypes or existing information of the eco-system). The combination of both qualitative data and quantitative data is powerful for two reasons. First, it can help to embrace complexity of the identified experience. Where we first could only receive subjective information about the experience and usage (through observations and interviews) data enables people researchers to study the 'objective' behavior of people. Interesting it to find difference in what people tell they do, or want to do, and what they actually do. Another source of inspiration, for proposition development, could be the abnormal situations people often forget to mention in interviews or which you cannot capture in a short observation. Through data representations, these can become visible. Second, the identified experience can be of value later in the design/people research process too. By continuously gathering data throughout the process, it can inform the creative and research process. Playing or exploring with data is different than thinking about what data could do. Besides, the gathered data can help in a later phase of the project to validate impact of the proposition as one can refer and compare data streams gathered through the final proposition.

**No specific order of activities.** Embedded in the design process, the four people research activities have no specific order of execution; they are neither linear nor iterative by definition. They are dynamic and there is no predefined order or static link to the design process. Hence there is no predefined starting or ending point for the process. Depending on the type of questions and status of the project the design research team can decide where to start and what to do after. It is possible to first define current context or to start in the co-creation phase to later identify the relevant information. With the interchangeable activities, every design process and linked people research process can be different [13]. This dynamic way of working fits the connected and dynamic environment the innovation has to land in.

### 5.3 Data as Enabler

In all steps of the people research process, data of behavior, cognition, emotion, context and experiences help people researchers and designers in the three challenges.

**Complex Data.** Data enables people researchers and designers to get more grip on complex matters to study. It helps to abstract patterns, to look for changes by comparing data or to understand the influencers in an eco-system. Interesting is to find discrepancies to what people tell you and what can be recognized in the data. The knowledge paradigm will request people researchers to truly understand the meaning of data. In early experiments with what we call 'intelligent probes', an evolution of the well-known probes methodology [14] with the inclusion of sensor data, already showed that interviews get a new direction when confronting participants with a visualization of their data.

**Personal Data.** The opportunity of data in personalization is that we are no longer limited to clustering or segmentations. Personalization through data enables dynamic profiling in which users don't have to be labeled with one profile. A combination of personal characteristics can help creating a profile that is unique. Where we put much effort in validating user profiles in the past, moving forward we should use hypothetical profiles as a starting point and use the different data streams and interaction measures to create a dynamic profile unique for each user. As result the main profiles will be strengthened and validated over time, meaning we can learn over time to enable personal experiences.

**Continuous meaningful data.** Since the propositions in the knowledge paradigm have to enable personal meaningful experiences, data is used to set up profiles and to adjust experiences to that person. The information used to make the experience personal can also be used by people researchers to study the experiences after the proposition launch. This way, data about the experiences can be studied continuously and so can propositions be developed over time to stay meaningful, even after going to market.

## 6 Discussion

With the knowledge paradigm unfolding we asked ourselves: How do people research and design enable personalized and evolving meaningful experiences in eco-system propositions? We envision that people research will consist of four main activities, which are strongly embedded in the design process; identify, envision, co-create and measure. These activities are

orchestrated in a dynamic process, which fits the connected and dynamic environment the innovations have to land in. Data plays an important role in all of these activities to embrace the complex, open and continuously developing experiences of eco-system propositions. To further develop the hypothesized framework we need to start putting the theory to practice and learn from case-studies. This enables the development of tools which strengthen data competences for design and people research in all four activities. These can contribute to the creation of dynamic profiles and persona's which overcome consumer segmentation. A constrain for full implementation is the development of new platforms that combine qualitative and quantitative data to identify, envision, co-create and measure complex experiences for evolving propositions in eco-systems. The theoretical framework illustrated in this paper is a first attempt to support people researchers and designers in the transition of people research activities for the future of interaction design. With this publication we aim to stimulate the debate on developing new ways of working and inspire third parties to join us on this journey.

## Acknowledgements

This paper is built upon the result of a communal effort in the People Research and Philips Design community. We would like to say thank you to all who are involved in framing the new ways of working. Furthermore, we would like to thank Creative Directors Mili Docampo Rama and Tom Djajadiningrat for their feedback and thorough editing. For all reflective questions and cooperation in the development of this theoretical framework we would like to thank Sander Bogers. This research was supported by the IMPULS perinatology framework.

## References

1. Gardien P., Deckers E., Christiaansen C.: Innovating Innovation – deliver meaningful experiences in ecosystems. DMI: Academic Design Management Conference London, London (2014)
2. Brand, R., Rocchi, S.: Rethinking value in a changing landscape: A model for strategic reflection and business transformation. Eindhoven, the Netherlands [http://www.design.philips.com/philips/shared/assets/design\\_assets/pdf/nvbD/april2011/paradigms.pdf](http://www.design.philips.com/philips/shared/assets/design_assets/pdf/nvbD/april2011/paradigms.pdf) (2011).



3. Carney, S., Gardien, P., Christiaansen, G., Deckers, E.: Connecting the dots: A fresh approach to experience design. Eindhoven, the Netherlands: Philips Design. Internal publication (2014)
4. Carney, S., Gardien, P., Christiaansen, G., Deckers, E.: Connecting the dots part I: Introducing Experience Domains. Eindhoven, the Netherlands: Philips Design. Internal publication (2014)
5. Simon, H.A.: The sciences of the artificial. MIT Press, Cambridge MA (1969)
6. Schön, D.A.: The Reflective practitioner. Basic Books, New York (1983)
7. Wind, Y., & Cardozo, R. N.: Industrial market segmentation. *Industrial Marketing Management*, 3, 153-166 (1974)
8. Gardien, P., Djajadiningrat, T., Hummels, C., & Brombacher, A.: Changing your hammer: The implications of paradigmatic innovation for design practice. *International Journal of Design*, 8(2), 119-139 (2014)
9. Peeters, M.M.R. & Megens, C.J.P.G.: Experiential design landscapes: how to design for behaviour change, towards an active lifestyle. Eindhoven: Technische Universiteit Eindhoven (2014)
10. Sanders, E., Stappers, P.J.: Co-creation and the new landscapes of design. *CoDesign: International Journal of CoCreation in Design and theArts*, 4:1, 5-18 (2008)
11. Hummels, C., Djajadiningrat, J., & Overbeeke, C.: Knowing, doing and feeling: communicating with your digital products. *Interdisziplinäres Kolleg Kognitions- und Neurowissenschaften, Günne am Möhnesee, March 2-9 2001*, pp. 289-308 (2001)
12. Boer, L., Donovan, J.: Prototypes for participatory innovation. In: *proceedings of the Designing Interactive Systems Conference*, pp. 388-397. AMC (2004)
13. Hummels, C., Frens, J.: The reflective transformative design process, *Proc.Extended Abstracts CHI2009* (2009)
14. Mattelmäki, T.: Design probes. Aalto University. (2006)

**M. Bordegoni<sup>1</sup>, M. Carulli<sup>1</sup>, S. Kyffin<sup>2</sup>**

<sup>1</sup>School of Design, Politecnico di Milano, Italy

<sup>2</sup>Northumbria School of Design, UK

# “Designing and virtualizing the multisensory product experience”

The advent of novel technologies has enabled us to experience the reality in a completely new way. What is real can be virtually augmented, and what is virtual can have pieces of reality inside, thus breaking down and mediating the boundary between what exists and what people imagine.

Actually, “virtualization” has led to widening both the realization and the fruition of the contents, thus providing final users with many possibilities, which were difficult to be imagined only 20 years ago.

According to Fukuda [1] “world is very rapidly expanding and boundaries are disappearing”, and novel technologies are contributing to change the life we are living, in a way that is completely different from the traditional one.

In this new open world we cannot have as reference solely our knowledge and personal experience. Enabled by virtualization, we can enrich our experiences of the real by adding aesthetic elements and new meanings, making reality more informed, beautiful, and wealthy. We can seamlessly be transported from reality to virtuality, where our senses are stimulated and deceived by the technology.

Moreover, virtualization has profoundly changed the modalities with which the products are conceived, designed and developed. This concerns both the theoretical bases, from which the products development derives, and the tools used to develop the products.

As a consequence, design research and practise have deeply changed over these recent years. The track “Designing and virtualizing the multisensory product experience” of the DeSForM 2015 conference aims at defining an overview of the novel virtualization-based design methods and tools focused on the development of novel products, both real and virtual. In addition, attention is paid to the user experience, intended as focal point for the design from a holistic and multisensory point of view.

Both the concept of experience and that of multisensory are fundamental and strictly linked each other.

The first theoretical basis for illustrating the link between these two concepts is related to the communication between users and devices. The communication is at the basis of the design of new products.

“So what will become important tomorrow is that we have to design a product that will communicate with us and with the outer world to provide us with emotional excitement and satisfaction [2].”

This communication can be defined as interaction. Several are the definitions of interaction reported in the conference papers. According to [3] “Interaction is the action accomplished by the user or by the artifact on each other that influences or modifies the User’s motor, perceptive, cognitive, and affective systems [4].”

“We consider interaction as a dialogue between user and product (service or a system), in a particular context.”

“Interaction surrounds the Design process, which creates a way to make it easily usable, useful, desirable and profitable relation with product.”

“Thus, understanding how interactions are lived by the User is decisive for product’s conception.”

As a matter of fact, the design of interaction is one of the key factors of an engaging User Experience with the product, able to meet the user’s wishes and expectations from functional as well as perceptual and emotional points of view.

“Design is nothing else than a generator of experience to live through products [5]. Indeed, the main goal for Designers should not be designing product, but the User Experience itself should be in the core of the design process [6].”

With User Experience we mean a multi-faceted phenomenon with diverse characteristics of complexity.

“Experience is not a property of artifact, but the outcome of the User [7]”, and it is “holistic, subjective, affective, cognitive and temporal [8, 9, 10].”

The means through which the user interacts with the product is the Interface. “Even if this expression is global, it is often used in informatics terms to define the junction between two systems.”

Traditionally, the interface is based on the use of vision (GUI – Graphical User Interface), while today the interfaces allow the users to interact with the product by involving also other senses as for instance touch, hearing and smell.

“Recent researches have approached new ways to interact through our senses. For example Mousette [11] proposes haptic interfaces; recent MIT researches define new sound desktop; smell research are already approach in User-experience and marketing... and even new ways to feel and experience are developed through our back sensors [12]”

“Thus, Interaction in User Experience is approached as a field materialized through interfaces and opportunities to capture our senses.”

This is due to the fact that “interactions with pixels on these Graphic User Interfaces are inconsistent with our interactions with the rest of the physical environment where we live”, while “Tangible User Interfaces (TUIs) are built upon our skills to manipulate various physical objects and situate the physically-embodied digital information in physical space.”

“The relation with tangible interfaces could metamorphose the way we dialogue with product by including senses of touch, gestures, feelings, enclosure, manipulations... etc... improving and developing feedback, sound, environment adaptation...etc... These modifications of our relation to interfaces could also improve and increase our emotions during interaction.”

Virtualization and the evolutions in the field of Interaction and User Experience have been influencing also the different fields of the market: furniture (that is becoming “smart”), fashion, white goods, automotive as well as all the devices that have been developed recently and, therefore, have been conceived directly in the era of the digitalization and virtualization, as computers, smartphones etc.

Also in the fields of robotics and its industrial applications, it is possible to perceive the effects of these changes. Today, robotics is not so evident, and sometimes even hidden to the final users, since the use of robots in everyday life has not been fully accepted by the users yet.

Actually, according to [13] “In the last decades, robotic solutions for industrial, military and medical fields have been, increasingly, consolidated.”

On the contrary, the examples of co-habitation “human-robot” in the home environment are really few. However, an emblematic case concerns the cleaning robots in the home environment. Indeed, the aesthetic features of these robots are particularly important for the acceptance of the device, so that now the same is happening also for other kinds of robots.

In the meanwhile, “Nowadays, robotic aesthetics is experiencing a further evolution, as contaminated by the relationship with the digital world. The world of digital devices is becoming, in fact, more and more extensive and pervasive, besides smartphones and tablets, that almost all now have, begin to spread wearable devices and diffuse sensors, such as beacons. Each of these artefacts introduces new possibilities of interaction with humans and between humans and robots.”

Since these issues are really important for the design of new products, the design theory needs to evolve towards a research line whose results should be novel product development processes centered on these aspects.

An example can be found in the Experience Map [14], which is a tool “to support designers in translating their initial idea (i.e. the product vision) into sensory qualities of the product”, by allowing the designers to induce the desired multisensory experience in the users.

This tool is based on the statement that “Even though designers tend to focus on the functionality and the visual aspect of the product, they are becoming increasingly aware of the importance of a multisensory approach”. Then, designers have to consider “every modality while shaping the product, so that all product properties cooperate to convey a specific experience to users. The initial, fuzzy idea in the designer’s mind must turn into a set of tangible properties that form a product.”.

The main idea is to create a structured tool, which can be used by the designers during the phases of the product development process to develop this set of tangible properties. Therefore, starting from the definition of a concept, i.e. the Product Vision, which is [...] a product-centred statement that provides straightforward information on the quality of the product “at a high level of abstraction, it is necessary to define the characteristics of the product”. In order to support this process, the Experience Map “tool supports designers with a structured layout that goes from the abstract level of the product vision to the selection of sensory properties.”

“To use the Map for creative purposes, designers should move from the centre, the most abstract level, to the external level of the map, the most tangible one.” (as shown in Fig.1).

The ultimate goal of this tool “is to increase designers’ awareness and to make their choices more deliberate, yet reflecting their personal subjectivity. Designers can also be stimulated to consider all the sensory modalities, with new possibilities to enhance the user experience of the product.”



Fig. 1. The Experience Map describing the case study of the Pulse concept by Deepdesign.

Further attempts for a methodological systematization include the multisensory approach to the project development. Some of these are mainly based on practical validations from which to derive guidelines and principles to be verified by means of methods and framework already accepted in the design field. This is the case of the research work named “Haptic Beats” [15], based on the idea that “aesthetic product interaction can be achieved by facilitating human-product interaction that engages all human skills, cognitive, emotional and perceptual-motor [16]”.

In particular, the aim is to use the sense of touch as an interaction tool, and “to transform actions, which are generally perceived as useless in human-product interaction into aesthetic interactions”.

In fact, “Haptics can offer a new layer that enriches the experience of interactive products, it can par excellence support the design for rich interaction as it extends and strengthens the human skill through its sensitivity. The subtle feedback of haptics could put the user-product interaction in a continuous loop of action and feedback [17]” “This mechanism, defined as hybrid materiality [18] supports rich interaction [19], as it triggers users to explore products through all human skills.”

Consequently, through the development of several prototypes of the Haptic Beats, which is “an interface that enables shuffling through songs and playlists and allows for volume control through gestures while providing haptic feedback”, it has been possible to evaluate the interaction by means of the Interaction Frogger Framework [20]. “This framework is based on six notions that stimulate a continuous coupling between user’s action and product’s feedback: time, location, direction, dynamics, modality, and expression.”

The results of this research work consist in some specific guidelines useful for designing a rich haptic interaction. Guidelines include “simplicity within the feedback, coupling of time, modality and location, and affording expressive actions”. Moreover, the development and use of physical prototypes is recommended “as they enable to experience the hypothesis and support in addressing the research question”.

Another example of the central role of the sense of touch in the current research into design concerns the exploration of materials and their use for characterizing the product from a tactual point of view. This allows creating and communicating, mainly by means of a tactual interaction, a specific user experience, both by using traditional and smart materials.

According to [21] “In recent years new visions have expanded the boundaries of interaction design, from graphical user interfaces (GUIs) to tangible user interfaces (TUIs) and material user interactions (MUIs) [22]. The new visions assume that bodily engagement and tactile manipulation can facilitate a deeper understanding and more intuitive experiences”. According to Hallnäs and Redström, “interaction design could be a real link between basic research in computer science and product applications for new expressive design [23]”.

An example of this approach can be found in the research presented in the paper “Tactility Trialing: Exploring Materials to Inform Tactile Experience Design” [24], which is based on the statement that although “the visual and auditory modalities are often mainly exploited in Human-Computer Interaction (HCI)”, tactile modality plays an important role“ and “the shape and material of (interactive) tangible artifacts largely determine the initial user experience.”. The proposed design approach, “entitled tactility trialing, is intrinsically iterative, since it is developed during all the phases of the product development process” and “it may start from any phase and can be repeated multiple times to optimize the outcomes “.

This approach, which “consists of five phases (experience formulation, material selection, artifact creation, user study and design translation)” is proposed as “not simply a method to help select (combinations of) materials. Rather, it is an approach that helps to gain better insights in the effect of material qualities on the user experience of one’s design, thereby informing choices of shape, material, interaction and intended experience”.

For what concerns the use of smart materials, both design research and practise are more and more interested in them, and the general aim is to look for inspiring ideas, both involving creativity and technology, that could be useful for improving the interaction.

By means of a multidisciplinary approach, starting from a wider vision – compared with that focused only on the aesthetics of a product - and leveraging new technologies, it is possible to design products whose meaning is deeply innovated and innovator for the end users.

Hence, innovative and smart materials, used as basis for the design of a product, constitute the characterising features of the product and of its interface that, sometimes, coincides with the product itself.

This occurs with the shape-changing materials, which are “materials that undergo a mechanical deformation under the influence of direct or indirect electrical stimuli” and are used “as a way to embody digital information”.

Also, “The computational composites (in short CCs) being able to convert particular forms of energy reversibly, in particular to/from electrical energy, can be programmed to dynamically change their physical features, such as color, texture, form etc. in response to external stimuli (e.g. touch, temperature, etc.).”

According to [25] “Designing with CCs, collectively, imposes multidisciplinary challenges (e.g., attuning diverse perceptions [26]), as well as technical and methodological challenges [27], which are related to their digital-physical nature [27-29] and temporal behaviors”. Designing with CCs is, therefore, not only a matter of giving them physical form, but also envisioning their temporal characteristics (i.e. interaction design challenges) as situated in the social, cultural and behavioral context of use [30]—within a ‘situational whole’ [31].

Therefore, starting from the results of the technological research in the field of materials, “the designer’s task is to create the physical embodiment and interaction within a set scenario of value creation”.

“an aspired value” can be anything from improving utility of an existing product to unfolding unforeseen practices, or changing the purpose for which a product is used (i.e., meaning-changing; [32]).

Then, both products and the quality of their interaction with users are improving. “With the emergence of new smart materials, like shape memory materials (SMMs), the evolution of digital technologies and the availability of mass customization methods, technological products can now ‘feel’, ‘hear’, ‘breathe’ and react.” [21].

“The designers have to invest and cultivate the imagination with regard to physical and psychological human needs, and link them to positive experiences such as stimulation, relatedness, and competence.” [21].

“If design with the multidisciplinary of skills and cross-fertilization of methods (product, interaction, and experience design) could incorporate the potential of smart materials in our daily lives, our reality would be much richer in communication, powerful in sensorial engagement, more sustainable, and pleasurable for individual and social life.” [21].

Obviously, the multidisciplinary and cross-fertilization approach can be extended to other research fields, where design is necessary to improve the designed products and their user experience.

In the medical field, for example, the design discipline is necessary to support the use of up-to-date technologies with a positive feeling among patient (user), product and professionals so as to improve the user experience. For this reason, it is also important to enable the perception of the technology as acceptable and not harmful or invasive. On the contrary, the technology has to be perceived by the patient as useful and positive, thus leading to the issues related to the social and ethical acceptability.

Similarly to the case of robotics [13], it is necessary “to define the conditions that make robots acceptable for society, in order to avoid unsuccessful or competitive situations.” It depends on various factors of human-robot interaction such as the main five identified by Rogers: relative advantage in compared to other tools; compatibility with the existing social practises; the level of complexity in terms of usability; trialability, namely the possibility to try the tool before its “enforcement” and observability, i.e. the expressive clarity that makes the technology easily recognizable [33].

Once these barriers are overcome, the use of the technology and of the virtualization can be fundamental for both heal and rehabilitate the patient as well as for the development of tool that can be a valid support for the everyday life of the patients.

In this context, it is worth citing a research work on orthoses, which is an example of an application where virtualization and rapid prototyping technologies are used together [34]. Currently, orthoses "around the world are mostly manufactured manually. This incurs in high costs and low accessibility to the right kind of medical treatments for many people."

The hypothesis is to optimize the process for the acquisition of the shape of the plastered limb as well as the process for the realization of the orthoses through, in the first case, digital 3D scanning systems and, for the second one, 3D printing systems, using only the material needed. Moreover, between these two steps of the process "The shape of the orthoses can also be calculated so that it creates optimal structures for its performance".

Although this kind of digitalized process still presents some technical problems due to the quality and the accuracy of the acquisitions, "the use of CAD in the design of orthoses in use in a variety of clinical settings [35, 36] and its potential to be more accurate than manual measuring and fabrication has been highlighted [37]."

Eventually, it is worth citing a research work on orthoses, which is an example of an application where virtualization and rapid prototyping technologies are used together [41].

Currently, orthoses "around the world are mostly manufactured manually. This incurs in high costs and low accessibility to the right kind of medical treatments for many people."

The hypothesis is to optimize the process for the acquisition of the shape of the plastered limb as well as the process for the realization of the orthoses through, in the first case, digital 3D scanning systems and, for in the second one, 3d printing systems, using only the material needed. Moreover, between these two steps of the process "The shape of the orthoses can also be calculated so that it creates optimal structures for its performance".

Although this kind of digitalized process still presents some technical problems due to the quality and the accuracy of the acquisitions, "the use of CAD in the design of orthoses in use in a variety of clinical settings [42, 43] and its potential to be more accurate than manual measuring and fabrication has been highlighted [44]".

Other important improvements due to the use of CAD tools in the design of orthoses are that "the digital file generated by the CAD software can play an important role in monitoring physical fit and progress of therapies" and "The data gathered by embedded pressure and movement sensors can also offer clinicians important information about the usage of the orthoses, including use compliance and pressure points."

Finally, due to the fact that "Treatment success depends upon the patient's subjective satisfaction with the orthosis", the hypothesis of the authors is that "the smarter, more responsive technology can be applied to motivate patients, particularly children, to complete physiotherapy exercises".

The analysis of the research works presented in the track "Designing and virtualizing the multisensory product experience" highlights how the virtualization of products and of the experience with products becomes the medium between what designers imagine for improving people's lives in aesthetically and ethically appreciable ways, and what the real world is.

Specifically, designers can use the multisensory virtual technologies to make visible their aesthetic ideas, and to study in which way they can impact people's lives, experiences and emotions.

Finally, by using a multidisciplinary approach designers can design products that embed new technologies for involving people in new engaging experiences, which could lead to an improvement in the quality and aesthetics of their life.

## References

- [1] Fukuda S., Design for flow in an age of material digitalization, DeSForM Conference 2015.
- [2] Fukuda S., Emotional Engineering, Vol.3, Springer, London 2015.

- [3] Mahut T., Bouchard C., Omhover J.F., Favart C., Esquivel D., Interaction, the core of User Experience, DeSForM Conference 2015.
- [4] Gil S., Comment mesurer les émotions en laboratoire? *Revue électronique de Psychologie Sociale*, 4, 15-24, 2009.
- [5] Vial S., *Court traité du design* Presses Universitaires de France, Collection «Travaux pratiques», 2014.
- [6] Mok C., *Designing business*. San Jose, CA: Adobe Press, 1996.
- [7] Desmet, P.M.A., Hekkert, P., Framework of product experience. *International Journal of Design*, 1 (1), 57-66, 2007.
- [8] Parrish P., *A Design and Research Framework for Learning Experience; The COMET Program* Brent G. Wilson; University of Colorado Denver, 2008.
- [9] Helander, M., Khalid, H., Affective and pleasurable design. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics*. New York, NY: John Wiley & Sons, 2006.
- [10] Overbeeke G.J.F., Smets, C.J., Expression taste in package, *Design Studies*, 16 (3), 349-365, 1995.
- [11] Moussette C., *Simple Haptics, Sketching perspectives for the design interaction*, 2012.
- [12] Eagleman D., Can we create new senses for humans? TED talk 2015.
- [13] Germak C., Lupetti M.L., Giuliano L., Ethics of Robotic Aesthetics, DeSForM Conference 2015.
- [14] Camere S., Schifferstein H.N.J., Bordegoni M., The Experience Map. A Tool to Support Experience-driven Multisensory Design, DeSForM Conference 2015.
- [15] Mailvaganam A., Alonso M.B., Haptic Beats: Designing for Rich Haptic Interaction in a Music Controller, DeSForM Conference 2015.
- [16] Overbeeke C.J., Djajadiningrat J.P., Hummels C.C.M., Wensveen S.A.G., Beauty in usability: forget about ease of use! In: W.S. Green & P.W. Jordan (Eds.), *Pleasure with products: beyond usability* (pp. 9-18). Taylor and Francis, London, UK, 2002.
- [17] Bruns Alonso M., Hummels C.C.M., Keyson D.V., Hekkert P.P.M., Measuring and adapting behavior during product interaction to influence affect. *Personal and Ubiquitous Computing*, 17(1), 81-91, 2013.
- [18] Parkes A., Ishii H., Bosu: a physical programmable design tool for transformability with soft mechanics. *DIS '10*, 189-198, 2010.
- [19] Frens J.W., *Designing for Rich Interaction: Integrating Form, Interaction, and Function*. Unpublished Doctoral Dissertation, TU Eindhoven, The Netherlands, 2006.
- [20] Wensveen S.A.G., Djajadiningrat J.P., Overbeeke C.J., Interaction frogger: a design framework to couple action and function through feedback and feedforward. *DIS'04*, 177-184, 2004.
- [21] Bengisu M., Ferrara M., Kinetic Materials Experience, DeSForM Conference 2015.
- [22] Ishii H., Lakatos D., Bonanni L., Labrune J.B., Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials. *Interactions* 19, 38-51, 2012.
- [23] Hallnäs, L., Redström, J., *Interaction design: Foundations, experiments*. Borås, Sweden: University College of Borås, 2006.
- [24] Bakker S., de Waart S., van den Hoven E., Tactility Trialing: Exploring Materials to Inform Tactile Experience Design, DeSForM Conference 2015.
- [25] Barati B., Karana E., Hekkert P., From Way Finding in the Dark to Interactive CPR Trainer: Designing with Computational Composites, DeSForM Conference 2015.
- [26] Edmondson A.C., Nembhard I.M., Product Development and Learning in Project Teams: The Challenges Are the Benefits. *Journal of Product Innovation Management*, 26(2), 123-138, 2009.
- [27] Redström J., On Technology as Material in Design. *Design Philosophy Paper*, 2005.
- [28] Löwgren J., Stolterman E., *Thoughtful interaction design: A design perspective on information technology*. MIT Press 2004.
- [29] Wiberg M., Robles E., Computational Compositions : Aesthetics, Materials, and Interaction Design. *International Journal of Design*, 4(2), 65-76, 2010.
- [30] Rosner D.K., Ikemiya M., Kim D., Koch K., Designing with traces. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, 1649, 2013.
- [31] Karana E., *Meanings of Materials*. Doctoral dissertation. Technical University of Delft, Delft, 2009.
- [32] Verganti R., Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda. *Journal of Product Innovation Management*, 25(5), 436-456, 2008.
- [33] Rogers E.M., *Diffusion of Innovation*. 5th Edition. The Free Press, New York, 1995.



- [34] Rodriguez Ramirez E.R., Chan K., Fraser S., Thurlow K., Sebastien, V., Fridman D., Brebner S., 3D Printing Sensor-enabled Splints and Exergaming, DeSForM Conference 2015.
- [35] Jerrell M.L., CAD/CAM in the O&P Industry, O & P Business News 15, 2006.
- [36] Smith, D.G., Burgess E.M., The Use of CAD/CAM Technology in Prosthetics and Orthotics - Current Clinical Models and a View to the Future. Journal of Rehabilitation Research and Development, 38(3), 2001.
- [37] Telfer S., Abbott M., Steultjens Martijn M.P.M., Woodburn J., Dose–response Effects of Customised Foot Orthoses on Lower Limb Kinematics and Kinetics in Pronated Foot Type, Journal of Biomechanics 46(9), 1489-95, 2013.

# Tactility Trialing: Exploring Materials to Inform Tactile Experience Design

## Abstract

Although materials of tangible interaction designs largely determine their user experience, material choices are often steered by practical motives. This paper presents ‘tactility trialing’, an approach to explore tactile experiences of materials to inform the design of tangible artifacts. Through experience formulation, material selection, artifact creation and short user studies, designers and design-researchers are enabled to make informed decisions on the materials to be used in order to evoke the intended experience. The approach is illustrated through two case studies of student work. Tactility trialing helped them in getting acquainted with tactile material qualities in practice, and with the applicability of material characteristics such as resilience and hardness in design.

## Keywords

Tangible interaction, materials, iterative design, interaction design, user study, user experience design, tactile experience.

## 1 Introduction

Our experience of (interactive) products is largely influenced by our perception. While these perceptions incorporate all of our sensory modalities, the visual and auditory modalities are often mainly exploited in Human-Computer Interaction (HCI). However, particularly in the area of tangible interaction [1], which

explores physical manipulation of tangible artifacts, the tactile modality plays an important role.

The shape and material of (interactive) tangible artifacts largely determine the initial user experience. Careful selection of materials should thus be an integral part of the process of designing for (tangible) interaction [2]. However, choice of materials in tangible interaction design and research seems mostly steered by practical motives or to create a certain look, rather than by considering the resulting ‘tactile experience’ when the design is manipulated. This differs from approaches used in product design, which usually consider sensorial aspects of materials throughout the design process [3]. The work presented in this paper aims to explore the value of, and increase understanding of material qualities in tangible interaction design and research.

Different materials may evoke different tactile experiences, depending not only on the material itself but also on the way it is used and shaped into the artifact. Therefore, iterative exploration of material and artifact is deemed relevant to result in desired tactile experiences. In this paper, we propose an iterative approach, entitled tactility trialing, for hands-on exploration of tactile experiences. This approach consists of five phases (*experience formulation, material selection, artifact creation, user study and design translation*), which alter making and thinking, and is intended to enable designers and researchers to make informed decisions on the materials to be used in order

to evoke the intended experience. In this paper we describe the tactility trialing approach and discuss each of the phases by illustrating them through two case studies.

## 2 Related Work on Materials and Interaction

The field of HCI has, in the past decades, gradually shifted its focus from ‘usability’ to ‘user experience’; focusing beyond functionality and productivity towards enhanced (emotional) experiences resulting from interaction with products and systems [4, 5]. In line with this development, research approaches involving design practice (e.g. ‘research-through-design’ [6]) are increasingly being applied. Such approaches advocate involving users throughout the process and engaging in hands-on making to gain a rich understanding of the topics at hand [7]. The proposed tactility trialing approach embraces the approach of research-through-design and suggests an implementation specified to exploring materials to inform tactile experience design. In the field of tangible interaction, a number of related studies explore people’s tactile experiences. Some studies apply methods suitable to *inspire design*. The material probe [8], for example, can be used to elicit participants’ stories about and experiences of materials, in order to inspire tangible interaction design. Landau et al. [9] explored tactile experiences of various materials to inform interior designs of vehicles, by having people create mood boards using pre-selected materials. Kaye and Brown [10] explored people’s tactile experiences of abstract vibrating objects with various material covers to gain insight in design opportunities to enhance haptic feedback.

Other studies use methods to *evaluate designs* leveraging the tactile modality. The sensual evaluation instrument [11] for example, uses various abstract objects to enable self-report of emotions through the tactile modality. Obrist et al. [12] studied verbalizations of tactile experiences of vibrating objects using specific interview techniques. Choi and Jun [13] studied the tactile experience of surface roughness by collecting and clustering pairs of antonymous adjectives. Inspired by this approach, Kierkels and van den Hoven [14] explored tactile experiences of physical artifacts of varying hardness, by having children manipulate these artifacts without seeing them.

We contribute to this body of work by proposing an approach that is not tailored toward a specific phase of

the design process, but which can be applied throughout the process to iteratively explore material qualities to inform tactile experience design.

## 3 Overview of the Tactility Trialing Approach

Tactility trialing was developed as a collaborative effort between a tangible interaction researcher and a materials and design expert (two of the authors), and used in an under-graduate course for interaction design students. This course has been taught 7 times at the Eindhoven University of Technology in the Netherlands, with approximately 14 to 24 students participating during each edition.

Tactility trialing aims to support designers and design-researchers in exploring appropriate materials for their (interactive) tangible artifacts, and consists of the five phases illustrated in Fig. 1. In the tactility trialing approach, the intended experience is summarized in an experience word such as ‘persuasive’ or ‘engaging’ (phase 1: *experience formulation*), and various materials are collected that may evoke this experience (phase 2: *material selection*). Promising (combinations of) materials are shaped into comparable artifacts (phase 3: *artifact creation*), which are experienced by participants (phase 4: *user study*). These findings are then translated into a (interactive) product or system design (phase 5: *design translation*). The tactility trialing approach is iterative; it may start from any phase and can be repeated multiple times to optimize the outcomes. Hence our description should not be seen as a step-by-step plan, but as flexible guidance for tactile experience explorations throughout the design process. In the following sections we illustrate each phase through two case studies from our under-graduate course, each executed by a pair of students. Note that these cases are included to exemplify possible ways to execute tactility trialing, rather than to present specific materials that are most appropriate for particular user experiences. After presenting the two case studies, we discuss generalized lessons learned for each phase.

### 4 Phase 1 ‘Experience Formulation’

The phase ‘experience formulation’ aims to specify the intended experience. This is done by selecting a key experience word, such as provocative, engaging, comfortable or intriguing. This word is detailed

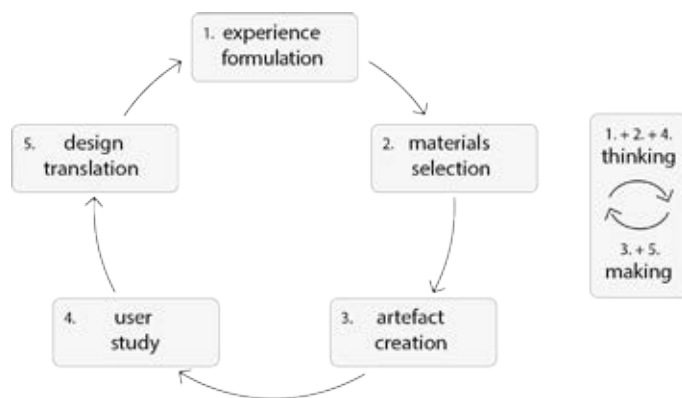


Fig1. Visualization of the Tactility Trialing approach.

through an elaborate description of the intended experience, usually involving a number of adjectives and antonyms, to provide a clear grasp on what the intended experience means to the designer or researcher.

**Case ‘Gentle Pockets’.** The first case is entitled ‘gentle pockets’ and started from the experience word ‘gentle’. This was further detailed by formulating its antonym as ‘harsh’, and by listing words the students associated with gentle, including soft, warm, squishy and smooth, and their antonyms (stingy, cold, rough and bumpy).

**Case ‘Bothersome Phone Covers’.** The students conducting the second case, entitled ‘bothersome phone covers’, started off with the experience word ‘bothersome’ and, after discussion, specified ‘soothing’ as its antonym.

**Lessons Learned.** While formulating the intended experience seems a short part of the overall process, we experienced it to be an important aspect of tactile experience design because it includes taking decisions on focus and prioritizing. Making the intended experience concrete by elaborately discussing it in the design team (students in our case) turned out useful in later stages when evaluating to which extent selected materials or artifacts could evoke the intended experience. In our experience, the discussions about the experience formulation helped to broaden the vocabulary of the designers (students) in the expression of an experience.

## 5 Phase 2 ‘Material Selection’

After specifying the intended experience, materials are collected that might evoke this experience (see Fig. 2). These materials can be sought anywhere: the first selection is intended to be as broad as possible, to widely explore material qualities. The collected materials, preferably cut into samples with a comparable shape, are discussed in groups to come to a selection of materials that likely evoke the intended experience.

**Case ‘Gentle Pockets’.** Starting from the word ‘gentle’, a large range of materials was selected, including metal, foam, felt and moss (see Fig. 2b and Fig. 2c). Through discussions, the students realized they had collected materials with both refined and coarse textures. To select materials, they placed the collected materials on a matrix, with ‘gentle’ versus ‘harsh’ on one axis and ‘refined’ versus ‘coarse’ on the other axis, see Fig. 2c. The discussion the students had while creating this matrix helped them in deciding they would continue exploring eight materials with varying textures, which they hypothesized as feeling gentle or harsh: steel wool, flat tin foil, feather-fabric, wood veneer, stingy fabric, wrinkled tin foil, tufted carpet and velvet fabric.

**Case ‘Bothersome Phone Covers’.** In the ‘bothersome phone covers’ case, the students sought materials that could feel ‘bothersome’, but also those which felt ‘soothing’ and might thus have the opposite effect, see Fig. 2a. When touching and manipulating the materials, rough textures and hard materials seemed more bothersome, while smooth textures and soft and flexible materials provided a more soothing experience. The students therefore decided to further explore smooth and textured versions of both hard and soft materials, namely wood, polypropylene plastic, foam and fabric.

**Lessons Learned.** While there may be various ways to approach material selection, we experienced that discussions on generalized material properties (e.g. refined versus coarse texture, soft versus hard surface) were often fruitful. This made student design teams aware of the relevant variables in material selection, of the materials aspects that may result in the desired experience and it provided handles to select new (combinations of) materials that may be even more successful than the initial selection. Furthermore, exploring the materials gave insight in the effects of the



Fig. 2. The material selection phase. (a) raw materials collected in the 'bothersome phone covers' case; (b) students discussing collected materials in the 'gentle pockets' case; (c) a matrix created to feed the discussion in the 'gentle pockets' case; and (d) an example of material qualities labeled and described in a third case study, not detailed in this paper.

way materials are handled on the tactile experience. For example touching a material with one finger results in a different experience compared to holding it with the entire hand.

## 6 Phase 3 'Artifact Creation'

Whereas material selection is usually done intuitively, through association and discussion, the next phase of 'artifact creation' aims to result in artifacts with various material qualities, which can be experienced and compared by users. To enable a fair comparison, the materials or material combinations need to be shaped as similar as possible and differ mainly in material qualities. In other words, a set of physical artifacts with similar shapes but varying (combinations of) materials or material surfaces needs to be created. To gain insights relevant to the tangible product or interface that is to be designed, these artifacts should be shaped such that they afford manipulation similar to the way users would manipulate the intended design. For example, if the intention is to design a steering wheel, one may explore the tactile experience when firmly grabbing a cylinder shaped artifact crafted out of or covered with various materials. However, when designing wearables, artifacts may be created that can be worn (e.g. around the wrist), of which the surfaces that touch the skin vary in material qualities.

**Case 'Gentle Pockets'.** When discussing the materials in the 'gentle pockets' case (see Fig. 2c), the students realized that when assessing how gentle a material was experienced, they were invited to stroke the materials with a flat hand rather than to squeeze

or grasp them. They therefore created a beam with a rounded edge inside a box (see Fig. 4b), on which they mounted the selected materials (see Fig. 3a). This would encourage user study participants to stroke the materials with the whole hand.

**Case 'Bothersome Phone Covers'.** In the 'bothersome phone covers' case, the students decided to compare rough and smooth textures of soft and hard materials. They created four pairs of two artifacts, each pair constructed of one of the four selected materials and each pair consisting of one artifact with a rough texture and one with a smooth texture (see Fig. 3b). Since the students reasoned that the textures were best experienced when touching the materials with the fingertips, the artifacts were shaped as flat squares that could be laid on a table. After conducting a user study with these artifacts (described in section 7), the students realized that their selection of materials had been too broad. They therefore decided to run a second iteration in which they explored seven different textures of a single material: hard plastic, see Fig. 3c.

**Lessons Learned.** As seen in Fig. 3., created artifacts sometimes clearly resemble a certain product category (e.g. shoesoles), while in other cases the artifacts are more abstract (as in both cases detailed above). This stems from the fact that some design-processes start with a rather concrete application in mind, while others have a more exploratory nature and cover a wider range of possible experiences. From our experience, in the first type of processes the artifact creation phase serves an important role in determining the details of



Fig. 3. The artifact creation phase. (a) 8 artifacts in the 'gentle pockets' case that can be stroked; (b) 8 artifacts created in the first and (c) 7 in the second iteration of the 'bothersome phone covers' case; and examples from other cases of (d) shoe soles, and of (e) materials that can be pressed, not detailed in this paper.

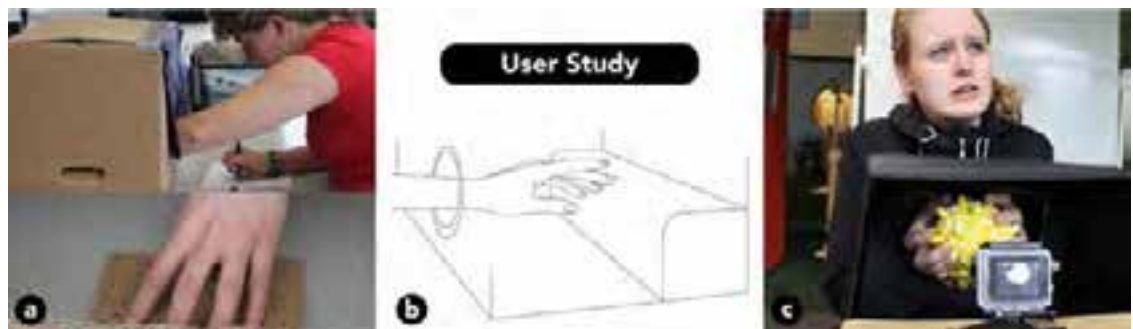


Fig. 4. The user study phase. (a) A participant touching and rating an artifact in the 'bothersome phone covers' case; (b) curved surface in a black-box to encourage stroking in the 'gentle pockets' case; and (c) a video-observation user study, not detailed in this paper.

the design. In the latter, more exploratory processes, this phase serves as inspiration for the direction of the final design, similar to the way material explorations conducted in related work inspired design (e.g. [6,10,13]). Tactility trialing may thus be applied for a range from concrete to exploratory design goals and in various phases of the design process.

## 7 Phase 4 'User Study'

To gain insight in the tactile experiences evoked by the material qualities of the created artifacts, they are to be explored in a user study. As detailed in related work (e.g. [9–12, 14]), various methods can be suitable for evaluating tactile experiences. To ensure minimal influence of factors other than tactile qualities, one approach [14] is to have participants manipulate the artifacts without seeing them (e.g. in a 'black-box', see Fig. 4). However, since experiences of tangible artifacts in everyday life are not limited to the tactile

modality, one may argue that this approach is not always appropriate. The most suitable user study approach thus depends on the aims of the study and the stage of the design-research process in which tactility trialing is applied.

In our course, the aim is to design an artifact that evokes the intended experience (defined in the experience formulation phase). Inspired by [14] we asked our students use a 'black-box' in their user studies to rule out influences of pre-conceptions about their experience resulting from visual appearance. To ensure user studies that were manageable in the short time available, while still leading to relevant insights, students were advised to use Likert scale ratings (also applied in [10, 13, 14]) of adjective and antonym pairs to evaluate the experiences evoked by the created artifacts. These adjective and antonym pairs were either formulated beforehand by the students (based on [14]), or generated by user study participants while



Fig. 5. The average results of 10 participants' ratings on 5 adjectives (pleasant, warm, refined, soft and friendly) of each of the 8 artifacts created in the 'gentle pockets' case. Materials: steel wool (1), flat tin foil (2), feather-fabric (3), wood veneer (4), stingy fabric (5), wrinkled tin foil (6), tufted carpet (7) and velvet fabric (8).



Fig. 6. The average results of 16 participants' ratings on 10 synonyms of 'bothersome' of each artifact created in the first iteration of the 'bothersome phone covers' case. Materials: wood (1 and 2), foam (3 and 4), fabric (5 and 6) and polypropylene plastic (7 and 8).



Fig. 7. The average results of 6 participants' ordering from most bothersome to most soothing, of 7 artifacts created in the 'bothersome phone covers' case 2nd iteration. Materials: polypropylene plastic finished in different textures.

touching the artifacts (based on [10]). While the latter approach may result in a more authentic formulation of participants' experiences, the first alternative involves fewer steps and is thus quicker to execute. Both approaches can easily be extended by adding elements such as interviews, (video) observation or 'thinking aloud'. In both presented case studies, all participants were fellow students who did not participate in the same course.

**Case 'Gentle Pockets'.** The students conducting the 'gentle pockets' case had selected eight materials that

may evoke a gentle or harsh experience, see Fig. 3a. The tactile experience of these materials was explored in a user study, in which ten participants stroked each material individually in a black box (see Fig. 4b). First, each participant touched each material separately, while thinking aloud and naming any word that came to mind (inspired by [10]). After all participants did this, the mentioned words were clustered into five categories of adjectives relating to gentle (pleasant, warm, refined, soft and friendly) and their antonyms related to harsh (unpleasant, cold, coarse, hard and unfriendly). Subsequently, the same participants again

touched each material in the black box and ranked them on each of the five adjectives mentioned above, on a scale of 1 to 7 (e.g. 1 meaning extremely pleasant and 7 meaning extremely unpleasant). The average results of this ranking exercise (all 5 adjectives combined) are found in Fig. 5. As shown in Fig. 5, materials 3 and 7 were, on average, rated most gentle. When touching these materials, participants thinking aloud mentioned “lovable”, “I want to lay down on this” and “makes me think of pastel colors”. Materials 1 and 5 were rated as most harsh, and received comments such as “annoying”, “makes me pull away” and “thorny”.

**Case ‘Bothersome Phone Covers’.** The students conducting the ‘bothersome phone covers’ case were interested in exploring the tactile experience of four selected materials, each with a smooth and a rough texture (see Fig. 3b). A user study was conducted in which sixteen participants touched and stroked the artifacts, which laid down in a black box, see Fig. 4a. The participants rated each artifact on the following ten adjectives (and their antonyms) which the students associated with bothersome: rough, irritating, painful, sharp, synthetic, unknown, annoying, awkward, dirty and strange. A 1 to 5 scale was used in which 1 for example meant very rough and 5 meant very smooth. Fig. 6 shows the average results of this rating exercise. As evident from Fig. 6, all textured materials were experienced as more bothersome compared to the smooth materials. It thus seems that texture has more influence on how bothersome an artifact is experienced compared to the materials it is made of. Textured material 8 (hard plastic) was experienced as most bothersome. While this finding is interesting, the students conducting this case expected that exploring various types of textures might provide more detailed insights in possibilities to evoke bothersome tactile experiences. Therefore they conducted a short second user study with 7 artifacts made of hard plastic, each with a different texture (see Fig. 3c). Six participants were handed the 7 artifacts (no black-box was used), and were asked to order them from most bothersome to most soothing. The average results of this ordering exercise are shown in Fig. 7. This graph reveals that materials 7 (triangles of hard plastic glued together) and 3 (hard plastic with sharp ridges created through sawing) were experienced as most bothersome.

**Lessons Learned.** In our course, students carry out short user studies using a ‘black-box’, and apply one of two variations [10, 14] of Likert scale evaluations. In our experience, this approach quickly leads to relevant insights and is easy to repeat when realizing a mistake or misassumption has been made (e.g. in the ‘bothersome phone covers’ case where a second user study with different artifacts was run). Using a black-box ensures that participants reflect on their actual tactile *experience*, without being influenced by the artifact’s visual appearance (as also elaborated in [14]). This teaches students that evaluations could focus on one single element of a design. However, depending on the phase of the design process and the sophistication of the artifacts created, other types of user evaluation methods may also be suitable, such as those detailed in related work [9, 11, 12].

## 8 Phase 5 ‘Design Translation’

Having explored the created artifacts with users, the gained insights can now be translated to the design of physical products or interfaces. Depending on the phase of the design process in which tactility trialing is applied, the exact product to be designed may be known, or only the targeted tactile experience may be determined. In the latter situation, the design translation phase includes idea generation of applications that may benefit from the developed tactile experience, and the conducting of the entire tactility trialing serves as inspiration for this. We can imagine this to be suitable for designs that ask for an enriched experience, or in cases where an interaction experience is defined while the (interactive) product is in its concept-phase. The design translation phase in our under-graduate course was rather limited and had to be conducted in a short period of time. The resulting designs are therefore often conceptual and not fully thought-out yet; in some cases they are abstract objects, to be pictured as a future interaction design. We discuss the designs resulting from the two cases here, in order to share the translation between user study and design.

**Case ‘Gentle Pockets’.** The students conducting the ‘gentle pockets’ case concluded from their user study, in which participants among other things indicated that “they wanted to lay down on the material”, that a gentle experience is an intimate, private experience. With this observation in mind, the students decided to design





Fig. 8. The design translation phase. (a) Two 'bothersome phone covers'; (b) trouser pockets that evoke a private gentle experience in the 'gentle pockets' case; and (c) an interactive 'persuasive' armrest designed in a fourth case, not detailed in this paper.

trouser backpockets with the more gently experienced materials inside, see Fig. 8b. This way, people can have a private, gentle experience by stroking the material.

**Case 'Bothersome Phone Covers'.** The students conducting the 'bothersome phone covers' case concluded from two iterations of user study, that triangles of hard plastic glued together and hard plastic with sharp ridges were experienced as bothersome by participants. When translating this finding into a design, the students thought about an application domain in which they would like to discourage people to use their devices. They choose to design two smartphone covers (see Fig. 8a) that feel bother-some, such that people would be less eager to pick up their phone in social settings. Their first design used triangles of plastic leading to a rather bulky cover, which makes more of an object for debate, rather than a usable product. The second design, which uses the ridges texture, makes a more practical cover.

**Lessons Learned.** When carrying out the phases of tactility trialing, design-researchers (students in our case) often come to realize that there is no single best material (-combination) to serve the intended experience. As a result, the translation between user study results and design is not always straightforward and may involve further exploration of materials or combining materials that were tested separately. The design translation phase thus requires design-researchers to interpret the insights gained throughout the process, giving them handles to inspire design.

## 9 Discussion

This paper proposes 'tactility trialing', an iterative approach for exploring material qualities and translating these to the design of (interactive) tangible artifacts. The approach is developed as part of an undergraduate course aimed at making interaction design students familiar with conducting short user studies to gain insights in the experiences triggered by their designs. Matching this educational aim, the presented case studies illustrate a rather specific way to apply this approach. However, having run this course seven times with around 10 pairs of students in each edition, we have realized that the approach is more generally applicable and can be seen as an umbrella-approach with many variation possibilities.

Most importantly, we realized that the approach is applicable in various stages of the design process; it may serve as early inspiration, can help explore alternative material qualities after the concept phase or can be used to more systematically explore suitable materials in a later stage of development. When used in different phases of the design process, different user study approaches may be applied. For example, in a later stage, a user study in which participants would use the design for a few days might provide insights in the everyday experience of using the design. Appropriate evaluation techniques in such a case may be contextual observations, interviews techniques (e.g. [12]), logging of usage or experience sampling [15].

The process of carrying out tactility trialing often leads to the insight that there is no single best material to evoke the intended experience. Additionally, the process regularly leads to a clearer image of what

exactly the intended experience is. For example, in the ‘gentle pockets’ case, the user study revealed that a gentle experience is often intimate. Tactility trialing is thus not simply a method to help select (combinations of) materials. Rather, it is an approach that helps to gain better insights in the effect of material qualities on the user experience of one’s design, thereby informing choices of shape, material, interaction and intended experience. After translating insights gained through tactility trialing into a design, the design process is likely not finished. In many cases follow-up iterations can optimize the user experience. Such follow-up iterations may make use of tactility trialing as well. For example, the students conducting the ‘bothersome phone covers’ case decided in the design translation phase to develop phone covers that would discourage people to use their phone in social settings. With this new goal in mind, a new experience formulation could be specified (e.g. involving words such as discouraging and confronting) and a new material selection may be conducted (e.g. multiple variations on the sharp triangles and ridges that revealed to be promising after the user study), leading to new artifact creation (e.g. phone covers of various materials). A user study with these artifacts likely leads to new, more specified insights for a (re-)design translation. Tactility trialing may thus offer an iterative approach to tactile experience design.

## 10 Conclusions

This paper presents an iterative approach for hands-on exploration of material qualities and resulting tactile experiences through short user studies with abstract artifacts of various materials and forms. This approach – *tactility trialing* – aims to inform tangible interaction design and supports designers and researchers in making informed decisions about the materials to use in order to evoke intended user experiences.

We presented two case studies from an under-graduate course in which interaction design students used the five phases of tactility trialing (*experience formulation, material selection, artifact creation, user study and design translation*) in the beginning of the design process. The variety of explorations, design-goals and eventual designs resulting from this course made us realize that tactility trialing could valuably be applied in various stages of the design process. By presenting tactility trialing, we contribute to the research area of tangible interaction, an umbrella approach that can be ‘filled in’

with various creative idea generation methods, different artifact creation (or interactive prototyping) approaches and diverse user study techniques.

## Acknowledgements

We thank all participating students, in particular Lizette van Gameren and Rachel Loop who conducted the ‘Gentle Pockets’ case and Carola Brus and Oscar van Beek who conducted the ‘Bothersome Phone Covers’ case. Furthermore we thank all participants of the conducted user studies for their time.

## References

1. Ullmer B., Ishii H.: Emerging frameworks for tangible user interfaces. *IBM Syst. J.* 39, 915–931 (2000)
2. Kesteren I. van, Stappers J.P., Bruijn J.C.M. de: Materials in products selection: tools for including user-interaction in materials selection. *Int. J. Design* 1: 41-55 (2007)
3. Karana E., Hekkert P., Kandachar P.: Material considerations in product design: A survey on crucial material aspects used by product designers. *Mater. Design* 29, 1081–1089 (2008)
4. Forlizzi J., Battarbee K.: Understanding Experience in Interactive Systems. In: *Proceedings of the Conference on Designing Interactive Systems*, pp. 261–268. ACM, New York (2004)
5. Hassenzahl M., Tractinsky N.: User Experience – a Research Agenda. *Behav. Inform. Technol.* 25, 91–97 (2011)
6. Zimmerman J., Forlizzi J., Evenson S.: Research through design as a method for interaction design research in HCI. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 493-502. ACM, New York (2007)
7. Golsteijn C., Hoven E. van den, Frohlich D., Sellen A.: Reflections on craft research for and through Design. In: *Proceedings of the Nordic Conference on Human-Computer Interaction*, pp. 412-430. ACM, New York (2014)
8. Jung H., Stolterman E.: Material Probe: Exploring Materiality of Digital Artifacts. In: *Proceedings of the Conference on Tangible, Embedded, and Embodied Interaction*, pp. 153–156. ACM, New York (2011)
9. Landau M., Koerber M., Loehmann S.: Towards a Multi-sensory Representation of Electromobility Characteristics. In: *Proceedings of the Workshop on “Electric Vehicle Information Systems” at AutomotiveUI* (2013)
10. Kaye J., Brown L.M.: An eggs-ploration of the influence of material properties on haptic experience. Presented in the CHI 2008 alt.CHI track (2008)
11. Isbister K., Höök K., Laaksolahti J., Sharp M.: The sensual evaluation instrument: Developing a transcultural self-report measure of affect. *Int. J. Hum-Comput. St.* 65, 315–328 (2007)

12. Obrist M., Seah S.A., Subramanian S.: Talking About Tactile Experiences. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1659–1668. ACM, New York (2013)
13. Choi K., Jun C.: A systematic approach to the Kansei factors of tactile sense regarding the surface roughness. Applied Ergonomics 38, 53–63 (2007)
14. Kierkels J., Hoven E. van den: Children's haptic experiences of tangible artifacts varying in hardness. Proceedings of the Nordic conference on Human-computer interaction, pp. 221–228. ACM, New York (2008)
15. Larson R., Csikszentmihalyi M.: The Experience Sampling Method. New Directions for Methodology of Social & Behavioral Science 15, 41–56 (1983)

# From Way Finding in the Dark to Interactive CPR Trainer: Designing with Computational Composites

## Abstract

This paper probes into the ongoing situation of designing with under-developed materials, in particular a computational composite. In response to the urge for more integral material-product development, we see that designers are increasingly asked to valorize new technology-push materials in the early stages of their development. In this paper, we argue that this situation imposes new methodological design challenges due to its paradoxical nature, being simultaneously open-ended and highly constrained by the composite's specific characteristics. We study the consequences of the new design situation on the design process across three cases. Our assessment of the processes shows that designers adapt to the situation through incorporating a variety of strategies, in particular 'framing'. The paper ends with a discussion of the fluency and efficiency of the three approaches and suggestions for future research.

## Keywords

Design Process, Materials and Design, Computational Composites, Assessment Tools, Design-driven Innovation, Smart Materials

## 1 Introduction

Designers are increasingly involved in collaborative projects with material scientists to open up innovation opportunities [1], [2] with developing technologies ranging from non-computational composite materials

(e.g. natural fiber composites; recycled waste) to more technology-infused 'computational composites' [3], e.g., DiaBSmart [4], ShapeShift [5]. So-called 'computational composites' (in short CCs) are possible assemblages of smart materials (e.g. Surflex [6]) or other more conventional materials with embedded electronics (e.g., Soft(n) [7]). Being able to convert particular forms of energy reversibly, in particular to/from electrical energy, CCs can be programmed to dynamically change their physical features, such as color, texture, form etc. in response to external stimuli (e.g. touch, temperature, etc.). Although the starting point of proposing a CC as a physical-digital material solution is typically *technology-push*, the hope is that through the collaboration with designers, the development path can be directed towards societally 'meaning-changing' applications (see [8], [9]). In this paper, we investigate the methodological challenges of designing with CCs, as this relatively new design situation is envisioned to be prevalent in the near future [10], [11].

Designing with CCs, collectively, imposes multi-disciplinary challenges (e.g., attuning diverse perceptions [12]), as well as technical and methodological challenges [13]. One eminent challenge reported in the literature is the digital-physical nature of CCs [13-15]. In addition and in relation to the static physicality, CCs also characterize certain temporal behaviors that need to be defined. Designing with CCs is, therefore, not only a

matter of giving them physical form, but also envisioning their temporal characteristics (i.e. interaction design challenges) as situated in the social, cultural and behavioral context of use [16]—within a ‘situational whole’ [17]. Aimed to cope with digital-physical nature of such technologies, many useful methods and strategies have been proposed (e.g. [15], [18-20]).

The *dual citizenship* of computational composites in embodiment and function of the application also divulges an opportunity to design inbetween the vanishing (both conceptual and physical) boundaries of materials and interfaces. Over the past decade, many design researchers have invested a great deal of effort in exploring expression possibilities and affordances of programmable materials (i.e. *horizontal* material exploration, for a review see [21]). Nevertheless, as highlighted by [21], not many material-related studies in the field of interaction design research are concerned with ‘the matter of purpose’. The main motivation of current work is to understand how designers design with underdeveloped CCs, departing from material properties and arriving at applications.

Grounding on the fundamental reasoning patterns behind design [22], a description of the situation of designing with CCs is presented in Section 2. Looking through this lens, we identify a key strategy that designers are expected to rely on: framing. Correspondingly, we propose the main ingredients of a frame and develop a mapping tool to analyze and reflect on design activities and decisions in relation to frames. In Section 3, we present three design cases with a developing composite of piezo polymer and OLED, namely the Light.Touch.Matter (LTM) [23]. Using the mapping tool, in Section 4, we analyze and reflect on designer’s frames and their role in transforming the given properties of the LTM materials to applications. In Section 5, we discuss the opportunities for more effective and efficient and sketch future research directions.

## 2 Designing with Computational Composites

### 2.1 A Logical Framework

Drawing on [22] and [24], we see design activities as organized to close the logical equation of ‘what’ plus

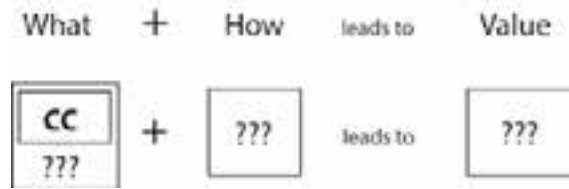


Fig. 1. The logical equation of design situations with a CC

‘how’ leads to ‘value’. According to [22], majority of design challenges fall into two main patterns of ‘close’ problem solving or ‘Abduction-1’, and ‘open’ problem solving or ‘Abduction-2’. In the first situation, the value (the ‘why’) and the ‘how’ (i.e., working principle; the abstract logic of how components need to be arranged) that will help achieve the value are known. The designer’s task is to create the physical embodiment and interaction within a set scenario of value creation (e.g., to make the process of brewing coffee more efficient).

Acknowledging the fact that products can have societal impact [9], designers and design researchers have been increasingly involved in open problem solving projects (e.g., to influence the behavior of people [25], or to improve subjective well-being [26]). In Abduction-2, the ultimate value is known and designer’s challenge is to figure out ‘what’ to create, while there is no known ‘how’ that he or she can trust to lead to the desirable impact. There are many ways to respond to the challenge presented by Abduction-2, ranging from ‘almost randomly generate proposals for the “how” and the “what”’ to a ‘more deliberate (and efficient) strategies to find a “thing” and its “working principle” that are linked to the attainment of a specific value [22, p. 525].

Applying the same logical framework, we can say that in the situation of designing with a CC, the only known is a fraction of ‘what’ (Fig. 1). In terms of openness, this situation is comparable to Abduction-2; however, the starting point which is also the only design constraint is more concrete. In such open design brief, designers have freedom to designate any aspired value as long as the proposed design exploits the unique characteristics of a CC. We expect, similar to Abduction-2, the most logical way to approach this situation is to adopt or develop up a frame from the only ‘known’ in the equation [22], the CC. This initial framing activity can be a result of reasoning back and forward between CC properties and multiple aspired values. ‘Once

a promising or at least possibly interesting frame is proposed, the designer can move to Abduction-1' [22, p. 525], designing an application that will allow the equation to be completed.

## 2.2 A Mapping Tool

Although myriad possible combinations of properties and use contexts imply a limitless design space, a designing trajectory with a CC is rather influenced by designer's framing of what it can afford (to offer) [28]. In order to scan design possibilities with a CC and track designer's activities in terms of closing the equation, we adopted Fokkinga et al's model of product impact [30]. The three levels in the model capture descriptive properties at Property level, non-affective events (e.g., seeing, touching and physically interacting) and product experience (e.g., product aesthetic) at Product interaction level, and impacts beyond the product (e.g., changing behavior, unfolding unforeseen practice) at Overall effect level. The model is suitable for our aim due to: (1) its comprehensive coverage from properties to products as experienced and the effects beyond them; (2) the differentiation between the non-affective events and product experience at Product interaction Level, which allows for subtle differences between CC affordances (e.g., portability) and experiential qualities (e.g., user's interpretation of portability in a situational whole as active and playful).

As shown in Fig. 2, our adopted tool inheres the four gradient level of the Fokkinga et al's model [30], to sufficiently map designer's conduct in bridging between the CC properties and design possibilities. In order to design with a CC, designer's understanding of its 'affordances' [31] is perquisite. Designers may perceive

a CC directly in terms of its potentials for action, 'without significant intermediate stages involving memory or inferences' [32]. For instance, they may perceive a CC in terms of its 'role-ability,' a measurable property of the relationship between people and a CC in application. Exploring and combining CC sensorial and physical properties (e.g., texture, input/output), in connection to what people can do with them, will extend designers' understanding of CC affordances.

Designers may see properties and affordances in the light of experiential qualities that a CC (or its certain properties or affordances) could elicit in interaction [33], such as personality characteristics and emotions. Exploring properties in relation to affordances as well as experiential qualities sets out a playground to forge design possibilities at Product-interaction level. Such explorations may as well reveal (product) purpose possibilities in relation to specific domains (e.g., improving health) reaching the Overall effect level. However, designers do not always go to Overall effect level through CC affordances and experiential qualities. To close the equation, they may approach top-down from preferences of specific place, time, and domain and generates proposals for both the 'what' and the 'how' and find a matching pair that does lead to the aspired value [22]. Either ways, at some stage in the design process, designers need to perform at Overall effect level to decide on the context and purpose of use (i.e., where, when, and why). Making references to context-related factors (e.g., cultural and social norms and dynamics; [34]) and purposes beyond experiencing the CC in application is registered at Overall effect level.

Corresponding to the emerged possibilities, designers may adopt certain concepts (frames) to seize on a situational whole, where a certain composition of CC properties, affordances, and experiential qualities can contribute to the attainment of a specific value. As discussed in subsection 1.1, an aspired value in an open design brief with a CC can be anything from improving utility of an existing product to unfolding unforeseen practices, or changing the purpose for which a product is used (i.e., meaning-changing; [9]). To depict possible instances of a frame (Fig. 2), we include a summit, where the intended aspired value (i.e., utility, experience, and impact) is designated, and two anchors (shown with dashed lines in Fig. 2) reaching to CC properties.

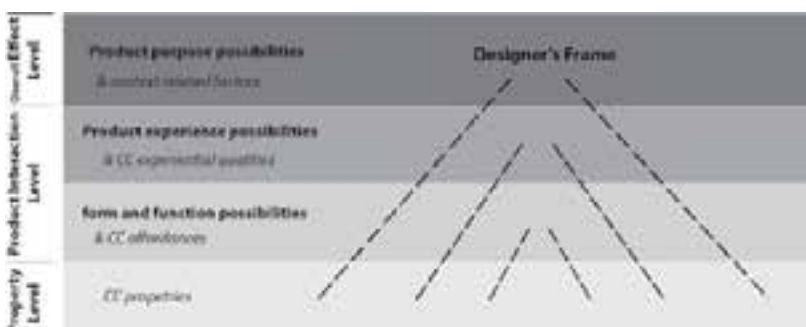


Fig. 2. The adopted mapping tool developed to analyze the design process

In the following sections, we look into three design processes with a case CC, the LTM materials, and inquire into the design activities and decisions in terms of opening up design possibilities and closing the equation.

### 3 Design Case: Light.Touch.Matters

The Light.Touch.Matters [23] (LTM materials) are underdeveloped CCs comprised of two main components of flexible OLED and Piezo polymer. The LTM materials feature some (known) unique characteristics due to their thin and flexible structure (properties) and their pressure and position sensitivity and surface lighting (functional principle). By giving an open design task: “to envision a meaningful application for the LTM material”, we bring about a design situation, where given properties of a CC is the only ‘known’ in the equation, and both the value and the ‘how’ should be determined.

#### 3.1 Method

In a semester course, three groups of M.Sc. design students, each comprised of 6 members, were given the brief. The course focuses on iterative prototyping and provides means and support with making and programming. In this way, we intended to reduce possible effects of the technical challenges students may face when designing with a CC. The LTM materials were introduced to the students through a presentation, which included a schematic picture of the composition and pictures/videos of its components. The known physical properties of the components (e.g. thin, flexible, surface illumination, pressure and position

sensitivity), and hard limitations (e.g. flexibility range and light color) were specified. Along the process students were assisted in technical aspects (e.g. programming) of making. They were also appointed to consult an informed material expert, who was also involved in evaluating the proposed concepts in terms of exploiting the LTM unique characteristics. Two intermediate prototype presentations and one final presentation at the end of the course were scheduled.

During the process, we closely monitored their design activities and decisions using multiple sources, namely students’ self reports of their activities on a daily basis uploaded on a weblog, weekly update meetings with the first author, and the three presentations. In the result section, we briefly introduce the final designs. Then, the activities and design decisions of each group are analyzed using the mapping tool.

#### 3.2 Results

Students’ efforts in finding meaningful application for the LTM materials resulted in three final prototypes (Fig. 3). The first one is Yi, an interactive flexible surface that aims to guide users in doing Yoga. The second application is Meddi, a cardiopulmonary resuscitation (CPR) trainer to make learning CPR easier for first aid trainees. The third application is Joe, an interactive punching box to make boxing fun for beginner players. As to exploiting the uniqueness of the LTM material and complying with the hard limitations, the two concepts of Meddi and Yi were evaluated more appropriate than Joe by our material expert. Nevertheless, in our analysis of the design processes, we included the Joe

Fig. 3. The final applications, from left to right: Yi, Meddi, and Joe



as an unsuccessful case and reflected on what possibly went wrong in their process. To prevent confusion, we refer to the groups according to their final designs (e.g. Yi group).

### 3.3 Analysis of Three Design Processes

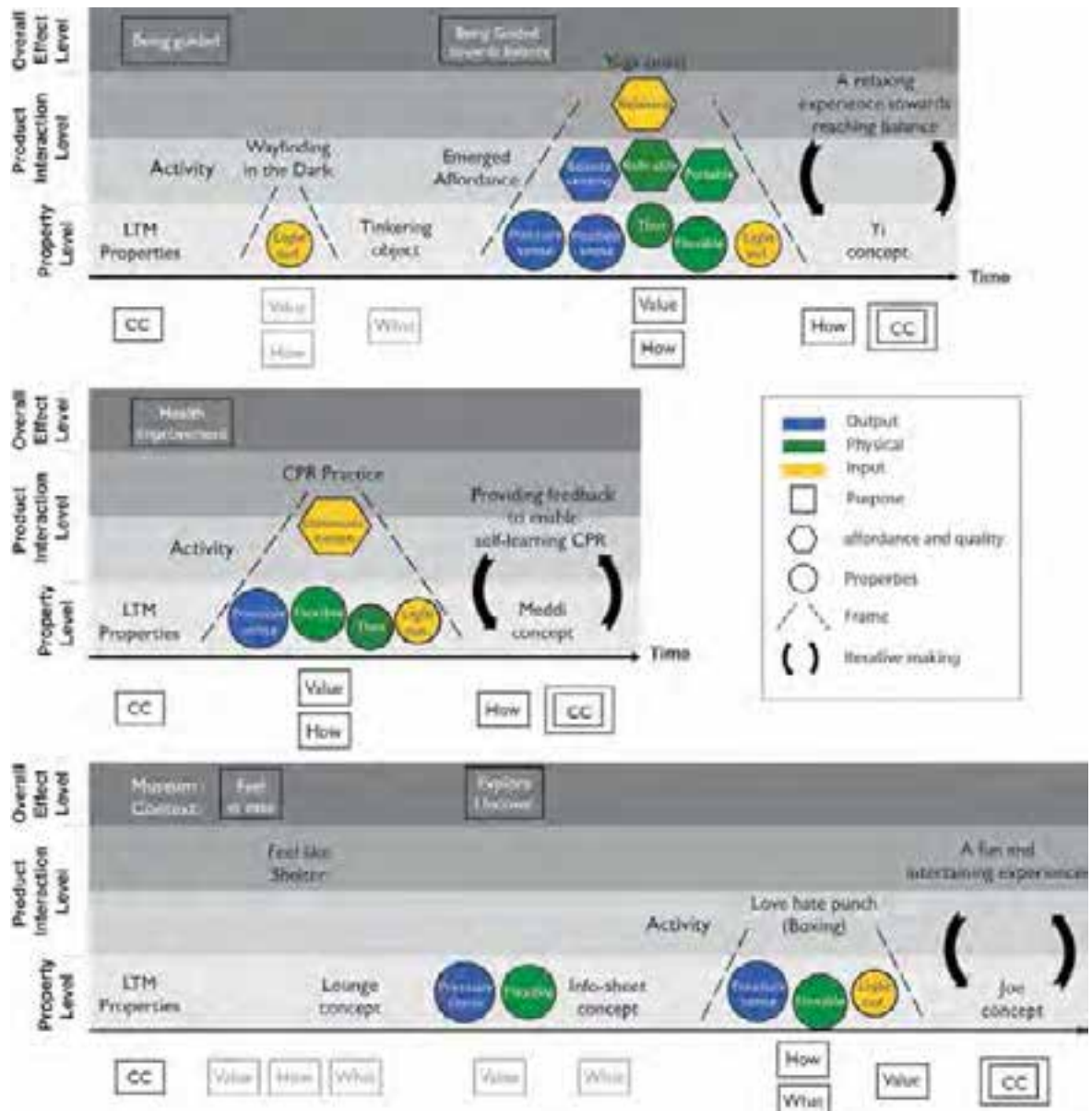
Although all the three processes ended up with applications, designers experienced the uncertainty of designing with the LTM materials differently. In this section, using the mapping tool explained in 2.2, we

illustrate their journeys in opening up design possibilities and closing the equation (through moving back and forth between the levels), identifying the content and evolution of their frames as shown in Fig. 4.

#### 3.3.1 Yi

With a brainstorm session, the Yi group explored application domains and activities in relation to the input/output aspects of the LTM material. Among all the other ideas, they decided that 'way-finding in the dark'

Fig. 4. Mapping the activities and frames in terms of closing the logical equation, from top to bottom (a) Yi (b) Meddi, and (c) Joe group





could be a relevant theme in relation to both touch/pressure and light. This initial frame allowed them to see the properties in relation to an activity where both light and touch aspects (i.e., input/output) of the LTM intersect. The theme signaled them towards making the first tinker prototypes (a network of water bottles that lit up in succession when squeezed and showed the way out). Experimenting with interactive water bottles helped unlocking further possibilities with input/output relation and worked as a vehicle to deeper associations. Having the objective of exploiting the guiding effect of light and the function possibility of giving precise feedback on bodily balance, they developed an interaction vision of 'guiding people towards balance'. Their search for a meaningful application at the intersection of LTM physical properties and the vision brought them to Yoga (mat). The Yoga (mat) frame allows them to bring the experiential qualities (e.g., relaxing and guiding quality of light) and affordances (e.g., role-ability combining bendability and thin-ness and balance-sensing combining pressure and position sensitivity) in a situational whole. After this point, the group moved to Abduction-1: designing an interactive Yoga mat that guides users towards reaching balance (the value), which is enabled through measuring body weight distribution and give subtle light feedback (the 'How'). Having the established practice of Yoga and a distinct experience (to feel guided), they elaborated on the temporal characteristics and simulated the LTM material in use.

Fig. 4a highlights the role of activity in relation to functional principle of the LTM materials and guiding effect of light in formation of the initial frame. It also shows that inspired by the initial frame and enabled by a tinker object, new affordances were emerged. This opened up function and form possibilities and purpose possibility that later were retained by the Yoga (mat) frame. Students' activities from then on were focused on iterative making of a simulated prototype and recreating the desired qualities.

### 3.3.2 Meddi

The Meddi group stepped into the design process with a brainstorm session using various design magazines and books to inspire possible application areas. Very soon, they picked an interest in improving health care, with respect to the communication function of light.

The group came to a consensus about CPR practice, which was mentioned by one of the students due to his personal experience. They all agreed that CPR practice could exploit pressure sensitivity of the LTM materials to the fullest as it needs accurate amount and speed of pressure. Gripping to this frame, students further moved to Abduction-1 where both the aspired value: an easier and more independent CPR experience, and the 'How': addressing the usability issues in performing a successful CPR were known. Their concept of CPR training tool closed the logical equation early in the process. Two third of the remaining time is, therefore, allocated to understanding the practice and making the interactions easily understandable through iterative refinements of the input/output relation and user tests. The final prototype despite slightly different embodiment relied on the same working principle to achieve the same aspired value.

Fig. 4b maps that students moved from the overall effect of improving health to an activity that was closely linked to functional principle of the LTM materials. The CPR practice frame gathered the communication function of light and the unique characteristics, such as thinness, flexibility and pressure sensitivity in one situational whole. After this point, the Meddi group mainly focused on technical and usability issues of a CPR trainer and addressed those issues in an iterative making and testing process.

### 3.3.3 Joe

Starting with a brainstorming, the Joe group decided that the material could be used as a landmark in places like libraries or museums, where light feedback is more appropriate than sound. Accordingly, they developed a vision of 'Giving visitors of a museum a moment to feel at ease...'. They immediately translated their vision into an interaction quality of 'feeling like a shelter' and started sketching and making physical manifestations of a lounge concept. Presenting their concept and desired interactions to the material expert, the group was convinced that using the LTM materials for the aim of merely illumination does not exploit its uniqueness in registering precise position/pressure-input. In the second iteration, they embarked on an idea inspired from the LTM physical properties flexibility and pressure sensitivity: an information sheet to explore and discover in a museum. They abandoned this concept after

interviewing some visitors in a museum. In the third iteration, they explored application opportunities where the LTM input/output could add extra functionality to an existing product. Eventually, they chose for a punching bag, and, inspired by Stefan Gross and Stella Boess's 'Love hate punch', they elaborated on the temporal characteristics to attain the aspired value of a fun and entertaining boxing experience.

Fig. 4c illustrates that the Joe group approached the challenge less rational and more experimental relative to the other groups. Their choice of museum context early in the process substantially narrowed down the application potential without enough related-ness to the LTM unique characteristics and hindered further searches for better-fit frames. Getting rid of the context constraint and focusing on the LTM functional principle, they adopted an existing concept within an established activity (boxing).

#### 4 Discussion

Analyzing the design processes in terms of the completion of the logical equation and designer's frame provides a useful lens to evaluate students' approaches in the situation of designing with the LTM materials. According to the analysis, the most effective approach is recognized as framing the LTM physical and functional properties (e.g. touch and pressure sensitivity) in connection to an action or activity (e.g. way finding, boxing). However, we cannot say for sure that the origin of such frames is the activity itself or similarity between the form of an object within an activity (e.g. plain surface of a Yoga Mat) and the sheet-processed material. Either way, we speculate that the students were mainly involved in analogical reasoning [35] and reusing episodic data [36] (e.g. personal CPR experience) to interpret design potential of the LTM material in connection to external sources (e.g., things, activities). The most efficient frames were built upon purposeful activities (i.e., Yoga and CPR), in which the physical and functional affordances of the LTM material could make sense. Such frames mobilize the process towards directions where people can benefit from the material/technology properties. However, such frames run a risk that the final applications are merely a 'digital augmentation of socially and culturally established practices' [33; pp. 7].

According to our analysis, we are convinced that process-wise the Yi group took a more gradual and fluent course in terms of closing the equation. They succeeded to postpone fixation of open variables till later in the process and keep the situation broad in the beginning. This provided the opportunity to explore combined physical and functional affordances (e.g. balance sensing) and better understanding of the LTM's experiential qualities within a situational whole. Tapping on deep interpretation of meaning and value of the LTM materials in the light of its experiential qualities, they envisaged a promising approach to foster a meaning-changing design [8].

Our analysis of the similarity between the two frames of Yoga and CPR suggests that a good frame offers threefold benefits: 1) to combine materials' individual properties under manageable design directions; 2) to understand their interplay and value within a situational whole, and 3) to supply enough grip so material- and value-conscious design decisions can be made. The latter implies that students' decisions to maintain and design within an established activity (the activity they used to frame the LTM) can be consciously decoupled from the frame. In our three cases, this was not the case and both frame and the activity (designed for) were the same. Two possible explanations can be given: first, students readily realized the aspired value in digital augmentation (interpreted as the purpose of the LTM). And second, that physicality of the LTM highly constrained their ability of thinking beyond existing objects within an activity (e.g. Yoga mat), which compromises a more profound search for something utterly novel. We believe that reflection on 'why' people do the activity the way they do, for example, through more conscious framing (e.g. [34]) can propel the design process towards unforeseen practices and meaning-changing applications. Additionally, to go beyond the obvious aspired value of digital augmentation, form [19] and material properties (e.g. texture [21]) and the values and effects elicited in experiencing them should be closely investigated.

Lastly, it is evident that student's approaches were influenced by the makeup of the course, which encourages a hands-on approach through tinkering and prototyping. Programming and making physical samples are inevitable part of designing with CCs, as

highlighted in [37], [18]. Our study did not focus on how the process may suffer or benefit from elimination of the rigorous prototyping. Nevertheless, to improve the CC's understanding (both technical and experiential), the role and potential of early prototyping need to be further studied.

## 5 Conclusion and future work

This paper looked into the methodological aspects of designing with CCs as digital-physical materials with under-defined physical and temporal properties. We proposed that the situation, similar to other design situations, could be viewed from the angle of solving a logical equation. Starting from a concrete technology, or in our case an underdeveloped CC, designers need to bridge between the properties and an aspired value. We used a mapping tool to explain the design possibilities and the role and content of frame in outlining a collection of possibilities in a situational whole so an aspired value can be attained. Our analysis of three cases in terms of closing the logical equation and frame creation helped us explain students' performances in the situation of designing with a case CC. It also gave us insights on how the design processed might be improved. We discussed that in order for meaning-changing applications and unfolding unforeseen practice with CCs, a more conscious framing is necessary. Future work will be oriented to support designers approaching the situation of designing with CCs systematically, leveraging on a better understanding of the unique characteristics and conscious frame creation.

## 6 Acknowledgments

This research has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 310311.

## 7 References

- Hargadon, A. B.: *How Breakthroughs Happen: The Surprising Truth About How Companies Innovate*. Boston, MA: Harvard University Press (2003)
- Page, S. E.: *The differences: How the power of diversity creates better groups, firms, schools, and societies*. Princeton, NJ: Princeton University Press (2007)
- Vallgård, A., & Redström, J.: Computational composites. In *Proceedings of the SIGCHI conference on Human factors in computing systems CHI '07*. New York: ACM Press (2007)
- European Project DiabSmart, <http://www.diabsmart.eu>
- ShapeShift, <http://www.caad-eap.blogspot.com>
- Coelho, M., Ishii, H., & Maes, P.: Surflex. In *Proceeding of CHI conference on Human factors in computing systems CHI '08*. New York, USA: ACM Press (2008)
- Schiphorst, T.: soft(n): Toward a Somaesthetics of Touch Abstract. In *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems - CHI EA '09* (p. 2427). New York, New York, USA: ACM Press (2009)
- Norman, D. A., & Verganti, R.: Incremental and radical innovation: Design research versus technology and meaning change. *Design Issues*, 30(1), 78-96 (2014)
- Verganti, R.: Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda. *Journal of Product Innovation Management*, 25(5), 436-456 (2008)
- Miodownik, M.A.: Toward designing new sensoaesthetic materials. *Pure Appl. Chem.*, 79(10), 1635-1641(2007)
- Miodownik, M., & Tempelman, E.: Light Touch Matters. The Product is the interface. Retrieved January, 1, 2015 from [www.light-touch-matters-project.eu/press/b079f8dc0dce2500df08ef2e657821e4.pdf](http://www.light-touch-matters-project.eu/press/b079f8dc0dce2500df08ef2e657821e4.pdf)
- Edmondson, A. C., & Nembhard, I. M.: Product Development and Learning in Project Teams: The Challenges Are the Benefits. *Journal of Product Innovation Management*, 26(2), 123-138 (2009)
- Redström, J.: On Technology as Material in Design. *Design Philosophy Paper* (2005)
- Löwgren, J., & Stolterman, E.: *Thoughtful interaction design: A design perspective on information technology*. MIT Press (2004)
- Wiberg, M., & Robles, E.: Computational Compositions : Aesthetics, Materials, and Interaction Design. *International Journal of Design*, 4(2), 65-76 (2010)
- Rosner, D. K., Ikemiya, M., Kim, D., & Koch, K.: Designing with traces. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, 1649 (2013)
- Karana, E.: *Meanings of Materials*. Doctoral dissertation. Technical University of Delft, Delft (2009)
- Vallgård, A., & Sokoler, T.: A Material Strategy: Exploring Material Properties of Computers. *International Journal of Design*, 4(3), 1-14 (2010)
- Jung, H., & Stolterman, E.: Digital Form and Materiality : Propositions for A New Approach to Interaction Design Research, 645-654 (2012)
- Döring, T., Sylvester, A., & Schmidt, A.: Exploring material-centered design concepts for tangible interaction. In *Proceedings of CHI conference on Human Factors in Computing Systems CHI EA '12*. New York, USA: ACM Press (2012)

21. Wiberg, M.: Methodology for materiality: interaction design research through a material lens. *Personal and Ubiquitous Computing*, 18(3), 625–636 (2013)
22. Dorst, K.: The core of “design thinking” and its application. *Design Studies*, 32(6), 521–532 (2011)
23. Light Touch Matters Project, [http:// www.light-touch-matters-project.eu/](http://www.light-touch-matters-project.eu/)
24. Cross, N.: *Design Thinking: Understanding How Designers Think and Work*. London: Bloomsbury Academic (2011)
25. Lockton, D., Harrison, D., & Stanton, N. A.: The Design with Intent Method: a design tool for influencing user behaviour. *Applied Ergonomics*, 41(3), 382–92 (2010)
26. Brey, P., Briggles, A., & Spence, E. (Eds.): *The good life in a technological age*. New York, NY: Routledge (2012)
27. Lindström, M., Gamstedt, K., Barthold, F., Varna, J., & Wickholm, K.: Hierarchical design as a tool in development of wood-based composite applications. *Proceedings of 13th European conference on Composite Materials*, Stockholm, Sweden (2008)
28. Bærentsen, K. B., & Trettvik, J.: An activity theory approach to affordance. In *Proceedings of the second Nordic conference on Human-computer interaction - NordiCHI '02* (p. 51). New York, USA: ACM Press (2002)
29. Kaplan, S., & Tripsas, M.: Thinking About Technology: Applying a Cognitive Lens to Technical Change. *Research Policy*, 37(5), 790–805 (2008)
30. Fokkinga, S., Hekkert, P., Desmet, P., & Özcan, E.: From Product to Effect Towards a human - centered model of product impact, 1–13 (2014)
31. Gaver, W. W.: Technology affordances. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '91)*. New York, USA: ACM press (1991)
32. Gibson, J. J.: *The ecological approach to visual perception*. New York: Houghton Mifflin (1979)
33. Giaccardi, E., & Karana, E.: Foundations of Materials Experience: An Approach for HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems CHI '15*. New York, USA: ACM Press (2015)
34. Hekkert, P., & Van Dijk, M.: *Vision in Design: A Guidebook for Innovators*. Amsterdam: Bis Publishers (2011)
35. Ball, L. J., & Christensen, B. T.: Analogical reasoning and mental simulation in design: two strategies linked to uncertainty resolution. *Design Studies*, 30(2), 169–186 (2009)
36. Visser, W.: Use of episodic knowledge and information in design problem solving. *Design Studies*, 16(2), 171–187 (1995)
37. Bergström, J., Clark, B., Frigo, A., Mazé, R., Redström, J., & Vallgård, A.: Becoming Materials: Material Forms and Forms of Practice. *Digital Creativity*, 1–17 (2010)

# Kinetic Materials Experience

## Abstract

Shape memory alloys and polymers respond to changes in temperature, light or other environmental stimuli by changing their shape. This paper shows new kinetic experiences with objects and surfaces that apply memory shape materials, describing some case histories based on design experimentations that open up new frontiers in design. The present article investigates how the shape memory effect can add useful features to everyday objects, create unusual user experiences, and how this new potential has been tapped by designers so far. The authors present considerations on design methods, describing the convergence of product design, interaction design and experience design in the new scenario of smart materials. They discuss models from literature to understand and describe the emotional aspects of interaction design with shape-changing materials. Such models could be useful reference points for designers of interactive products that offer kinetic experiences.

## Keywords

Smart materials, shape memory materials, kinetic experience, tangible interface, interaction design

## 1 Introduction

At this stage of scientific development, technology and materials proliferate. Traditional materials take on a new life; they perform better than ever.

They become less and less natural and more and more artificial, but more compatible with human life and more environmentally sustainable. Their complexity increases, moving to the direction of alloys, composites, copolymers, and functionally graded materials. At the same time new materials appear in our life, absolutely unusual for a common understanding and experience of materials, typically characterized by properties such as weight, volume and resistance, and soft (i.e. sensorial) qualities such as color, opacity, texture; fixed in time and defined by design. Today, smart materials show us that products will become lighter, tinier, more dynamic, and generating their own energy. The behavior is inscribed in the material as a code in its molecules, crystals, or micro-structure. This new essence of material introduces elements of radical changes in the material design cultures.

In smart materials, an input such as a temperature change, an increase in light intensity, or any other change in environmental variables, triggers a reaction in their molecules or crystal structure, which in turn causes a change in shape, volume, color, transparency, or density [1]. This makes them look like living organisms with their specific character and behavior, ready to interact under the influence of other living organisms or environmental changes. The reaction is visible, and through the filter of a code of communication, can be utilized to transmit messages. Shape memory alloys or polymers react to changes

in temperature or magnetic field, by changing their shape. Under the effect of the stimulus, they move back to a memorized form. They move without the need for mechanical or electromechanical components or mechanisms of movement, hence their intrinsic sustainability, i.e. less material and fewer manufacturing processes for the realization of the products. Materials that change shape and materials that change color [2] have a dynamism that allows them to continually adapt to environmental conditions, so as to be called "chameleonic" for their ability to change color and form almost in a "magical", extraordinary way. The qualities of smart materials include sustainability, compact size, very often bio-compatibility, the ability to react and interact, the ability to communicate in the interaction, to describe something that is approaching, and to make visible what is normally invisible [2]. Ecology, engagement, materiality-driven communication and interaction are some of the new qualities that smart materials offer to the design community. It is up to the designer to ensure that smart materials are used in a manner actually useful in the future we envision.

## 2 Shape memory experience

The shape memory effect was discovered in Au-Cd alloys by Arne Ölander in 1932 [3]. This was followed by the development of various shape memory alloys including NiTi (nitinol), Fe-Mn-Si, Cu-Zn-Al, and Cu-Al-Ni [4]. Among these materials, nitinol proved to be the most reliable and feasible material of its kind, making it the material of choice for most shape memory applications.

The market diffusion of nitinol shape memory alloys took about three decades from their first introduction in 1962 [4] to applications in the medical field in the 1990s [5]. Shape memory alloys were mostly used for their superelastic properties in the medical field, rather than the shape memory effect. The superelastic effect was later employed in consumer products, for example in eyeglasses frames, bra wires, and headphones [6, 7]. Nitinol eyeglass frames were comfortable to wear and their spring-like quality was a competitive advantage. Superelastic bra wires were preferred due to their soft feeling, flexible fit, and aesthetically pleasing body line [6]. The superelastic headband of MiniDisc Walkman headphones allowed it to be folded into a compact egg shape, earning it the nickname "eggo" in the 90s.

The headphones were comfortable to wear and they provided a constant push on the ears.

Although products making use of shape memory materials (SMMs) have been in use for many years as summarized above, the sensory experience has been addressed by designers only recently. The first sensation of someone who is not familiar with SMMs and watches its motion when exposed to heat is typically surprise. As one of the authors demonstrates the effect of a flame on nitinol wire, causing it to "remember" a previously given shape in the Materials for Industrial Design course, students make sounds of surprise and ask many questions about it. Similarly, any product that clearly demonstrates the shape memory effect has the potential to surprise and please the customer, at least during the first few uses. A design strategy of surprise and a "perceptual slip" have been utilized by designers to influence people's appreciation. In products that people can use without any cognitive effort, a surprise may be welcomed by the user. Conversely, in products with a complex functionality that requires full attention from the user, a surprise will probably not be appreciated [8].

Below, some case studies are briefly presented. These show a variety of different user experiences with SMMs that open the possibility for new aesthetic and technical explorations capable of playing a significant role in the development of design-driven product experiences.

### 2.1 Hanabi lamp by Nendo

One of the earlier examples which benefited from the surprising effect is the Hanabi lamp, which spreads up its petals like a flower trying to catch some rays from the sun (Fig.1). The lamp blooms as it gets warmer by the heat of the light bulb. The Japanese word hanabi means firework or literally flower + fire, referring to the fragility of flowers that flicker between beauty and disappearance [9].

This design was presented for the first time in 2006 at Salone del Mobile di Milano, in a setting which proposed a field of hanabi in order to create a surprising aesthetic experience to engage the visitors in a satisfying emotional contemplation. The unfolding of the petals of nitinol with the lighting creates a synesthetic stimulation that leads back to the beauty and harmony of nature, like slow movements of plant organisms, using the design strategy of metaphor.



Fig. 1. Hanabi lamp designed by Oki Sato for Nendo. The lamp made of shape memory Nitinol alloy “blooms” when it is warmed up by the heat of the light bulb. Cour-tesy Nendo.

## 2.2 Fashion design by Hussein Chalayan

Fashion designer Hussein Chalayan’s garments that use shape-shifting fabrics push the limits of moving textiles to the extreme. His spring/summer 2007 collection displayed a combination of different materials and technologies including remote control electronics, motor driven levers, and shape memory fabric. The shape memory fabric contained one nitinol fiber weaved into five nylon fibers [10]. This material technology enabled the design of garments which “open like the flowers that remember how to take several forms” as Chalayan puts it. The shape change in the garment causes the skirts to be lifted slowly, creating an erotic experience for the viewer. Unlike an ordinary dress that moves in concert with a moving body, many of Chalayan’s garments move independently from the body’s movements. A new spatial relationship is built between the garment and the environment [11].

## 2.3 Shape memory jacket by Marielle Leenders

Designer Marielle Leenders developed shape memory textiles through the years 1999-2000. Thin nitinol wire is either woven into the textile or added later as one or more lines of stitching. Various uses were intended during the development of these textiles ranging from sleeves that automatically roll up and down to blinds that descend when warmed up by sunlight and roll back up when room temperature drops. The shape memory jacket is programmed to shrink at a temperature of around 45°C. When temperature is cooled down, the jacket resumes its initial shape. A sense of playful surprise can be observed in the

shape memory jacket with a hint of teasing (Fig. 2). The dynamic and smart attitudes of the jacket propose a simple tool for an expressive human body experience that extends and transmits information from the inside (the human body) to the outside (the cloth), making the changing body heat visible.



Fig. 2. Shape memory jacket designed and realized by Marielle Leenders for the Museum of Science and Industry, Chicago. Heating the jacket with a hair dryer causes it to shrink. Courtesy Marielle Leenders.

## 2.4 Chair by Carl de Smet

Carl de Smet is a Belgian designer and engineer who experiments with different types of SMMs. One of his designs involved a styrene-based thermosetting resin reinforced by E-glass fabric or carbon fiber twill weave. A shape shifting small chair prototype was produced with this material that transformed from a coil shape to the final chair shape at 75°C. However, certain problems such as low recovery rates were reported [12]. His recent efforts focus on polyurethane shape memory foams which have the advantages of low density and



Fig. 3. Series of photographs showing how a compressed slab of shape memory foam recovers its original shape and becomes an armchair upon heating at 70°C. Shape memory polyurethane has the ability to grow up to 20 times and form soft but rigid furniture. Courtesy Carl de Smet.

extreme volume change from one state to another. The objective of his team's efforts is to develop a product which can be compressed into flat, lightweight slabs during purchase. The user will take them home, heat them up, and the armchair will recover its programmed shape (Fig. 3). De Smet is collaborating with researchers at several Belgian universities to upscale the prototype and create a feasible product for the market. The final product will have a flexible heating system; the customer will plug it in and the furniture will pop out. This experience might be comparable to purchasing a box of ready to bake cinnamon rolls, putting them in the oven, and watching them grow while they are baked. Through a project for easy packing and transport, this design proposes an "experience of creation" where a

piece of furniture grows and expands right before the eyes and under the control of users.

## 2.5 Bloom by Doris Kim Sung

Today also architecture is beginning to implement new smart materials, contributing to the success of a new design strategy: kinetic adaptive architecture. This is an innovative strategy for the development of energy conservation through new structures and components that can be dynamic in order to react to environmental conditions, such as temperature shifts, performing as environmentally integrated living organisms that can learn from previous experiences, therefore evolving with embedded intelligence. Responsive skins and kinetic components are able to move without motors or mechanical parts. A design example of kinetic architecture is the project Bloom by Doris Kim Sung, an architect with a biology background, interested in developing and prototyping intelligent panel systems integrating thermo-bimetals<sup>1</sup>. The material curls when heated and blocks the sun's rays. A bimetal shutter system can be calibrated to completely block the passage of sunlight, if needed.

Bloom is a climate-controlled pavilion made out of about 14000 laser cut pieces (Fig. 4). The surface of this floor-to-ceiling installation acts as a sun tracking system that indexes time and temperature. When the temperature rises above 22°C, the metal sheets curl up and when it gets cooler, the sheets flatten out. This smart solution is useful to balance internal heat accumulation, improving the comfort level of the space. It reduces the need for airconditioning and saves energy, without the need for manual controls or additional power. "In houses now we don't need drapes or blinds" says the architect [13].



Fig. 4. Bloom skin detail, an architectural research installation displayed at the Materials and Application Gallery in Los Angeles, 2011. Courtesy Doris Kim Sung.



## 2.6 Hylozoic ground by Philip Beesley

Among the most surprising examples of kinetic architecture there is Hylozoic Ground<sup>2</sup>, an immersive, responsive, interactive environment installation by Philip Beesley and his team. This installation explores the idea of an environment that lives<sup>3</sup>, and reacts to the presence and actions of people who are in it with movement that imitates the interaction of physical bodies moving around, and behaviors like caressing and other empathic motions [14].

Mechatronics, synthetic biology, chemistry, art and design are embedded in this performance of an artificial forest that moves and breathes around its viewers. The movement of the forest is being powered by muscle wire (electro active polymers). This wire is activated by a small amount of electrical power, and through leverages it is able to move. Organic power cells provide weak amounts of current in pulses like unconscious reflexes within a human nervous system. All elements work in concert.

## 3 Discussion on design approaches and new prospects

Various projects shown here make us predict that in the future our objects and architectures will no longer be rigid and stationary, but flexible and adaptable, active and responsive. With the emergence of new smart materials, like SMMs, the evolution of digital technologies and the availability of mass customization methods, technological products can now 'feel', 'hear', 'breathe' and react. However, there are many areas that might be developed before they are really useful to the user and ready for public consumption and standard architectural or product application. That's why the experimentation and the ability to design with smart materials embedded in products are becoming increasingly important for designers. This is becoming especially important since it has been shown that the realization of components and objects made of smart materials is feasible with advanced manufacturing technologies such as 3D printing and computer aided laser cutting.

The designs shown here, demonstrate many interesting elements that allow us to understand how these materials can change form and stimulate users' senses and emotions with surprising, expressive, erotic, comfortable and pleasurable experiences. These issues generate new questions on the necessary

evolution of design methodologies. The main question from the product designer is: how to design with smart materials for better user interaction and experience?

Product design undoubtedly requires dealing with a greater technical complexity and organization seen that the materials have at least two states: an inactive and an active state. Furthermore the phase transition during the passage from one phase to the other needs to be accommodated by the design as well<sup>4</sup>. The design will have to manage various aspects or conformations of the object in its temporal dimensions. The variables involved multiply, considering the variability of the sensorial aspects in time and the time dependent form of the interaction between product and user.

Additionally, the design of material (or tangible) interaction requires a multidisciplinary approach that involves at least both product design and interaction design besides material science knowledge.

*Interaction design* started as a new field of design in the late 80s with the development of screen graphics and computer input devices by engineers. The initial concern of interaction designers was to make computerized devices accurate, easy to use, and pleasurable [15]. However the field of interaction design developed rapidly with the inclusion of computerless interactive products and many other aspects such as user experience, ergonomics, and sustainability. Today, this field of design encompasses the design of all possible types of interactive products [16]. Thus, the original term is gradually replaced by the more specific term human-computer interaction (HCI) design. Interactive products cover all classes of interactive systems, devices, tools, applications, technologies, and services. Since smart materials, surfaces, and systems are inherently interactive, they are naturally the subject of interaction design [17].

In recent years new visions have expanded the boundaries of interaction design, from graphical user interfaces (GUIs) to tangible user interfaces (TUIs) and material user interactions (MUIs) [18]. The new visions assume that bodily engagement and tactile manipulation can facilitate a deeper understanding and more intuitive experiences. Some important capabilities of kinetic interaction have been underutilized such as motion's natural ability to draw our attention and convey information through physical change. According to Hallnäs and Redström, interaction design could be a real link between basic research in computer science and

product applications for new expressive design [19]. Various models exist that are related to the emotional aspects of interaction design. Such models could be useful reference points for designers of interactive products. One such model [20, 21] attempts to explain various channels of pleasure while interacting with products. According to this model, four types of pleasure can be distinguished, namely physio-pleasure, socio-pleasure, psycho-pleasure, and ideo-pleasure. *Physio-pleasure* represents pleasure experienced through the senses, such as taste, smell, and touch. The caressing stroke of a soft fabric on the skin, or by a plume of the Hylozoic Ground is an example to tactile physio-pleasure. Such an emotion could actually be created on purpose by a shape-memory jacket or dress as depicted in Fig.2, although that was not the intention of the designer in this particular case. The tactile pleasure of kinetic surfaces or products that exploit SMMs is just one of the many possible fronts worth exploring by designers.

*Socio-pleasure* is defined as the type of pleasure that arises when we are socially interacting with friends, colleagues, and people we love. Interactive products can enhance social interaction or they can generate new channels of communication. Nowadays, friends of all ages use their mobile phones to show each other photographs or videos. The adoration of photographs and shared laughs while watching funny videos, are examples to socio-pleasure.

Using the idea of socio-pleasure, we generated a nucleus of a new application. A dynamic message could be an interesting way of sharing a sentiment with someone you love. In this concept example, a shape-memory wire is programmed by Sandra to express her feeling towards Piero. When Piero heats the wire with a lighter, the

wire takes the shape preprogrammed by Sandra. Thus, Piero realizes her warm feelings towards him (Fig. 5).

Granted, the expressive potential of a single wire is quite limited and such a product would require a lot of imagination from the user. Still, it may be an interesting product for creative people.

*Psycho-pleasure* refers to emotional or cognitive satisfaction. For example, a user-friendly teller machine (ATM) would provide a higher level of psycho-pleasure than the one which causes errors due to misinterpretations.

In a product that employs shape-memory materials, the kinetic effect should not confuse the user or cause them to make errors while interacting with the product. Or when looking from the positive side, the designer should explore possibilities to give emotional or cognitive satisfaction to the user. A related example will be given under the discussion of experience design.

*Ideo-pleasure* signifies pleasure that is caused by an idea or by people's values. In environmentally conscious societies, using a product manufactured from biodegradable polymers may create appreciation by the society and satisfaction of the user. These feelings are examples to ideo-pleasure. Smart materials in general, and shape-memory materials in particular, possess a great amount of symbolic and real benefit for the society. They would also generate the added value of ideo-pleasure to users of products made of such materials.

Another design approach connected to our design discourse is *Experience Design*. This approach focuses on the quality of the experience of a specific user when interacting with a technical device. In addition to the simplicity and ease of operation during use, experience design studies the feelings and emotions of users through the involvement of all the senses, and the evolution of the values and significance of use, within a clear framework of social, material and cultural reference, with a holistic vision [22]. Experience design takes the quality of interaction into consideration and benefits from interdisciplinary research related to the analysis of phenomena that occur when a user interacts with an interface. Many disciplines such as cognitive and perceptual psychology, neuropsychology, linguistics, and semiotics may be involved in such research studies.

Hassenzahl, created a link between psychological needs and human experience [23]. Sheldon and his colleagues



Fig. 5. The Kiss by Sandra (a hypothetical interactive product shaped from SMM. Illustration courtesy of Soner Göksay)

listed the top-ten psychological needs based on a review of theories about the content of motives [24]. These are autonomy, competence, relatedness, influence, pleasure, security, physical thriving, self-actualizing, self-esteem, and money. Hassenzahl claims that these needs could also be used as categories of experience. This hypothesis was supported by a survey conducted by his team, which analyzed over five hundred positive experiences of people that used interactive products such as mobile phones, mp3-players, and navigation devices [25]. Their study revealed a clear correlation between need fulfilment and positive affect and suggested that experiences can be categorized by the primary need they fulfil. The most pronounced needs that were linked to positive experiences were stimulation, relatedness, competence, and popularity. We can use this model in order to dwell deeper into the ocean of possibilities through experience and kinetic interactive products. One of the drivers that possesses the potential of a positive experience is *stimulation*, here used to indicate the feeling of enjoyment and pleasure. We already proposed a possible application of shape-memory clothing that could stimulate the naked body of the person wearing it. We also discussed some examples where fashion designers Chalayan and Leenders used shape-memory garments to evoke eroticism and surprise, respectively. These are positive experiences for the majority of people. Other examples where the need of stimulation could be satisfied include products that cause some type of amusement, surprise, or playful action. Designers could explore the possibility of surprising the user with random reactions in products specifically aimed for enjoyment, such as toys or sports equipment. We suggest a random reaction in such applications because a single type of reaction or movement has the potential of surprising someone only once but a random reaction may surprise the user many times.

The second human need in the list is *relatedness-belongingness*. Relatedness represents the feeling of intimate contact with people who care about someone. A kinetic product experience that satisfies such a need could be an object used to teach a phenomenon to a child or an object that is modeled by a group of people who are peers or colleagues. A concrete example to the former case is a shape-memory wire that parents use to demonstrate the shape-memory effect to their child. When the wire is immersed in boiling water, it

takes the shape of a fish. An example to the latter case is a clay-like shape-memory material with different colors. Design students work in groups to experiment with these materials, share ideas, generate interactive product concepts, and model it from the shape-memory clay. In both of these hypothetical cases, the shared experience would bring a sense of belongingness to all who lived through the same activities.

The third need we will discuss here is *competence*, which is described as being capable and effective in one's actions. Elderly people gradually lose some of their motor abilities, for example their dexterity. The former author's mother enjoys making embroidered pillow cases with different patterns. The pillow cases are supplied with the pattern stamped on them together with threads of different color. A beautiful pillow case can be embroidered if one follows the simple instructions. Many people who are not keen in this craft can get a sense of achievement when the embroidery is complete and a colorful pillow case is ready to be displayed.

A similar but somewhat more high-tech product could be an embroidery kit with thin shape memory wires and a targeted 2D or 3D pattern with the help of such wires. An elderly person (also a child or an adult) will now have the task of embroidering the shape-memory wire into the correct marking lines on a fabric. If the embroidery is performed correctly, the targeted shape will be realized when the fabric is heated with a blow-dryer. If not, the result will not be satisfactory, although you can try it once more. The successful embroidery would give the person a sense of satisfaction. The approach we used here is experience design since the user scenario is constructed aiming for a positive experience that will, at the same time, satisfy one of the human needs, namely competence.

As shown in these examples, the integration of product design, interaction design and experience design approaches can help to deal with the new design questions of kinetic interaction.

## 4 Conclusion

There are still many questions that designers will have to consider in relation to the meaning of the applications of SMMs and qualities of interaction experiences with the product that apply these. Current applications make use of the kinetic performance in terms of functionality, as well as the lead of novelty and sustainability of

new materials. Designers are experimenting with the expressive, symbolic and aesthetic potentials of shape-changing materials.

Meanings change in relation to how the new products are designed, and to what emotional experience the user gets during the interaction with the shape-changing objects.

The performance in terms of interactivity could be enhanced by the awareness of the emotionality of visual and haptic sensations (physio-pleasure), psycho and ideo-pleasure of experience related to the meaning that it produce for the users. The designers have to invest and cultivate the imagination with regard to physical and psychological human needs, and link them to positive experiences such as stimulation, relatedness, and competence.

Surely among the research field of interaction design in the near future there will be new visions of experiences, and user interaction mediated by objects and architectures. Smart materials suggest a realm of interactive possibilities that can continually adapt to users' requirements and it seems logical that more open design methodologies that leave space for user input and meaningful appropriation may yield products that can have genuine everyday impact. The challenge for designers and materials developers remains working with shape-changing materials to exploit the materials' potential in perceptibly different ways that resonate functionally, aesthetically and emotionally, with users. If design with the multidisciplinary of skills and cross-fertilisation of methods (product, interaction, and experience design) could incorporate the potential of smart materials in our daily lives, our reality would be much richer in communication, powerful in sensorial engagement, more sustainable, and pleasurable for individual and social life.

## References

- Cardillo, M., Ferrara, M.: *Materiali Intelligenti, Sensibili, Interattivi*. Lupetti Editori di Comunicazione, Milano (2008)
- Ferrara, M., Bengisu, M.: *Materials that Change Color*. Springer, Heidelberg (2013)
- Mavroidis, C.: Development of Advanced Actuators Using Shape Memory Alloys and Electrorheological Fluids. *Research in Nondestructive Evaluation*, 14, 1-32 (2002)
- Mohd Jani, J., Leary, M., Subic, A., Gibson, M. A.: A Review of Shape Memory Alloy Research, Applications and Opportunities. *Materials & Design*, 56, 1078-1113 (2014)
- Duerig, T. W., Pelton, A., Stöckel, D.: An Overview of Nitinol Medical Applications. *Materials Science and Engineering: A*, 273, 149-160 (1999)
- Takaoka, S.: Overview of the Development of Shape Memory and Superelastic Alloy Applications. In: Yamauchi, K., Ohkata, I., Tsuchiya, K., Miyazaki, S. (eds.) *Shape Memory and Superelastic Alloys: Applications and Technologies*. pp.77-82. Woodhead Publishing, Cambridge (2011)
- Van Humbeeck, J.: Non-medical Applications of Shape Memory Alloys. *Materials Science and Engineering: A*, 273, 134-148 (1999)
- Wiberg, M., Robles, E.: Computational Compositions: Aesthetics, Materials, and Interaction Design. *International Journal of Design* 4, 65-76 (2010)
- Nendo, <http://www.nendo.jp/en/works/hanabi-2>
- Beylerian, G. M., Dent, A.: *Ultra Materials: How Materials Innovation is Changing the World*. Thames & Hudson, London (2007)
- Quinn, B.: *Techno Fashion*. Berg, Oxford (2002)
- Ivens, J., Urbanus, M., De Smet, C.: Shape Recovery in a Thermoset Shape Memory Polymer and its Fabric-Reinforced Composites. *eXPRESS Polymer Letters* 5, 254-261 (2011)
- Sung K. D.: Metal that Breathes, TEDxUSC [www.ted.com/talks/doris\\_kim\\_sung\\_metal\\_that\\_breathes](http://www.ted.com/talks/doris_kim_sung_metal_that_breathes)
- Beesley, P., Ohrstedt, P., Isaacs, H.: *Hylozoic Ground: Liminal Responsive Architecture*. Riverside Architectural Press, (2010)
- Moggridge, Ishii, H., Lakatos, D., Bonanni, L., Labrune, J.B.: Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials. *Interactions* 9, 38-51 (2012)
- Yvonne, R., Sharp, H., Preece, J.: *Interaction Design: Beyond Human-Computer Interaction*. Wiley, Chichester, West Sussex (2011)
- Ferrara M.: Smart Materials Based Research for Tangible User Interfaces. *PAD* 12, 2014
- Ishii, H., Lakatos, D., Bonanni, L., Labrune, J.B.: Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials. *Interactions* 19, 38-51 (2012)
- Hallnäs, L., Redström, J.: *Interaction Design: Foundations, Experiments*. University College of Borås, Borås, Sweden (2006)
- Tiger, L.: *The Pursuit of Pleasure*. Little, Brown & Co (1992)
- Jordan, P.W.: *Designing Pleasurable Products* Taylor & Francis, Philadelphia PA (2000)
- Battarbee, K.: Co-experience: Product Experience as Social Interaction. In: Schifferstein, H.N.J., Hekkert, P. (eds.) *Product experience*, pp 461-476. Elsevier, Amsterdam (2007)
- Hassenzahl, M.: *Experience Design: Technology for All the Right Reasons*. Morgan & Claypool, Reykjavik, Iceland (2010)

24. Sheldon, K. M., Elliot, A. J., Kim, Y., Kasser, T.: What is Satisfying About Satisfying Events? Testing 10 Candidate Psychological Needs. *J. Pers. Soc. Psychol.* 80, 325-339 (2001)
25. Hassenzahl, M., Diefenbach, S., Göritz, A.: Needs, Affect, and Interactive Products—Facets of User Experience. *Interacting with Computers* 22, 353-362 (2010)

—

<sup>1</sup> Thermo-bimetal materials, used as shape-changing thermal actuators, are composed of two thin layers of metal with different thermal expansion coefficients. Thanks to the difference in the thermal response, each layer expands and contracts at a different rate. Since the two layers are mechanically connected, the difference in expansion rates causes the entire bimetal to curl as the environmental temperature changes.

<sup>2</sup> The term hylozoic refers to hylozoism, an ancient philosophical view that matter has life.

<sup>3</sup> Thousands of lightweight digitally-fabricated components (acrylic links, mechanical imitations of ferns, leaves and whiskers, kinetic valves, pumping systems meshed microprocessors and proximity sensors), contribute to create a 'metabolic' system in constant flux that replicate the processes of natural environments, such as filtering moisture and organic particles from the air.

<sup>4</sup> Design tools such Grasshopper and Firefly parametric software are needed to draw, control, and digitally simulate shapes, morphing patterns, and atmosphere.

# The Experience Map. A Tool to Support Experience- driven Multisensory Design

## Abstract

Product designers may struggle to materialize their initial, abstract idea into tangible sensory features forming a product. Being aware of the role of every sensory modality in conveying a specific experience, they are more likely to come up with original and meaningful solutions. However, it can be challenging to manage an experience-driven, multisensory approach. This paper investigates the variables that designers must consider, and how they can design for rich multisensory experiences. We introduce a tool, namely the Experience Map, to improve designers' awareness of the process. The final aim is to support designers in their intuitive choices to design pleasurable products able to elicit meaningful and engaging multisensory experiences for people. We will discuss the possible benefits and applications of the tool, and the results of a small study conducted for educational purposes.

## Keywords

Product design; multisensory; design tools; creativity; sensory features

## 1 Introduction

A rich multisensory experience is usually considered to be a pleasant characteristic in a new product. However, it is not simply through choosing a nice smell, a fancy texture or a nice shape that enables designers to elicit a pleasurable and meaningful experience in users. Even

though designers tend to focus on the functionality and the visual aspect of the product, they are becoming increasingly aware of the importance of a multisensory approach. This means considering every modality while shaping the product, so that all product properties co-operate to convey a specific experience to users. The initial, fuzzy idea in the designer's mind must turn into a set of tangible properties that form a product. Several choices must be made, such as making the idea more or less explicit in the product, deciding which sensory properties are more appropriate to convey it, using different modalities without overloading the user, adding sensory incongruences in the product or not, and so on [1-3]. It requires a degree of expertise and sensitivity from the designer to effectively navigate through all these alternatives, and come up with aesthetical and meaningful solutions that can evoke a pleasant experience in users [4]. In this paper, we introduce a tool, namely the Experience Map, to support designers in translating their initial idea (i.e. the product vision) into sensory qualities. The tool draws on a first, preliminary version [5] to follow the process of idea materialization in a more structured way. Whilst the previous version of the tool focused only on the choice of sensory features, the current version includes several levels, to reflect a progressive transformation of the product vision into concrete product properties. In this way, the Experience Map can provide a clear and synthetic visualization of a Multi Sensory, experience-

driven process, from the beginning to the end, guiding designers through the five steps of the approach. To frame the context of the tool, we will first provide a definition of experience and the role of sensory modalities in subjective experiences. Secondly, we will focus on how designers can give shape to their idea and design with a multisensory approach. We will then describe the structure of the tool, going through all the levels, and explain how designers can use the Experience Map. In the present work, we concentrate on the assessment of the tool's usability and clarity. To do so, we applied the Experience Map in an education course, using it for reverse analysis of existing products. The results of this first study with students will be described.

## 2 A view on Product Experience

In order to understand how to shape the product's sensory qualities to appropriately express an idea, and therefore how to elicit a specific experience in users, we must first define what an experience is and how every sensory modality can fuel it. Product Experience is commonly described through three components [6], namely the aesthetic experience, the emotional experience and the experience of meaning. At the aesthetic level, the sensory qualities of the product can be regarded as distinct sensory channels carrying information, although products are perceived as a whole [7]. Thus, each sense can play a different role in conveying an impression. The natural smell, the fading colours and the woven pattern of a Japanese tatami, for example, stimulate our sensory system in a different way, yet generate altogether a holistic experience. Given the traditionally accepted dominance of the sense of vision, sensory modalities can acquire a different importance depending on the product to design. From a design point of view, for instance, the visual aspect will definitely dominate in a wall clock, while touch can sparkle innovative inspirations in the design of a carpet [3], [8-9]. Moreover, designers may choose to shape all the sensory qualities in a congruent way, which usually results in a more appreciable product, or, alternatively, they can add some incongruities to stimulate the senses in a surprising way [2]. On the cognitive level, people understand how to use a product, which action it affords and what it signifies in terms of its attached symbolic meaning. The product sensory qualities can be considered as small clues, elements of an integrated vocabulary, which communicates a specific semantic

association [10]. For instance, a rounded, pale-coloured and glossy toaster will probably link to a 50's style. Hence, *product features* (e.g. the glossy surface and the elongated shape of a Macbook Pro®) make users form *product attributes* (e.g. elegant, allured). The overall bundle of elegance, performance, high-technology etc. makes of the Macbook Pro® a product with a unique and distinctive *character* [11]. Designers aiming at embodying a specific idea into a product can thus exploit this relation in an appropriate way, bearing in mind that meaning is subjective and culture-specific. Lastly, at the emotional level, products are considered for their ability to elicit feelings and emotions in the users [12]. The role of the different sensory modalities in affecting the users' emotional reaction has been found to differ substantially: for instance, tactual and olfactory experiences were found to predominantly lie in the affective domain [9]. Additionally, designers may choose to shape the pattern of sensory qualities to specifically elicit some kind of positive or negative emotions. As mentioned before, they may want to elicit surprise in the user [2] and therefore evoke a more pleasant experience. Or, they may choose to trigger the fear of being chased to motivate the act of running [13]. Thus, designers have several alternatives to make use of the different sensory modalities to materialize their ideas. In the section that follows, we will discuss which factors influence this process and which methods can support designers in the challenge.

## 3 Designing for a multisensory experience

In this framework, we would like to focus on how designers transform their initial, abstract idea into a tangible product. Designers usually start this process from defining a concept, i.e. the Product Vision, which originates from preparatory activities, such as researching and reflecting on the context of use and on the user-product interaction [14]. In this moment, designers shape their personal and subjective view, which will guide them through all the subsequent phases. The product vision is a product-centred statement that provides straightforward information on the quality of the product. It describes the value to aspire, and the challenge is to understand *what* to create and *how* to create it [15]. The way designers will answer these questions is highly related to the designers' expertise and sensitivity. Consequently, students and novice designers seem scarcely aware of how to turn

an abstract idea into tangible features, while expert designers manage the process with a more conscious approach [15-18]. A possible design strategy to reduce this gap and tackle the process in a more effective way is to progressively decrease the level of abstraction. Designers can start exploring their idea, first at a very conceptual level, to subsequently look at every sensory modality and consider all the properties that will shape the product (e.g. its colour, material, details, etc.). In order to link the conceptual exploration to the sensory description of the product, they may define some specific expressive qualities that support the product vision. For example, they may assert that their idea could be better expressed by a 'fresh', 'elegant' and 'intimate' product. These product expressions help the designer to associate certain patterns of sensory qualities with their idea. Thinking of all the details in the product, and analysing the possibilities from each sensory modality, designers will be able to refine their product in a step-by-step manner. However, in this phase, designers need to alternate between a holistic and specific viewpoint, to ensure the coherence between the different parts of the product and the overall final result, which is never the sum of selected qualities. Two recent examples of methods that support designers in managing the complexity of designing for a specific experience are the Vision in Product Design approach [14] and the Multi Sensory Design approach [19]. The former offers a description of which activities designers should carry out in order to develop an innovative, experience-driven product from an abstract vision based in a future context. The Multi Sensory Design approach addresses instead the exploitation of all sensory modalities in an intentional way to come up with a pleasurable and original result. Both methods examine the theoretical concepts and provide designers with guidelines. Yet, they do not include any specific tool to integrate all the several phases and manage the entire process. The existing literature offers on the one hand overarching theoretical models [20] and design approaches [14], [19]. On the other hand, it supplies tools to address specific activities, already after the concept has been shaped. Examples are tools for material selection [17], [21] or user testing [12], [22-23]. The Experience Map provides instead a comprehensive tool to help designers in transforming their idea into a pleasurable and meaningful product, while taking into account all the sensory modalities.

## 4 The tool

In this context, the tool we developed supports designers with a structured layout that goes from the abstract level of the product vision to the selection of sensory properties. The main goal is to increase designers' awareness and to make their choices more deliberate, yet reflecting their personal subjectivity. Designers can also be stimulated to consider all the sensory modalities, with new possibilities to enhance the user experience of the product. Furthermore, the tool can help in training designers' sensitivity and their ability to explore the product vision and generate more original solutions. In order to cope with these aims, the design of the tool must meet a number of requirements. First of all, it needs to provide a clear and synthetic overview of the process, starting from the abstract level of product vision until the tangible level of sensory properties. To effectively manage it, the tool must be organised in a structure that reflects the steps of a Multi Sensory design approach. Distinguishing between these different steps aims to enhance the richness of design considerations. For instance, even though products are perceived as complex, multisensory whole, the tool requires designers to consider each sensory modality separately. Our objective is to decrease the chance of neglecting some types of sensory inputs, not to induce rigorous artificial separations between sensory modalities. Secondly, it should encourage designers to adapt the structure to fit their subjective perspectives. The tool needs to allow for intuitive design activities and should, therefore, incorporate more traditional tools, such as moodboards. Lastly, the Experience Map should entail a good structure while being neutral, i.e. not influencing designers' choices. This aspect will be especially relevant for the last step, the sensory analysis phase, which includes a list of sensory properties that must be expressed in an objective way.

### 4.1 The structure of the tool

The Experience Map is composed of 5 levels, arranged on a radial layout. The structure is based on the Multi Sensory Design approach [19], similarly reflecting the process (Fig. 1). To use it for creative purposes, designers should move from the centre, the most abstract level, to the external level of the map, the most tangible one. The upper part of the map considers the intrinsic properties of the product, such as shape, colour, and material; these are defined as static



The diagram is a circular chart representing the 12 zodiac signs. Each sign is represented by a small image and a list of associated elements, planets, and symbols. The signs are arranged in a circle, with their elements (Fire, Earth, Air, Water) and planets (Mars, Venus, Mercury, Jupiter, Saturn, Uranus, Neptune, Pluto) listed around them. Symbols for each sign are also provided.

Sign	Element	Planet	Symbol
Aries	Fire	Mars	♈
Taurus	Earth	Venus	♉
Gemini	Air	Mercury	♊
Cancer	Water	Moon	♋
Leo	Fire	Sun	♌
Virgo	Earth	Mercury	♍
Libra	Air	Venus	♎
Scorpio	Water	Pluto	♏
Sagittarius	Fire	Jupiter	♐
Capricorn	Earth	Saturn	♑
Aquarius	Air	Uranus	♒
Pisces	Water	Neptune	♓

Fig. 1. The Experience Map describing the case study of the Pulse concept by Deepdesign.

**Statement of Product Vision (1).** At this level, designers should explicitly formulate the product vision they wish to embody in the object. In the example provided, which uses as a reference story the development of the 'Pulse' concept by Deepdesign in the 'Project F' by Whirlpool [27], designers were looking for a product that would express a feeling of care for clothes. This was their starting point.

**Conceptual exploration (2).** As a second step, designers should explore their idea on a conceptual level, searching for inspirations from various contexts, such as art, exhibitions, culture, trends, etc. They should be representative of the experience that the designer would like to make the user perceive. In the Experience Map, this level includes a mood board, where the designer can either insert images or create collages. Although still abstract in its representation, it corresponds to the first deep interpretation of the product vision, focusing more on 'how' that specific experience can be rendered in a product, than on 'what' kind of experience it will evoke. In (Fig.1), the images describe the feeling of a bubble, a hug and the freshness of laundry.

**Selection of expression (3).** In a subsequent moment, designers should start elaborating on the expression of the product, trying to describe elements of the product character [11]. With the expression of the product, the product vision develops into more detailed and specific qualities of the user-product interaction. For example, the product vision of the Pulse concept can be described as 'caressing, quiet, faded' (Fig.1). At this step, designers should try to elaborate a set of keywords defining the expression of the product vision. The more specific and unique they are, the better they will help selecting the sensory properties of the product. To further reflect on the product expression, designers can connect the keywords to the sensory properties that better convey that specific expression. For instance, a product can give a soft feeling through its shape and tactual qualities, and it can be characterised by olfactory sensations that evoke freshness (Fig.1). In this step, designers start challenging themselves on the role of the different sensory modalities to communicate the product vision.

**Sensory exploration (4).** The following level addresses a further moment of conceptual exploration,

where designers look for more specific inspirations about each sensory property. This phase includes another mood board, which should describe in a more tangible way the expression of the product, how it must look or feel, its finishing and its dynamic qualities. As in the previous exploration, designers are free to look for whatever source of inspiration they may find; however, they should focus on each sensory property, looking for details. The sensory properties are divided in ten groups to facilitate a distinction between their roles. The static properties are listed as: the visual domain, the shaping of the product, the texture, the tactual aspect and the olfactory properties. The categories including the dynamic qualities of the product are instead: auditory, visual changes, force feedback, vibration feedback and olfactory feedback. Some considerations are needed: first, the category of 'shaping' refers to the qualities coming from manufacturing, rather than to the intrinsic properties of the material, which are included in the visual section. Similarly, a distinction has been made between qualities related to the texture of the product, and the properties related to the tactual domain. In this case, we preferred to clearly distinguish between the tactual experience given by the material itself, i.e. its warmth and softness, and other qualities related to a decorative pattern, which is perceived not only through the tactual system but also through vision.

**Sensory analysis (5).** Lastly, the external circle of the Experience Map covers the least abstract step, where designers are asked to carry out a sensory analysis (5) based on their personal interpretation of the product expression. For each group, a list of sensory qualities is provided: designers should rate them according to how much that specific quality is relevant to describe the selected expression (0=not all; 5=very much). Some free space is left to let designers add any term they might miss. The list included in the Experience Map was built based on various literature sources (Table 1), with some additions. It is meant to comprehend the possible variables that designers wish to consider while shaping the product. Yet, this selection has not been validated, as it is based on the aggregation of other verified lists present in the literature. Additionally, it is not, strictly speaking, the focus of the tool, and designers are free to adjust it to their personal needs. The list should not be considered as a definite list of sensory qualities to address while designing a product, but rather as a basis

Vision	Shaping	Texture	Tactual	Olfactory
>colourful [21] >vivid colours[21] >high colour contrast >bright >glossy [21] >transparent [21]	>decorative join-ing [21] >many materials [21] >organic [28] >rounded [28] >regular >discontinuous >massive [28] >balanced [28]	>large patterns >bumpy >rough [21] >hairy [28]	>soft [17], [21] >heavy [17], [21] >elastic [17], [21] >robust [17], [21] >warm [17], [21]	>perfumed [21] >pervasive [29] >strong [29]
Auditory	Visual changes	Force feedback	Vibration feedback	Olfactory feedback
>loud [29-30] >noisy [29-30] >sharp [29-30] >harmonious [30] >regular (rhythm) >fast (rhythm)	>opacity ch. [26] >shape ch. [26] >light signal >color ch. [26]	>strong [29] >smooth [29] >elastic [29] >fast	>intense >regular (rhythm) >fast (rhythm)	>odour production [26] >pervasive [29] >strong [29]

Table 1. List of the terms describing the sensory properties and corresponding sources in the literature.



Fig. 2. Some examples of completed maps.

to start. Designers are encouraged to add terms and qualities in the free space provided, to customize the map according to the specificity of the project.

## 5 Study results

The main aim of the Experience Map is to support designers in shaping their ideas through an experience-driven, multisensory approach. Doing so, it can increase designers' awareness of the process. Therefore, the tool can be used to train designers' sensitivity and help them think of all the possibilities given by each sensory modality. Providing a step-by-step guideline, it allows the transformation of the product vision towards a decreasing degree of abstraction. Hence, it is a tool to support design thinking with an experience-driven and multisensory approach. Other possible benefits include

using the map to structure and communicate to other stakeholders the abstract complexity that entails the design process. The Experience Map can help presenting to customers the underlying frame of a design project, and therefore facilitate the communication between designers and companies. Moreover, it can foster easier confrontations with technicians and engineers. Here we present the results of a study using the Experience Map for educational purposes. 62 students following the Design for Interaction Master program at the faculty of Industrial Design Engineering (TU Delft) used the tool in a reverse mode (Fig.2). They were asked to utilise the map to deconstruct one object of their choice. They started first analysing the product through its sensory properties, rating how much, from 1 to 5, the suggested qualities could describe the product. Subsequently, they were asked to complete the mood boards, select the expressions and, lastly, to try to infer the designers' intentions underpinning the product. They were provided with an example map (Fig.1) and a vocabulary listing all the sensory properties, with definitions and antonyms to understand them more precisely. Finally, they were asked to fill in a questionnaire with several open questions as a qualitative evaluation and to rate the tool through an evaluation sheet as a quantitative assessment.

### 5.1 Quantitative assessment

The Experience Map was evaluated according to several criteria, as shown in Table 2. The evaluation sheet was

Criteria	M	sD	Criteria	M	sD
Usefulness	4.97	1.19	Completedness	4.82	1.12
Improved my skills	4.76	1.04	Immediateness	4.18	1.34
Easy to understand	4.79	1.33	Appropriateness	4.63	1.12
Intention to use it	5.00	1.39			
Visual clarity	5.35	1.55			
Effort demand	5.53	1.21			
Flexibility	3.60	1.18			
Freedom to interpret	3.85	1.25			

Table 2. Results of the quantitative evaluation for the tool (left) and the sensory list (right).

based on a 7-point scale (1=not at all; 7=very much). The mean value ( $M=4.0$ ) was taken as the test value to consider the criteria as satisfied. Table 2 shows the results of the assessment. Almost all parameters were rated as positive: the Map was found useful, skill-refining, easy to use, visually clear and 82% of the participants stated they would like to use it in other projects. However, other criteria were less satisfactory. As expected, the map required a significant effort, as well as the flexibility can be improved. In the same evaluation sheet, three general questions assessed the list of sensory properties according to its completeness, immediateness and appropriateness. All values were good.

## 5.2 Qualitative assessment

Students were asked to comment about (1) the usefulness of the Experience Map in the design process and how they would use it, (2) benefits and limitations of the tool, (3) other suggestions on their personal interpretation of the map. Interestingly, many participants reported the willingness to use the tool to support concept generation. They also found the tool useful to first deconstruct existing products and then to generate new solutions. They generally agreed on the tool's ability to stimulate design thinking and the value of the step-by-step guideline. The tool was found very helpful in visualizing the design process, and therefore to discuss ideas with others. In some comments, students suggested to use the map to analyse the product portfolio of companies. The majority of the

students reported the need for a greater flexibility (see also Table 2), to adapt it to other uses or phases of the design process, or, more generally, to improve the creative flow. Another point that needed attention was the time-consuming activity of looking for appropriate images; some students suggested to create image databases to accelerate the process.

## 6 Conclusions

In this paper, we framed the need of a comprehensive tool to support designers in transforming their initial, abstract ideas into a ready-to-prototype concept. This need was found especially relevant in the context of an experience-driven, multisensory approach, which starts from the definition of a specific experience to elicit through the product, to look at the role of every sensory modality in conveying it. Therefore, we introduced a tool called the Experience Map, structured on 5 levels to reflect a step-by-step process that can help designers in progressively decreasing the degree of abstraction, to come up with meaningful and original solutions. The main goals of the tool are to increase designers' awareness of the process without influencing their subjective view on the design problem, and to help them considering all the possibilities given by the different sensory modalities. Side-benefits of the map can come for designers that use it to communicate their intentions and their thinking process to other stakeholders. The tool preserves designers' freedom and subjective interpretation of the design problem, while offering a structured layout to tackle all the steps

of an experience-driven, multisensory design approach. Moreover, it provides a clear overview of all the aspects and facets designers need to consider seeking coherence between the initial, abstract vision and the final, tangible product. The Experience Map should not be considered as a tool telling designers what they should design, rather it supplies a structured layout to organise their intuitions in a purposeful approach. The main strength of the Experience Map lies, therefore, in its visual comprehensiveness and its roots in solid methodological approaches present in literature.

## References

- Schifferstein, H.N.J., Spence, C.: Multisensory Product Experience. In: Schifferstein, H.N.J., Hekkert, P. (eds.) *Product Experience*. Elsevier Science Limited, pp. 133-161. Elsevier (2007)
- Ludden, G. D., Schifferstein, H.N.J., Hekkert, P.: Surprise as a design strategy. *Design Issues*, 24(2), 28-38 (2008)
- Schifferstein, H.N.J.: The perceived importance of sensory modalities in product usage: A study of self-reports. *Acta psychologica*, 121(1), 41-64 (2006)
- Lawson, B., Dorst, K.: *Design expertise*. Oxford Architectural Press (2009)
- Camere, S., Bordegoni, M.: The Role of the Designer in the Affective Design Process: the Principle of Accordance. In: *Proceedings of the 5th Conference on Applied Human Factors and Engineering*, pp. 66-77. AHFE Conference (2014)
- Desmet, P.M., Hekkert, P.: Framework of product experience. *International Journal of Design*, 1(1), 57-66 (2007)
- Schifferstein, H.N.J.: From salad to bowl: The role of sensory analysis in product experience research. *Food quality and preference*, 21(8), 1059-1067 (2010)
- Fenko, A., Schifferstein, H.N.J., Hekkert, P.: Shifts in sensory dominance between various stages of user-product interactions. *Applied ergonomics*, 41(1), 34-40 (2010)
- Schifferstein, H. N., & Desmet, P. M.: The effects of sensory impairments on product experience and personal well-being. *Ergonomics*, 50(12), 2026-2048 (2007)
- Krippendorff, K., Butter, R.: Product Semantics: Exploring the symbolic qualities of form. *Innovation*, 3(2), 4-9 (1984)
- Hassenzahl, M.: The interplay of beauty, goodness, and usability in interactive products. *Human-Computer Interaction*, 19(4), 319-349 (2004)
- Desmet, P.: *Designing emotions*. Unpublished PhD thesis, TU Delft (2002)
- Fokkinga, S., Desmet, P.: Darker shades of joy: The role of negative emotion in rich product experiences. *Design Issues*, 28(4), 42-56 (2012)
- Hekkert, P., Van Dijk, M.: *ViP-Vision in Design: A Guidebook for Innovators*. BIS Publishers (2011)
- Dorst, K.: The core of 'design thinking' and its application. *Design Studies*, 32(6), 521-532 (2011)
- Schifferstein, H.N.J., Hekkert, P. (eds): *Product Experience*. Elsevier Science Limited. Elsevier (2007)
- Sonneveld, M., Schifferstein H.N.J.: The Tactual Experience of objects. In: Schifferstein, H.N.J., Hekkert, P. (eds.) *Product Experience*. Elsevier Science Limited, pp. 41-67. Elsevier (2007)
- Cross, N.: Expertise in design: an overview. *Design studies*, 25(5), 427-441 (2004)
- Schifferstein, H.N.J.: Multi Sensory Design. In: *Proceedings of the 2nd Conference on Creativity and Innovation in Design*, pp. 361-362. ACM, New York (2011)
- Crilly, N., Moultrie, J., Clarkson, P. J.: Seeing things: consumer response to the visual domain in product design. *Design studies*, 25(6), 547-577 (2004)
- Karana, E., Hekkert, P., Kandachar, P.: Material considerations in product design: A survey on crucial material aspects used by product designers. *Materials & Design*, 29(6), 1081-1089 (2008)
- Gatti, E., Bordegoni, M., Camere, S.: Experience and Senses. An Experimental Based methodology for Product Design Optimization. In: *The Colors of Care. Proceedings of the 9th Conference on Design & Emotion*, pp. 380-389. Ediciones Uniandes, Bogotá (2014)
- Hassenzahl, M., Burmester, M., Koller, F.: AttrakDiff: A questionnaire to measure perceived hedonic and pragmatic quality. In Ziegler, J., Szwillus, G. (eds.): *Mensch & Computer. Interaktion in Bewegung*, 187-196 (2003)
- Diefenbach, S., Lenz, E., Hassenzahl, M.: An interaction vocabulary. describing the how of interaction. In: *CHI'13 Extended Abstracts on Human Factors in Computing Systems*, pp. 607-612. ACM, New York (2013)
- Lim, Y., Lee, S., Lee, K.: Interactivity Attributes: a New Way of Thinking and Describing Interactivity. In: *CHI'09 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 105-108. ACM, New York (2009)
- Colombo, S., Rampino, L.: Information embodiment: how products communicate through dynamic sensory features. In: *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces*, pp. 211-220. ACM, New York (2013).
- Bazzicalupo, M., Mangiarotti, R.: *L'Anima Sensibile delle Cose (The Sensible Soul of Things, in Italian/English)*. Exhibition Catalogue. Electa, Milano (2009)
- Gorno, R., Colombo, S.: Attributing intended character to products through their formal features. In: *Proceedings of*

- the 5th Conference on Designing Pleasurable Products and Interfaces, pp. 16-24. ACM, New York (2011)
29. Malnar, J.M.,Vodvarka, F.: Sensory Design. University of Minnesota Press, Minneapolis (2004)
30. Van Egmond, R.: The Experience of Product Sounds. In: Schifferstein, H.N.J., Hekkert, P. (eds.) Product Experience. Elsevier Science Limited, pp. 69-89. Elsevier (2007)

# Design for flow in an age of material digitalization

## Abstract

It is pointed out in this paper that to respond to the frequent and extensive changes of environments and situations and quickly diversifying customer requirements, our design has to be very much adaptive and responsive and should be developed as a closed loop system with rich feedbacks. And design is to make our customers dream come true, we should pay more attention to emotion in addition to product functions. As humans would like to actualize themselves, we have to remember that the process of adapting or responding to changes is a challenge for our customers and will provide them with a great joy of emotional excitement. Thus, processes themselves yield value in addition to the product. As technology of digital materials is emerging, we should develop design to assign desirable attributes element by element and develop a product that will communicate with us and with the outer world in an emotional exciting way, just like a child plays with sand on the beach.

## Keywords

Design for flow, Design for change, Emotional engineering, Responsive material, Material digitalization

## 1. Discretization, digitization and digitalization

Discretization or Digitization and Digitalization are different. But they are not distinguished clearly. Their

difference may be explained by taking musical scores as an example. Musical scores are discretized or digitized symbols, but their interpretations differ from player to player and their impressions differ from listener to listener, depending on their experiences. The played music is digitalized material. It carries meanings. So changing from analog or continuum to discrete element is discretization or digitization but when the change carries meanings, it is digitalization.

## 2. Examples of discretization

### 2.1 Functional modularization

Interestingly enough, discretization is called modularization in engineering. Most modularization in engineering is function-focused. In engineering, modularization has been carried out since long time ago. Take trucks for example. Although their bodies have to be customized to different needs, the same type of chassis can be used for all purposes. Thus, truck design is separated into body and chassis modules and they are manufactured in different companies and are assembled together (Fig.1).



Fig.1 Example of Modularization (Truck)

Modularization is attracting wide attention these days in engineering, because

- (1) If a product or a system becomes large and complex, it becomes far easier if we divide it into smaller modules and we can solve the problem rationally, because the problem space is small and bounded.
- (2) We can realize mass customization and personalization. Thus, we can reduce cost, time and energy in spite of the increasing diversity of customer requirements.

## 2.2 Shape Discretization

**Finite Element Method.** Although it is not called modularization, there is another famous discretization in engineering relating to shape. Finite Element Method (FEM) divides a continuum into finite discrete elements and reduces the number of degree of freedom from infinite to finite so it enabled us to analyze any shape. Without FEM, most of the current engineering products cannot be designed and manufactured. But it has nothing to do (at present or directly) with emotion.

**ORIGAMI.** When it comes to shape discretization, there is another interesting field. It is ORIGAMI or paper folding. ORIGAMI produces a very wide variety of shapes out of the single sheet (Figs.2, 3, 4) (Sometimes there are cases where several sheets are used.).



Fig.2 ORIGAMI crane



Fig.3 ORIGAMI tree



Fig.4 ORIGAMI serpent

ORIGAMI is often called the art of paper folding, but it is not just for art. It constitutes a basis for many engineering applications; deployable structures in space

such as solar panels, solar sails, etc. and car airbags and so on. ORIGAMI is basically a divergent approach (Fig.5). You start with a single paper and come up with a wide variety of shapes. The other discretization described earlier is a convergent approach (Fig.6).

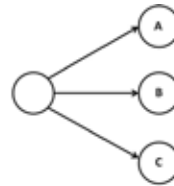


Fig.5 Divergent approach

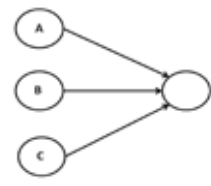


Fig.6 Convergent approach

Convergent approach is the one we apply different pieces to reach the goal. Divergent approach is the opposite. We start from what we have and expand it into different goals. But there is a convergent shape discretization. It is a jigsaw puzzle. Lego, however, provides us with a set of pieces and we can build many different things with them. So it is divergent. But we have to remember these discretization is only focusing on shape. However, we have to remember that ORIGAMI, jigsaw puzzle and Lego provides us with great emotional excitement because their processes are challenging and especially in the case of ORIGAMI and Lego, the final shapes we come up are often beyond our anticipations. Traditionally, we have been paying our primary attention on products, but we should remember processes are none the less important for providing emotional satisfaction to our customers. Such processes may be interpreted as communication between the customer and the product. And humans need someone to communicate with. Although products are not humans, they can be our companions. We, especially engineers forgot that our products are not just things, but companions.

## 2.3 Emotional modularization

Although it sounds completely engineering-oriented, functional modularization is deeply related to emotional satisfaction of our customers, because they look for better performance. And as their expectations are rapidly diversifying, engineers have to think seriously about mass customization and personalization to minimize time, cost and energy and to maximize emotional satisfaction at the same time.

But we have to remember that there is emotional



modularization. For example, ladies would like to wear a wedding dress just for herself. But not every lady is rich. So most of them have to go for a rental dress. Rental dress makers cannot make a profit at a rental price, if they produce a different wedding dress for each lady. So they observe at fashion shows, etc., what parts of the dress are attracting their attentions. So just like truck design, the dress makers produce the common part in mass and produce such attention-attracting parts in a wide variety, and they combine them to offer a great variety of wedding dresses. Such emotional modularization may be called Feature-Based Modularization (Fig.7). But in this case, time, place and occasion are fixed. Then, what do we do when they vary?

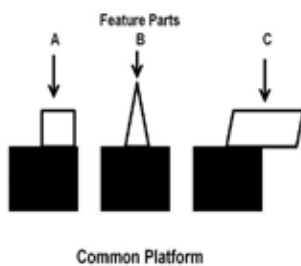


Fig.7 Feature Based Modularization

That is what fashion accessories are for. Even if clothes are the same, we look or feel different, depending on what accessories we put on. But our clothes themselves are modularized and we combine modules in a different way to adapt to time, place and occasion. That is dress code. So functional and emotional modularization have been practiced for a long time in our clothing. Same idea can be seen in many other areas. Daihatsu developed interchangeable parts for dressing up a car (Fig.8, Fig.9) in their Copen model.



Fig.8 Daihatsu Copen



Fig.9 Daihatsu Copen – Interchangeable parts

### 3. Process-focused design

The above examples are indeed modularized for emotion, but for s specific time, place and occasion. But there are emotional modularization considering changes with time.

#### 3.1 Breaking In

Let us consider why users are called customers. It is because they would like to customize our products. They expect our products to work as they expect. They have to be customized to customer's need and preference.

Hardware products are physical, so they deteriorate. What our customers expect is our products not only work best as they prefer in their operating conditions, but also keeps operating in the best condition for them for a long time. To achieve this goal, functions must be considered from the standpoint of customers. But such changes with time as deterioration are not truly considered. Maintenance is just to restore the degrading functions back to the original design specifications. But users would like to use our product in their own customized conditions. There is not much work done how we can design to customize our products, considering deterioration.

In the case of machines, breaking in is very important, because it is to adapt or customize a machine to each operating condition. This is very much associated with deterioration. Although many researches have been or are being done on deterioration, most of them focus on how we can prevent failures due to deterioration. There are very few, if ever, researches which discuss how we can control or manage deterioration.

Deterioration is thus, in most cases, considered to be unfavorable. But if we can control it, then we can manage adaptation. For example, ASICS, Japanese shoe making company, developed shoes by taking notice of this. Shoes worn for a long time deform as shown in Fig.10. People throw away such deformed shoes. So most shoe makers develop shoes with the material that would not deteriorate so easily. But ASICS thought the other way around. Why the middle portion deform so much is because that part needs more amount of adaptation. So they introduced material in the middle part which deforms or adapts much easily, but still do not deteriorate quickly. People loved the shoes. They say they feel like walking on their own feet. They do not feel wearing shoes. And they say they enjoy walking for

a long distance (Fig.11). But ASICS did not stop there. They developed sport shoes, because it demonstrates how your feet deform. Unlike long walking shoes, such sport shoes must adapt very quickly and bear strong forces. But the basic idea is the same. This was also a big success (Fig.12).



Fig.10 Worn Shoe



Fig.11 Shoes you can enjoy long walk



Fig.12 Sport shoes

This example teaches us that not only discretizing a product is important, but it is none the less important how we can allot desirable attributes to each discretized elements not only for functional performance, but also for emotional satisfaction. Therefore, we should focus more on how we can manage deterioration for customization and personalization.

### 3.2 Hardware and Software Development

In the above, we have discussed hardware products. Let us compare hardware and software development at this point.

Fig.13 shows hardware development. In the case of hardware, products are developed with fixed functions which meet design requirements. As hardware is physical, it deteriorates once it is sold. So maintenance plays a very important role. But we have to remember maintenance is just restoring the degrading functions back to the design specifications. In the 20th century when environments and situations did not change appreciably, this approach worked. But in the 21st century, environments and situations change very frequently and extensively.



Fig.13 Hardware development

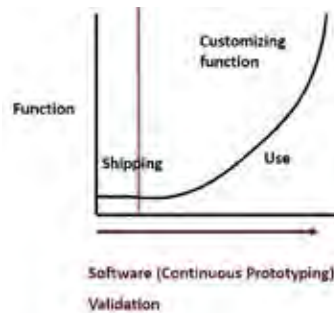


Fig.14 Software development

On the other hand, software is developed with growing or evolving functions (Fig.14). Software used to be developed in the same way as hardware. But we soon realized hardware is physical and software is nonphysical so the hardware way does not work for software. And physical hardware deteriorates and has a finite life. But software do not and it has an infinite life. So, software changed its development style. Software developers first provide basic functions. As the functions are very basic and their range is limited, it is not so much difficult to debug and to develop. When customers get used to it and get confident, developers upgrade the functions a little bit. And as customers get used to this little higher functions and get confident again, developers upgrade a little higher. Thus step by step developers upgrade functions. This is called continuous prototyping. Customers get more and more confidence, as the functions grow, because they have time to learn and to master. Interestingly enough, as their confidence grows, customers put more and more trust in the system. Confidence and trust go together. In fact, in German, they are called by the same word "Vertrauen". And we

have to remember that it also increases attachment. As the system is upgraded with their feedback, they feel more and more the system is theirs and they become a lifetime customer.

It would be interesting to remember what distinguishes humans from animals. Humans can see the future. But animals cannot. Animals live for now. Some animals can use tools, but they do not make tools. Animals can select things from nature to use them for tools. But humans make tools to realize their dreams. Design is to make our customer's dream come true. Software developers grow not only functions, but they also grow our expectations so we can keep on dreaming. Hardware developers make our dreams come true, too but only for once.

### 3.3 Open Loop and Closed Loop System

To describe their difference in another way, hardware is developed as an open loop system (Fig.15), while software is developed as a closed loop system (Fig.16). Software is being developed with extensive feedback from their users. Open loop system and closed loop system are, in other words, fixed model approach and adaptive model approach. In an age of small changes, fixed model approach was effective. But in an age of extensive and frequent changes, we have to move toward adaptive models. Thus, transition from fixed model to adaptive model approach is called for in our hardware design to respond to such changes and to respond to increasing diversification of our customer expectations.

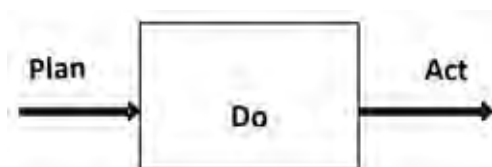


Fig.15 Open Loop System

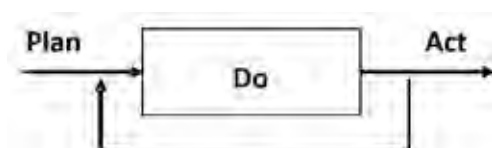


Fig.16 Closed Loop System

It should also be added that the growing or evolving function curve in software development is very similar

to learning curve. In fact, software communicates with the user and they learn to grow or to evolve.

And it should also be mentioned that if we turn the figure of Fig.14, it is nothing other than the hardware development figure. The growing function curve, then, changes to deterioration curve. Thus, we have to remember that management of deterioration is deeply associated with that of growing functions and that of learning.

### 3.4 Learning products

Stewart Brand, who coined the word “Stay Hungry. Stay Foolish”, published an interesting book “How Buildings Learn” [1]. He points out that buildings designed by a very smart architect do not survive, but those designed by a less smart architect survive for a long time, no matter how the environments and situations change. This may be interpreted that smart means too much focused on a particular goal so that there is only small allowance or a little leeway. But to adapt to the changes in environments and situations, wisdom is needed rather than intelligence.



Fig.17 Pier 21 Canada's National Museum of Immigration



Fig.18 London Docklands

Fig.17 and Fig.18 are such examples. Fig.17 is the case where the building itself remained the same, but it has been used for different purposes as time went on. This demonstrates that the buildings you see everywhere

are in fact most adaptive and enduring. Fig.18 is just a combination of containers. This might be developed for a makeshift, but changing the combination produces different structures for different uses. This is the case of a divergent approach. What interests us is the fact this is the way of metabolism of biomolecules. In fact, there was architectural movement called metabolism in Japan to adopt their way into architectural design. This may be interpreted that they moved away from the traditional smart design to wise design. Smart design is a fixed model approach, while wise design is an adaptive approach and it will change adaptively with the change of the outer world by communication. Wise design, to put it in another way, is responsive design.

#### 4. Changing environment of design

##### 4.1 Closed and Open World

Our world has been closed until very recently. In a closed world, boundaries are clearly defined so that set theory holds and we can apply such logics as induction and deduction. There, rationality worked. But now our world is very rapidly expanding and boundaries are disappearing. In such an open world, rationality does not hold as it used to be and such pragmatic approaches as abduction, PDSA, reflective thinking, etc. are taking over. They are, in short, approaches of trials and errors. Their basic philosophy is all's well that ends well.

A closed world and an open world can be described in other ways. A closed world can be compared to railroad. As there are rails, all you have to decide is which rail and which train to take. And your only interest is how you can get to your destination without difficulty and fast. An open world can be compared to voyage. On a voyage, you may have a beautiful weather today. But tomorrow hurricane might hit you. Then, you have to call an unplanned port. Or in the worst case, you may have to change your destination. Then, you have to ask yourself what motivated you to this voyage. So a voyage is fundamentally navigating through uncharted waters. They could be compared to agriculture and hunting. In agriculture, the land is bounded and with increasing experience, you can expect a rich harvest. In hunting, however, you cannot tell what animals you may come across and if the animal is stronger than you, you will be eaten, instead of you eat it.

Therefore, strategy is more important in an open world, while tactics play an important role in a closed

world. This means that the processes becomes more important than the goal or the product in an open world. You will be deeply satisfied if you think you manage to get through all the difficulties very wisely when you finally get to your goal. You feel your decision making is very adequate and your strategy is very good, when you overcome such difficulties. This is the same feeling you will have when you climb a mountain or you play a game. Challenge is the core and mainspring of all human activities. We get emotional excitement when we challenge. Of course, the result is important, but what is more important is whether you feel excitement when you head for the goal. No matter whether you succeed or not, you will have a great emotional satisfaction, when you feel such excitement as you go on. This means that we have to throw a new light on the value of processes instead of just paying attention to the value of a product. Maslow proposed the hierarchy of human needs (Fig.19). As we go up the ladder, our needs change from material satisfaction to mental satisfaction. Challenge is self-actualization. And challenge is the exploration of the new unknown world. So we need wisdom there. It is wisdom to come up with the best decision for the next step by communicating with the outer world. Self-actualization may be interpreted as our desire to demonstrate how wise we are.



Fig.19 Maslow's Hierarchy of Human Needs

It should also be added that as the world expands, more and more peaks appear. When the world is small, there is only one peak so if we do our best, we can reach to the top of the mountain in a straightforward manner. So, tactics was important. But when there are multiple peaks, we have to study which peak to climb before making decisions. Thus strategy becomes increasingly important.

#### 4.2 Optimization and Satisficing

Engineers would like to discuss about optimization. But when the world is small, we can carry out local optimization and can find an optimum. But when the search area becomes very large and we carry out global optimization, we cannot find an optimum easily. Simulated Annealing is often used for global optimization, but the optimum found this way is what we think optimum and there is no guarantee that it is truly an optimum. We believe so because that is the optimum after many repetitions. We only assume that it is the optimum. This is very much emotional.

Herbert Simon pointed out rationality is bounded and he proposed the idea of satisficing (satisfy + enough) [2]. He told us if the problem space is small, we can solve the problem rationally, but when it becomes very large, we cannot. We have to resort to emotion, because we cannot compute any more due to such problems as combinatorial explosion, etc. Global optimization is a good example. As the world expands, we have to think more about satisficing. And since this is a problem of emotion, we have to consider how we can develop emotional excitement when our customers use our products. User experience is one of such issues. Although the product is the same, its value varies with user experience. And there is no optimum value. What we can develop is satisficing value for each customer.

#### 4.3 Predictable and Unpredictable World

There were changes yesterday, too. But the changes were not so frequent and extensive as they are today. But the greatest difference between yesterday and today is changes were smooth yesterday. But they are very sharp and jaggy as a saw-tooth today. Therefore, yesterday, change curves were differentiable so we could make predictions, but today they are not differentiable. Thus we cannot make predictions (Fig.20). So apart from what Simon pointed out, rational approaches are becoming more and more difficult to apply with the expansion of our world.



Fig.20 Changes of Yesterday and Today

#### 4.4 Controllable and Rational World

Many people, even including engineers, think engineering is rational. But in fact it is not. Let us take arc for example. Many works have been done and are being carried out on arc, but if we can rationalize arc, then we can prevent thunder. As everybody knows we still do not have an effective way to prevent it. But we know how to control it. That's why we could build so many buildings, ships, etc. by using arc welding. And if we study carefully, we will know most of engineering activities are established by controlling such irrational phenomena.

Engineering is to make our customer's dream come true and it deals with the real world. And most of the constraints are hard. Time, Money, Human, etc. are limited. We have to develop a product with these hard constraints. That is where engineering is different from science. Science can take time, money and human, as you like. At least their constraints are very much negotiable and soft. Engineering progressed because engineers became aware that even though they could not rationalize the phenomena, they could control them.

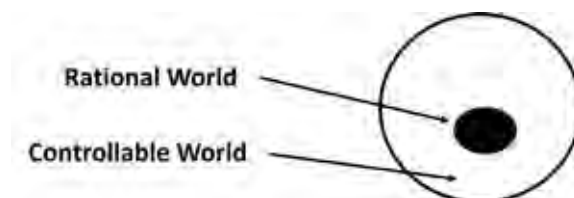


Fig.21 Rational World and Controllable World

#### 4.5 Controlling Points

Then, how can we control them? Let us remember how we identify the name of a river. If we look at a river itself, it is flowing and changing all the time. Today, there are solid banks, but yesterday banks were changing, too. Then, how could we?

It is because we do not look at the river itself, but we look for some identification points which does not change or even if they change, they do very slowly. Thus, we can identify the name of a river (Fig.22).



Fig.22 Identification Points

In fact, a welding robot is controlled in this way. It is not controlled by observing arc itself, but by observing the surroundings. Most products are controlled adequately by finding appropriate control points, even when the phenomena cannot be rationalized.

## **5. Changes in material**

### **5.1 Soft material**

One of the greatest changes happening in material field is that materials are getting softer and softer. That is why haptics are increasing its importance. For example, when materials are hard, you can grasp an object from a distance by using vision alone. When you see the object, you know what it is so you can grasp it at a distance without too much difficulty. But when the material becomes soft, you cannot tell what it is until you grasp it and observe or feel how it changes its shape. We have to study how it behaves in response to our actions. Thus, haptics is becoming increasingly important in robotics.

In other words, when the material is hard we can act on the principle of an open loop system. We have fixed models for each object. But when the materials become soft, we have to change it to a closed loop system and change our models adaptively as we act.

Then, what happens to the discussion above about identification points and control points. It must be stressed that the basic idea holds. But in the case of soft materials, we have to observe how these points change. So it may be better to say that we now control by observing how objects communicate with us. In fact, communication is a tool to know the target person or object. And if we can communicate well, we can decide and act wisely to respond to the situation. Thus, what we will be important in engineering from now on is how we can communicate with the outer world or with the object. So we have to pay more and more attention on behaviors. In other words, how the object changes or behaves in response to our action becomes very important.

This is deeply associated with tacit knowledge. Michael Polanyi proposed the idea of tacit knowledge [3]. He pointed out that there are knowledge which cannot be explicitly expressed. One of the major reasons why tacit knowledge cannot be expressed explicitly or in words is because it is not a fixed knowledge. It is a knowledge about flow or change. In other words, Behaviors

become important in tacit knowledge and we cannot express behaviors well enough in words.

Bike riding is often taken up as an example of tacit knowledge. But if we note a group of certain identification or control points and study their changing patterns with time, we could teach a learner how he or she can ride a bike without words. This is something like teaching how to swim in the flowing water. The situation is really flowing (changing), but if we note how our body responds to the flowing water, for example, by observing the changing patterns of skeletons or those of joints and muscles, we could possibly teach how to swim, although it is much more difficult than to teach how to ride a bike.

So what will become important tomorrow is we have to design a product that will communicate with us and with the outer world to provide us with emotional excitement and satisfaction [4], [5], [6]. And we should remember that the communication process itself provides us with a great joy.

### **5.2 Material digitalization**

Material Discretization technology is progressing rapidly. In fact, traditional composite materials are also examples of material discretization, but new technology of digital materials is emerging [7], [8]. But they are still focusing their attention on discretization or digitization. If we would like to digitalize materials, we have to attach meanings to the act of digitization. Most research on digital materials focus their attention on functions. We have to develop research on emotional digitalization. To achieve this goal, we have to develop methodologies to assign desired attributes to desired locations element by element, just as described in the section of emotional modularization. But what we have built up was a fixed model of emotional modularization. But materials are becoming softer and softer, so what we have to develop now is an adaptive model of emotional modularization or emotional digitalization. This design is not a smart design, which is very intelligent and effective toward achieving a certain goal, but a very wise design, which is a design responsive and adaptive enough to any changes of the outer world and provides us with emotional excitement and satisfaction over time. We have to remember that such changes or flows provides us with great emotional excitement or psychological flow. In fact, why we love to drive a car is because we feel we feel we overcome all the difficulties in spite of

the challenging changes of environments and situations. Driving a car is in fact a challenge. And we enjoy the challenge itself. It is not just a vehicle to take us from A to Z.

So we must develop design for flow with the help of responsive materials and their digitalization to cope with the frequent and extensive changes of our world and situations and to provide us with such a joy of challenge for change.

And finally it must be added that as the fact personal fabrication is attracting wide attention these days demonstrates, our customers would like to develop their own products. Therefore, we have to develop such a system, too, which allows everybody to enjoy design and manufacturing, just like a child playing with sand on the beach or playing with Lego.

## 6. Summary

It is pointed out in this paper that to respond to the frequent and extensive changes of environments and situations, our design have to be very much adaptive and responsive and should be a closed loop system with rich feedbacks.

As humans would like to actualize themselves, we have to remember that the process of adapting to changes of the outer world is a challenge for our customers and this challenge will provide them with a great joy of emotional excitement. We have to pay more attention to processes values.

As technology of digital materials is emerging, we should develop design to assign desirable attributes to desired locations element by element and develop a product that will communicate with us and with the outer world in an emotional exciting way, just like a child plays with sand on the beach.

## References

1. Brand, S., : How Buildings Learn: What Happens After They're Built, Penguin Books, New York (1995)
2. Simon, H.A.,: Models of Man, Wiley, New York (1957)
3. Polanyi, M.,: The Tacit Dimension, University of Chicago Press (2009)
4. Fukuda, S.,: Emotional Engineering, Vol.1, Springer, London (2011)
5. Fukuda, S.,: Emotional Engineering, Vol.2, Springer, London (2013)
6. Fukuda, S.,: Emotional Engineering, Vol.3, Springer, London (2015)
7. Popescu, G.A.,: Digital Materials for Digital Fabrication, Master Thesis, The Center for Bits and Atoms, Dept. of Architecture, MIT (2007)
8. Lipson, H., Kurman, M.,: Fabricated: The New World of 3D Printing, Wiley, New York (2013)



# Ethics of Robotic Aesthetics

## Abstract

This article explores the relationship between expressivity morphology and acceptance, defining the conditions that make service robots desirable by man. In the attempt to define “an ethic for robotic aesthetics”, it is discussed the evolution happened in robot design and how they were perceived by people, both in scientific community and in pop culture. The conception of robots begins with an approach strongly oriented to a biological imitation, especially anthropomorphic, conversely, nowadays, the scenario is various and robots assume a multitude of synthetic aesthetic languages and, moreover, are characterized on the basis of the context. In the final part of this article, it is described, through a series of examples, the contemporary scenario in which to the multitude of languages is added also the contamination of the digital world, outlining new morphological types. One of the examples is Virgil, a service robot for Cultural Heritage enhancement, designed by the research team JOLCRAB Telecom Italia/Politecnico di Torino.

## Keywords

Robotic Design, Expression, Aesthetics, Acceptance, Human-Centered Design

## 1 Introduction

Over recent years, Service Robotics has spread widely and its rising trend shows no signs of deceleration

thanks, mostly, to the lowering of the costs and the improved performances of the components, both hardware and software [1]. In the perspective of a society in which humans and robots will have to coexist, it is necessary to investigate all the aspects that regulate their relationship, in order to ensure an ethical dimension and an effective benefit for people. It is necessary to shift from a technology based approach, that drove the development of most robotic projects until today, to a human centred one, in which the focus of the design activity is the man, the context with which he relates, his activities and needs.

In Robotics, as well as in any other project discipline, it is important to be aware that human existence is characterised by three fundamental dimensions: biological, social and ethic. To the primary needs for conservations, indeed, is added the need of interaction with other humans, which takes place in modality defined by the individual system of values. These three dimensions generate the cultural life [2]. For this reason, the research activities that investigate the conditions at the base of acceptance in HRI become crucial. The acceptance depends on many factors, first of all the perceived utility and usability [1], but, even before the user interacts with the robot for the purpose it is designed for, other influential factors are involved, especially expressive aspects of the machine.



### 1.1 Towards a new conception of robot

The conception of robot over time evolved as well as its capabilities and morphologies. If at the beginning a robot was conceived as a mechanical surrogate of humans [3] already in 1979 the Robot Institute of America raised a reflection on the modern evolution of Robotics and agrees in defining robot *“a reprogrammable multifunctional manipulator designed to move material, parts, tools or special devices through variable programmed motions for the performance of various tasks”* [3]. In 2007, the Italian agency for New Technologies, Energy and Sustainable Economical Development (ENEA) published a report curated by Attilio Sacripanti that is a sort of summary of the state of Robotics worldwide, in which describes the main aspects of this discipline: operating principles, application fields, geo-political aspects, human-robot interaction principles and ethics of relationships. In this document the robot is defined as *“any artificial agent, either mechanical or virtual, that is able to perform one or more (intelligent) operations autonomously”* [4].

Compared to the previous definition it is noticeable the concept of robot is, increasingly, moving away from the mechanical aspects on behalf of greater consideration for cognitive aspects. This evolution reflects what is happening in robotic world: from a preliminary diffusion limited mostly in industrial area, service robotics is now spreading in everyday life. In this regard, the Interaction Design team of Polytechnic of Turin extended the Sacripanti's vision, defining robot *“any artificial agent, either mechanical or virtual, that is able to perform one or more (intelligent) operations perceiving, analysing and acting in the space-context”* [5]. The purpose of this extension is to include the relationship with the context that influence and define, more and more, nowadays robots.

A last definition useful to interpret the contemporary world of Robotics is the one suggested by Nourbakhsh, in 2014, according to which *“robot represent a new form of glue between our physical world and the digital world that we have created”* [6], thanks to the fact that robots are connected to the environment they are placed in and provided of decision-making skills, that interpret circumstances and determine the appropriate actions. A robot, then, can be defined as an intelligent agent provided of perceptive system that receives input from the environment, an executive system that produces

output, namely the actions and, finally, a cognitive system that processes the sensations to deliberate the actions that have to be carried out [6].

### 2 Perception and Acceptance

In the last decades, robotic solutions for industrial, military and medical fields have been, increasingly, consolidated. At the same time, as already mentioned, the Service Robotics diffusion becomes one of the hot topics in contemporary robotics research. In the future, most probably, service and personal robots will move and act in dynamic and unpredictable environments, and will be employed and driven by untrained users [7]. This diffusion of increasingly autonomous robots will drive to a shift from a condition of man possess and control of robots to a **coexistence** condition [7]. So, it is necessary, as already mentioned, to define the conditions that make robots acceptable for society, in order to avoid unsuccessful or competitive situations. The acceptance is defined as *“the willingness, demonstrable within a sample of users, to use information technologies for the task to which these were designed”* [8]. It depends on various factors of human-robot interaction such as the main five identified by Rogers: relative **advantage** in compared to other tools; **compatibility** with the existing social practises; the level of **complexity** in terms of usability; **trialability**, namely the possibility to try the tool before its “enforcement” and **observability**, i.e. the expressive clarity that makes the technology easily recognizable [9]. In addition to usability, functionality, safety and costs, the **physical appearance** assumes a central role [10] because it relates with the user both at the cognitive and emotional level [11]. The effects that it generates are strongly connected to the socio-cultural context, in which are crucial factors like the level of explosion to consumer products and rhythms of consumption [11]. In Robotics it is possible to identify two main morphological orientations: mechanical and anthropomorphic aesthetic. The first one concerns, mainly, industrial robots, in which the design is based on functionality and performances, whereas the anthropomorphism concerns, particularly, personal robots [10] in which all the human-robot interaction assume a key role. People, in fact, tend to act in a more natural and emphatic way when interact with humanized robots [12].

### 2.1 Morphology and acceptance in pop culture

The idea of robot, diffused in pop culture through comics, books, series and movies, matches, at least partially, to the scientific conceptions. In particular, from the morphological point of view, there is a sort of parallelism between real robots and those ones described by science fiction, indeed, an initial anthropomorphic trend is gradually abandoned on behalf of a more abstract aesthetic and a language diffused by digital products. Besides to the aesthetic appearance, the parallelisms concern conceptual themes, such as the already diffused and consolidated idea that robots could overtake human abilities, physically and cognitively, with the consequent risk that this widespread could drive to their taking of power at the expenses of human beings freedom. This scenario, although extreme, is widely investigated in scientific debate about ethical and legislative issues that should drive the contingent diffusion of robots in our society. The good-evil dualism assumes a key role, therefore, in the perception and acceptance of robots from people and, in pop culture, it is represented through different acting roles assigned to robots. In a first period, as shown in movies such as *Metropolis*, the robot is represented almost always as **evil helper**, anthropomorphic and extremely strong, that, in some cases, free itself from the human control and becomes a real **enemy** who threatens humanity. Afterwards, both in Asimov's novels and in many movies, robots acquire the ability to have feelings. Consequently the robot assumes, sometimes, the role of **antihero**, such as in *Blade Runner* and *RoboCop*, while in others become a good helper who collaborate with men for the salvation of humanity, as in *I, Robot*. The figure of the robot as a good helper acquires greater strength, especially in *Star Wars*, in which it is introduced an additional shift: robots are not necessarily anthropomorphic anymore, but rather introduce a mechanical aesthetics, as in the case of R2-D2. However, the anthropomorphic aesthetics is completely abandoned in the movie *Wall-E*. In this movie, moreover, the robot is not longer conceived as a perfect and indestructible machine. In fact, in this case the spectator feels strong empathy towards this small robot, ordinary as much as heroic, thanks to the fact that it shows its limitations and brittleness instead of explosive power. The robot is represented as unquestioned **hero** of the story and it's completely accepted.

### 2.2 The limits of anthropomorphism

In scientific research, as well as in pop culture, the purely imitative approach has been abandoned and emerged the limits of anthropomorphism. In particular, the famous study by Masahiro Mori, highlights the fact that although people are more likely to interact with humanized robots, there is a limit within which these are preferable to an mechanized aesthetic [12]. Beyond that limit, there is the so-called *uncanny valley* by which a robot is perceived as disturbing and repulsive. Mori compares this type of effect to the feeling you get in shaking hand with a person and realize, just by touch, that the one that you are clutching is a prosthesis. Similarly, a person that interacts with a highly anthropomorphic service robots will have at first a sense of familiarity and will tend to interact naturally, but after the first impression, the limits in the fluidity of movement, speech, and other characteristics will show the mechanical nature of the artefact, arousing in the user a strong sense of repulsion. This mainly occurs because the appearance does not manifest the true nature of the robot, tricking the user who is not able to evaluate the proper type of interaction to be adopted. At the same time, he points out how a puppet (*bunraku*) when is observed at a proper distance during a show, despite its size and its synthetic form, can achieve a high level of affinity with the observer [12]. This shows that it is not necessary to perfectly replicate the biological beings to gain acceptance by the users. In recent years, these reflections about acceptance related to the aesthetic aspects, have led to a definition of three main categories: the androids, appearing, as technically possible, similar to humans; humanoids, which are not realistically anthropomorphic but rather manifest their nature of robots despite having human characteristics and finally the mechanoids, in which is clear the mechanical nature [13].

### 2.3 From anthropomorphic to humanized

Robotics is now far away from the romantic idea of biological reproduction and in the future that lies ahead, robots will be highly diversified and increasingly less anthropomorphic. These new robotic artefacts will be, for many aspects, inferior to humans but high-skilled and most sophisticated in specific abilities [6]. In addition to physical appearance, both movement and behaviour can be humanized in order to reach the sense of affinity useful to establish an effective human-

robot interaction [14]. This affinity can be obtained, for example, through **facial expressions** and the related ability to communicate emotions, extremely useful because allows the user to understand both personality and the intentions of the robot, which results much more engaging [1]. In this sense it is an exemplary case study the robot developed by Cynthia Breazeal: *Kismet*. This can be defined as a social robotic creature, able to interact physically and emotionally with the people, in order to learn from their behavior [15]. Expressive and learning skills allow the robot to deal with a complex social environment and, above all, allow people to adjust their expectations and modes of interaction to be implemented with *Kismet*.

Another aspect that significantly increases the degree of familiarity between the robot and the user is **movement**. As pointed out by Masahiro Mori, when an industrial robot is off, is perceived simply as a machine, but in the moment it is turned on and moves the user establishes a substantial degree of affinity [12]. The fluid and articulated movements, visible especially in industrial robotic arms, evoke movements of typical in biological world and generate a sense of empathy, thanks to the phenomenon of motion interference, namely the tendency of individuals to imitate the movement of another encountered in their trajectory [16]. At the same time, however, it is necessary to bear in mind that a reduced variety of movements and high repetitiveness generate the opposite effect, emphasizing the mechanical aspect of the robot. Therefore, it is preferable to design the robot with the ability to move fluid and variable both in positions and speed.

Last but not the least important factor that influences the perception of a robot by the user, is the **formal synthesis**. Especially with regard to service robotics, products relate to humans in contexts highly characterized by the activities that take place there, from the objects that populate them to the social relationships that take place there. Then, in order to be accepted and become part of the everyday life, the robot needs a recognizable function [1] and has to refer to the environment in which is located. In the home environment, for example, robotics has become part of everyday life with great success through cleaning robots. In particular, the robotic vacuum cleaners have an aesthetic similar to electrical appliances, in which the function is declared and this generates an immediate sense of familiarity in people. Moreover, the fact that

they are perceived more as appliances than robot creates lower expectations in the user [21]. The wide acceptance that this type of robot gets is witnessed by a number of common practices among the owners of robot vacuum cleaner, many, in fact, tend to give it a name and a personality, interact with the robot, spend time to observe it or do a demonstration of its capabilities to other people [22].

The aesthetic and discreet familiarity introduced by cleaning robots in the home environment is, increasingly, also adopted in robot companions, who gradually lose anthropomorphic and zoomorphic aspects on behalf of synthetic lines and more abstract aesthetics.

In the relationship between morphology and expressiveness it is possible to identify three main characters, namely: the expressiveness, the fluidity of the movements and the formal synthesis familiar to the context of reference.

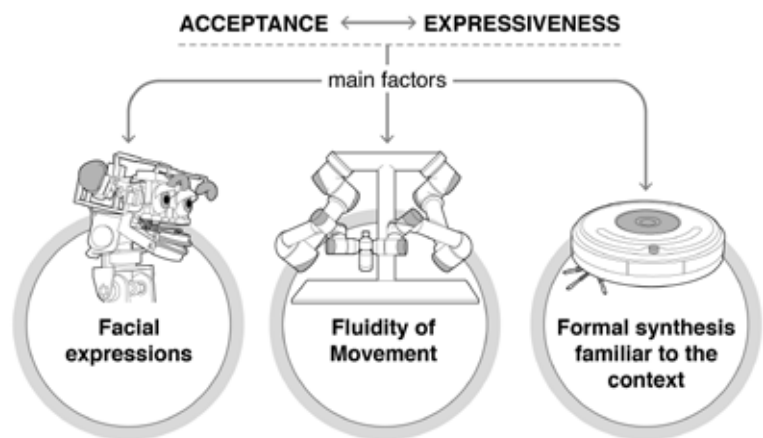


Fig. 1. Expressiveness and acceptance: main factors.

### 3 Digital world in robotic aesthetics

Nowadays, robotic aesthetics is experiencing a further evolution, as contaminated by the relationship with the digital world. The world of digital devices is becoming, in fact, more and more extensive and pervasive, besides smartphones and tablets, that almost all now have, begin to spread wearable devices and diffuse sensors, such as beacons. Each of these artefacts introduces new possibilities of interaction with humans and between humans and robots. A smartphone can then act in a case as a joystick while in another as face and distributed sensors can help robots to move into environments.

From these relationships emerge some main areas that characterize the contamination between the digital world and service robotics.



Fig. 2. Emerging trends and related factors, in contamination between Robotics and Digital world.

### 3.1 Makers e Manufacturers: from the Arduino robots to Jibo

The animation movie Wall-E shows two opposite versions of robots, on the one hand Wall-E, male figure of robot that can be ascribed to the category of cleaning robots, characterized by a mechanical and composite aspect, in fact to its original components were added or replaced components found in time. It does not have a particular strength, but is smart, clever and versatile. The other figure, Eva, is a female robot, of military matrix, that appears compact, streamlined lines and glossy surfaces. It speaks the language of digital devices and, not surprisingly, is reminiscent of products like iPod and MacBook. In fact, its design was developed in collaboration with Jonathan Ive, head of design at Apple [1]. Eva can be read, then, as an allegory of the deceptive allure of digital technologies [1]. These two figures, Wall-E and Eve, represent the dichotomy that characterizes today's world of service robotics: the maker and the manufacturer approach [6]. The

world of makers includes all those composite robots, generated by the associations of printed circuit board, 3D printed components and other available materials, such as **Arduino robots**, characterized by a total open approach, both hardware and software [19]. This approach promotes the free dissemination of the design concept, each application, indeed, is shared on web platforms in a perspective of *sharing knowledge* [19]. An example of the manufacturer approach is, instead, **Jibo**, a robot companion designed by Cynthia Breazeal. Jibo is a small family robot, able to observe, recognize faces, take photos, interact via speech, learn from user behavior and communicate emotions. Its functions are not very different from those of a smartphone, in fact to it are entrusted mainly communication activities, but to these it adds the execution autonomy and the ability to orient itself according to user. This object is, therefore, inseparable from the digital world. Familiarity and engagement, even in this case, are obtained through the expressiveness, taking advantage of the results matured in the project Kismet. While this robot does not imitate in detail the face expressions, it is extremely effective in communication because it uses synthetic, and already familiar, expressive language [20]. Jibo is not able to move around the environment but is able to orientate itself due to the three axes of rotation placed in his body, appears in fact as a head with a neck able to move towards its interlocutor. Also from the aesthetic point of view it is extremely familiar. Jibo, in fact, seems perfectly in line with the objects of everyday life, it is reminiscent of the modern aesthetic typical in cult objects of design history, as the lamp Eclisse by Vico Magistretti, and it is, avowedly, inspired by robots of pop culture like R2-D2 and Wall-e. In particular it reminds the figure of Eve, also from the Wall-E movie, in its streamlined shapes and glossy surfaces.

### 3.2 Towards a new humanization: Double

In some cases a robot reaches a high level of acceptance in the moment in which manifests its function and is in line with the context in which it is located, but there are cases in which the high level of engagement can be reached through charm. This is the case of the telepresence robot **Double**, that consists of a base similar to a Segway on which is inserted a pole with support for iPad. Its function, in fact, is to allow a person to participate in an event of various kinds (business meetings, medical, school lessons) via

streaming video and differs from a traditional video conferencing for the ability to move in the environment. The Double arises from the digital world, integrating the ability to move into an existing service. However, the charm of this robot is achieved through the expressivity. Its morphology reminds the human one, but dematerialized [21]: the slender structure supports a sort of head (tablet) and the wheels represent the feet, which give it an apparent fragility and generate a gentle oscillatory motion. It is precisely the sense of precarious balance, combined with the archetypal morphology of human skeleton, which makes this robot fascinating and highly accepted. In addition, this robot, thanks to its function, represents also the overcome of the human-robot interaction on behalf of the human-robot-human interaction. The head, represented by the tablet, allows a physical dematerialization on behalf of the virtual, in which the empathy is entrusted to the multimedia communication.

### 3.3 The parasitic approach: the Romo robot and the Draghe project

The ability to connect a digital device to a robotic artefact is a phenomenon in large rise and can be ascribed within the concept of parasite robot [22]. The phenomenon of parasitism, in fact, concerns solutions, robotic or not, that works by exploiting the capabilities of others, called guest. In this parasitic relationship, the two identities are distinguished primarily on the basis of cognitive and motor abilities. It is possible to identify, in fact, two main types of robot parasite: robotic devices with movement ability whose cognitive part is assigned to a device, such as the smartphone, and smart devices that are attached to mobile robots, to expand their cognitive abilities. The robot **Romo**, for example, consists of small crawler that only works if hooked to an iPhone, on which it is installed an app that manages the movement, allows to make video calls and acts as the face of the robot, which acquires, thus, expressive skills. In the project **Draghe** [22], instead, is proposed the idea of creating a robot companion by adding an intelligent module to a robotic vacuum cleaner, taking advantage of both the increasing spread of the robot vacuum cleaner and from their high level of acceptance. This second case generates, also, an unpredictable aesthetic, since the composite and open nature of the robot.

### 3.4 Virgil: between contextualization and customization

The concept of formal synthesis familiar to the reference context is at the basis of **Virgil** [23]: tele-presence robot designed as part of a project that aims to promote cultural heritage, in particular the network of Savoy's royal residences. Royal Residences are rich and, at the same time, delicate contexts, where take place two main activities: the preservation and fruition [24], which in some cases are incompatible. There are, in fact, areas excluded from the tour, mainly, because of the state of conservation. The service proposal consists of an extension of the tour through a real-time virtual tour, made possible by the robot placed in inaccessible areas. The remote control of the robot is entrusted, mainly, to the museum guide but also to the visitors to experience a cultural game. For this purpose, the team has designed a mobile robotic platform, equipped with a camera that sends a streaming video displayed to users on a special screen or on personal devices.

Similarly to Jibo, designed with the aim to be accepted into home environment, the robot Virgil has been designed taking into account the **artistic and cultural context** in which have to be inserted. The cover is made of PMMA (poly-methyl-methacrylate) and is composed in a shape of truncated pyramid, reminding to the similar shape largely diffused in Savoy tradition, used in obelisks, bollards and other architectural elements or furniture. The choice of a transparent material is determined by two requirements: from the technical side, it was necessary to ensure maximum lightness and from the acceptance point of view was essential that the robot does not catalyse the attention of visitors distracting them from the cultural goods. Therefore, this project tries to go beyond the formal synthesis by introducing the concept of **customization based on the context**, consisting in a decorative pattern applied on the robot coverage, that varies on the base of the location. In this case the decoration represent the Palagianà palm, an already existing decoration that can be found in the castle. In particular, when the service will be extended to other residences it will assume in every location a slightly different image.

In addition, the robot Virgil appears as an open platform, whose functions and components (such as camera, speaker, LED, photovoltaic panels ...) can be replaced or simply added, outlining a new world of multitasking robots.



Fig. 3. Robot Virgil with a particular of Palagian palm, 2014.

#### 4 Conclusions

In the near future there will be a strong spread of service robotics, which will affect, almost, every aspect of daily life and generate growing concerns [25]. For this reason it is necessary to put the community, its needs and social habits at the centre of the design process. Putting people at the centre of the project means, therefore, analyse and improve as much as possible the degree of acceptance of the robot, dealing with the three main requirements: **empathy**, through the expressiveness and similarity; **engagement**, through the use of simplified language and imitation of movements similar to those of the biological world and, finally, **collaboration**, based on the task performed by the robot and the consequent perceived usefulness.

#### References

1. Montgomery C., 2011. Woody's roundup and Wall-E's wunderkammer. *Technophilia and nostalgia in Pixar animation*. Animation Studies, Vol. 6. Nicola Dobson.
2. Germak C., 2008. Man at the center of the project. Design for a new Humanism. Umberto Allemandi & C., Torino, Italy.
3. Longsdon T., 1984. The robot revolution. Simon & Shuster, Inc., New York.
4. Sacripanti A., 2008. Robotica (2007). La Robotica nel Mondo, il Mondo della Robotica. Stato della Robotica Mondiale. Report ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development).
5. Giuliano L., 2014. Roboethics design: how cultural approach design could change the robotics human interaction. Proceedings of the workshop: Connected Service Robotics for Telecommunications Operators. The 13th International Conference on Intelligent Autonomous Systems, IAS 13, July 15-19, Padova, Italy.
6. Rotman D., 2013. The difference between makers and manufacturers. MIT Technology Review, January 2, 2013.
7. Salvini P., Laschi C., Dario P., 2010. Design for Acceptability: Improving Robots' Coexistence in Human Society. *International Journal of Social Robotics*, 2, Springer.
8. Dillon A., 2001. User Acceptance of Information Technology. In W. Karwowski (ed). *Encyclopedia of Human Factors and Ergonomics*. Taylor & Francis, London.
9. Rogers E. M., 1995. Diffusion of Innovation. 5th Edition. The Free Press, New York.
10. Walters M. L., Syrdal D. S., Dautenhahn K., Boekhorst R., Koay K. L., 2007. Avoiding the uncanny valley: robot appearance, personality and consistency of behavior in an attention-seeking home scenario for a robot companion. *Autonomous Robots*. Springer.
11. Forsythe S., Kim J. O., Petee T., 1999. Product cue usage in two Asian markets: a cross cultural comparison. *Asia Pacific Journal of Management*, vol 16. Wiley & Sons.
12. Mori M., 2012. The Uncanny Valley. *IEEE Robotics Automation Magazine*, June 2012.
13. Gong L., Nass C., 2007. When a talking-face computer agent is half-human and half-humanoid: human identity and consistency preference. *Journal of Human Communication Research*, 33, Wiley & Sons.

14. Dario P., Guglielmelli E., Laschi C., 2001. Humanoid and Personal Robots: Design and Experiments. *Journal of Robotic Systems*, Wiley & Sons.
15. Breazeal C., 2003. Toward sociable robots. *Robotics and Autonomous Systems*, 42, Elsevier
16. Kupferberg A., Glasauer S., Huber M., Knoll A., Brandt T., 2001. Biological movement increases acceptance of humanoid robot and human partners in motor interaction. *Artificial Intelligence & Society*, Springer.
17. Forlizzi J., Di Salvo C., 2006. Service robots in the domestic environment: a study of the Roomba Vacuum in the home. HRI'06, March 2-4, Salt Lake City, Utah, USA.
18. Sung J. Y., Grinter R. E., Christensen H. I., Guo L., 2008. Housewives or technophiles?: understanding domestic robot owners. HRI'08, March 12-15, 2008. Amsterdam, Netherlands.
19. Chorianopoulos K., Jaccheri L., Nossum A. S., 2012. Creative and open software engineering practices and tools in maker community projects. EICS'12, June 25-26, 2012. Copenhagen, Denmark.
20. Salah A. A., 2014. Natural multimodal interaction with a Social Robot: what are the premises? RFMIR'14, November 16, 2014. Istanbul, Turkey.
21. Marras L., Mecacci A., 2014. La sparizione del design. *Aisthesis. Pratiche, linguaggi e saperi dell'estetica*, Firenze University Press.
22. Lupetti M. L., 2014. From a robotic vacuum cleaner to a robot companion: acceptance and engagement in domestic environment. HRI'15, Extended Abstract. March 02-05, 2015. Portland, OR, USA.
23. Germak C., 2014. From the interview of Strappavecchia M. C., *La Robotica nei Musei*. L'Indro, 17 November 2014. <http://www.lindro.it/0-cultura/2014-11-17/158271-robotica-musei>
24. Barile S., Saviano M., 2012. From the Management of Cultural Heritage to the Governance of Cultural Heritage System. *Patrimonio culturale e creazione di valore*, Verso nuovi percorsi, Cedam, Padova.
25. Nourbakhsh I. R., 2013. Robot futures. The MIT Press.

# Interaction, the core of User Experience

## Abstract

This paper constitutes an exhaustive state of the art focused on the understanding of interaction design in user experience design. The topic and this ongoing research come within a long-term work on Kansei Design, Experience Design and now Interaction Design. The aim of this paper is to present a wide bibliographic basis on Interaction in User Experience in order to compare, structure, highlight and propose a better understanding and a new definition of Interaction during early design phases. Through this state of the art, we suggest that different contexts of user experience imply different ways of integrating aspects of physical and digital interaction. Indeed, that parameter of interaction truly impacts experiences that users are living with their artifacts. That is why this paper constitutes a global understanding of Interaction in User Experience, encompassing definitions, models and authors presented hereafter.

## Keywords

Kansei design, interaction design, user experience, tangible interaction, digital interaction

## Introduction

In the literature, User Experience is presented as a multi-faceted phenomenon that involves manifestations of different kinds of reaction presented as 'Interactions'. This paper aims at understanding which components

characterize an Interaction from a User Experience point of view. Indeed, if many authors approached the notion of User Experience, defining it is still a complex task because it depends of the context in which the research takes place. So how to consider User Experience from an Interaction Design field, and how to characterize Interaction occurring in User experience?

In this paper, we introduce a general framework for user experience that applies to all interactive responses that can be experienced. It constitutes a focus on both the physical and the digital side of interaction, that authors mentioned in this paper, used to call the User Experiences.

The experience the user is living with a product has been studied for few years. Many models and frameworks tend to focus on specific issues with User Experience, focusing and highlighting various parameters. There are the direct consequences of the extraordinary relationship between a user and a product. This variety of views is of value for a thorough understanding of what User Experience is. The way we consider User Experience starts from the two main components of Experience: the user and the context. This part is defended in the section named '**1 Experience**'. Then, by implementing the notion of artifacts, in the section '**2 Experience and Artifact**', it transforms the simple Experience in a User



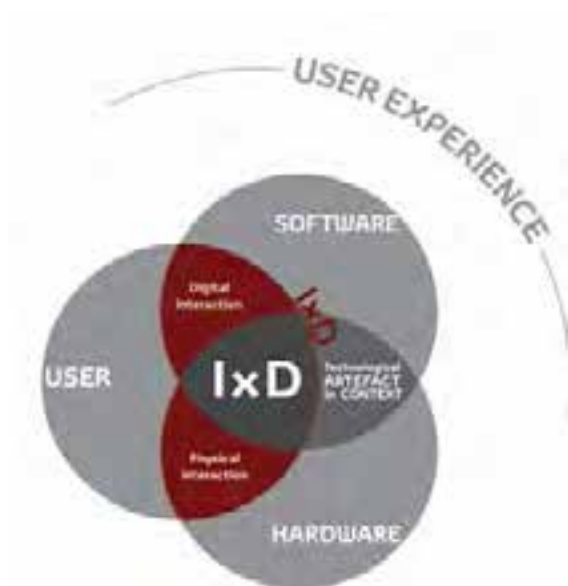


Figure 1: Model of User Experience

Experience argued in **'3 User Experience'**. Then, the section **'4 Interaction'** focuses on the relation between User and Product in User Experience. And finally, the last section proposes to open on the future of Interaction both from the industrial and the academic sides: **'5 discussion'**.

## 1. Experience

The aim of this section is to understand what is an Experience, and what is it composed of. In order to reach this goal, we suggest to firstly define the two main components of an Experience presented by Ortiz and Aurisicchio[1]. These components are the User and the context. Indeed, we can acknowledge that an Experience is lived by the **User**. According to Desmet and Hekkert [2], Experience is not a property of artifact, but the outcome of the User. Secondly, we can acknowledge the relevance of the context in **Experience**. Indeed, Parrish's work [3] highlights that an Experience is highly contextual. Those two elements are proposed in this chapter as the key components of an Experience. Finally, this chapter proposes to highlight several notions that those two elements involve: such as temporality or subjectivity...

### 1.1 User

The User, or consumer, is the one who pays or just use and consume the goods and services produced [4]. The user brings to the interaction with the artifact a set of systems affecting the assessment of the User Experience. Example: senses [5-6] motor skills [7];

values [8]; expectations [9]; needs [10]; personality traits [11]; individual sense of fun [12]; and attachment [13]. All those parameters affect the user and allows him to perceive something. In their work, Helander & Khalid [14] thought that people perceived a stimulus through two systems: affective system and cognitive system; both systems are not separated. Affective system relies on cognition and vice versa [14].

### 1.2 Context

Hutchins mentions that context is not a fixed set of surrounding conditions but a wider dynamic process where the cognition of an individual is only a part [15]. Later and in the same way of thinking, Forlizzi [16] mentions that context is understood as a complex, dynamic set of factors: social, historical, cultural, and institutional [16]. It is also supported by Parrish [3]: he defends that an experience is highly contextual and depends on several factors. Indeed, context is often described by scholars as a five broad types that are: physical, social, cultural, situational, and temporal [17-18].

Finally we can acknowledge that the relevance of the User and the Context in Experience is no more challenged. Nevertheless how it influences Experience is still a strong field of research. The following part highlights two characteristics of Experience based on the influence of both the User and the context side:

### 1.3 Experience's characteristics

#### a) Subjective (because it is based on the User)

According to Overbeeke [19], an Experience is based on several senses. For example in his work he highlights that the taste is link to our ability to see. Furthermore, he has characterized Experience as holistic. Indeed, all of those ways to identify stimuli are ways to provoke user's reactions [14]. Thus, reactions of the user in front of a stimulus create specific changes according to Gil [20] (behavioral, cognitive and physiological changes). What is interesting is how people can react differently to a stimulus. Indeed, it affects the internal state of the user, so it can be lived differently by different people according to Schifferstein and Hekkert [21]. And the way we can all respond differently to the same stimulus is all about subjectivity. For example emotions are some of those unpredictable reactions specific to the user. Several strong fields are working on this subjective understanding of reactions of the User in Experience.

The Emotional Design field [2;22], the Affective Computing field [23] or the Kansei Engineering field [25-26]

We can develop one of these fields as an example of the impact of subjectivity in Experience: Kansei is a discipline which regroups three under-domains according to Pierre Levy. The kansei engineering (industrial process), the kansei science (sensation measure) and the kansei design. The notion of 'Kansei' brings to the 'design definition' a strong focus on human emotions. Kansei engineering is originated from Japan and progressively also appears in design science, including Harada [25], Nagamachi [26], Schütte [27]. Then, Several European researchers have proposed theories and models in order to understand emotion in design [2;22;28]. In a broader view, Kansei could be slightly considered as a human psycho-cognitive process related to human experience [24].

Thus, we can consider Experience as subjective and holistic, because it is based on the User and his ability to rely with his cognitive and affective systems.

#### **b) Temporal (because it is contextual)**

According to several authors, an Experience is temporal. This temporality highly impacts how the User is going to live his Experience, is living his Experience, and has lived his experience. These three temporalities are supported by several authors through various appellations: Parrish [3] presents them through these three stages: Experience is 'composed' or 'constructed' (Experience expected); 2 Experience 'un-folds over time' (experience lived); and finally 3, Experience is historically situated (experience remembered). Furthermore, Krippendorff [29] has also worked on this temporality. He based his works on Poole and Folger researches [30] to highlight three simplest temporalities in experience: firstly, the 'Observing' phase; then, the 'interfacing' one; and finally, the 'anticipating' phase, corresponding to the narrative one. What is interesting is how this temporality highlights three distinctive phases. The 'observing' one can correspond to all visual interaction with something. The 'interfacing' could be associated with the physical relation with the same thing. And finally, the 'anticipating' phase could be associated with the way the user relates his experience, or more interestingly, could be associated with the designer's works. Indeed, as supported by Hassenzahl [10]; Vial [31]; Desmet and Hekkert [22]; David Kelly

[32]...The Experience should be considered as the core of the design process. It reflects the approach called "Experience Design" or "User experience goal driven design" [33-34]. It suggests that "Experience goals" should be defined in the very beginning of the design process. In other words, designers should, in principle, first choose what kind of emotion the design should support and after this product related design ideas could be generated [35]. So finally, designers role is to define the 'anticipating' phase at first (as the narrative phases), to finally design the two other phases (Observing and Interfacing). But this is only relevant for Experiences that are designed.

#### **c) Conclusion on Experiences:**

After this presentation of these two main components, we can define an experience as the correlation of the User within a specific Context.

Experience is felt, not just observed or reflected upon. An individual's relationship to the situation at a given moment, before rational analysis and when affective influences hold at least equals way to cognition, is a critical factor in the ultimate value attached to it. The qualities of immediate experience can color all other aspects, determining the entire Experience. Thus, we can highlight Experience as subjective, and temporal, involving the entire set of User and contextual parameters, such as culture, habits, skills, value, personality...

Thus, we can define experience as a subjective and temporal phenomenon lived by the User in a particular context.

In the following section we will discuss experiences if we add an artifact. Indeed, by considering Artifact as the designer's creation, the 'narrative temporality' really makes sense.

## **2. Experience and artifact**

Implemented a product in an experience is an opportunity to influence the experience that users are living. In design, we can highlight **three kinds of effect**, presented by Vial [31] based on his sentence: « Design is not products field, but effects field ». In other terms, the real importance in design is not the appearance of the product, but its ability of producing effects conditioning the Experience. Design is nothing else than a generator of experience to live through products [31]. It consists in specifying an artifact. Indeed, the main

goal for Designers should not be designing product, but the User Experience itself should be in the core of the design process [36].

Thus, current research on User Experience has referred to the artifact through the following terms: product, object, item and system. An artifact is an object made by a human being that performs technical and non-technical functions, e.g. social and aesthetical [37-38].

When looking at the definition of Artifact's System through authors, we can notice that Artifact can be considered as a double side system: the first one corresponds to all 'Artifact's characteristics': Hassenzahl [39], and more recently Minge [40], call it the instrumental, or the 'pragmatic' qualities of the Artifact. It refers to performance and pure usability aspects. Ortiz Nicolas and Aurisicchio [1] and Crilly [38] present it through what they call the 'technical' side of the product. Finally, Dias [41-42] refers to 'physical attributes' of the product. It refers to form, scale, volume, color, material, texture, brightness, sound, smell and other very concrete elements of the Artifact. More recently Gentner [18] and Mahut [43] highlight that if concrete elements of the artifact can be easily considered as what is designed. We could also consider abstract dimensions of the Artifact as attributes that are decided in conception [28]. For example Style, functions and sector of object are some of those abstract elements that are indirectly designed. Amic G.Ho [44], in his work dedicated to Emotional Design, has approached and tentatively explained this abstract conception through what he calls 'the emotionalized

design'. It corresponds to the second part of Artifacts systems: the perceived artifact. According to Gibson [45], it would be a categorical mistake to describe the physicality of things separately from how we perceive and act on them. Indeed, Gibson made the profound suggestion that we perceive not the physicality, but what the product affords us to do. Thus, we previously highlighted that artifacts' system is designed as Characteristics, through attributes (concretes and abstracts attributes). Moving on, this part is the relation of the User with the product through all dimensions that it implies. For example, Dias [41-42] created a method called the Perception of materials by Users (Permatius) where is listed 58 subjective attributes. Through his method he suggests that a Product is composed of Physical Attributes. But he also describes Products as 'Practical Attributes', 'Symbolic Attributes' and 'Aesthetic Attributes'. By doing that, Dias highlights the 'qualitative perception' of product when the user is interacting with it: through pleasure and effectiveness ('Practical attributes'); through esteem, psychological and social aspects ('Symbolic attributes'); and finally through aesthetic impressions that are felt ('Aesthetic attributes').

So we clearly see the link between Artifact systems that are created by the designer, and the way the user perceives this system. The table 1 summarizes authors definitions of this relation between what we named 'Artifact Characteristics' and 'Perceived Artifact ' within the full Artifact's System.

Finally, the Experience can be managed and conceived if we implement a designed artifact, giving the opportunity

ARTIFACT SYSTEM	[46] Norman		[47] Jordan	[41-42] Dias	[1] Ortiz Nicolás, Aurisicchio	[39] Hassenzahl [40] Minge
	Artifact Characteristics			(Physical attributes) physical elements, form, scale, volume, color, material, texture, brightness, sound, smell and others	Technical related to what the product is related to (Crilly 2006)	Instrumental "pragmatic" qualities refers to performance and pure usability aspects
	Perceive Artifact	Cognitive, mental and emotional reaction of individuals and behavioral design	Psychological pleasure	Practical attributes related to the use in terms of pleasure and effectiveness		
		Perceptive design	Social and Ideological pleasure	Symbolic attributes aspect of system, psychological and social	Social related to the social context of the user in the artifact system through the system's contribution to the perception of artifact (Hassenzahl 2008)	non-Instrumental Technical qualities refers to beauty, visual aesthetics, identification and stimulation
		Universal level design	Physiological pleasure	Aesthetic attributes aesthetic impression that is felt about an object through the senses	Aesthetic related to the aesthetic reaction of the user in the artifact system through the system's contribution to the perception of artifact (Hassenzahl 2008)	

Table 1: Artifact Understanding

to impact, influence or even create particular Experience with the User. This field of research is called the ‘User Experience’ by opposition to Experience (where there is no artifact conception).

Thus, we saw what a User Experience is composed of: User+Context+Artifact. In the following section, we propose a focus on the User Experience and its affects.

### 3. User Experience in early conception

The most relevant view of User Experience has been recently presented by Ortiz Nicolás & Aurisicchio [1] and also supported by Gentner [18]. It offers a broad view on the essential element previously presented. They defend that the user experience is determined by many factors, which interact with one another in a complex way. Four elements characterize the User Experience:

- The user's internal state (predispositions, expectations, needs, motivation, mood, etc.)
- The characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.)
- The context (or the environment)

And the interaction occurring in the context (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use, etc) [18]

Indeed, as we saw previously, a simple Experience plus an artifact is now what many researchers call the User Experience [48-54]. The definition we will use in this paper comes from Desmet and Hekkert's work. They define User Experience as following: User Experience is a change in core affect that is attributed to human-product interaction [22]. But, some researchers do not want to talk about user experience but plain experience [54] so the definition should state on how User Experience differs from Experience. From definitions of various authors, we tried to identify the components of the User Experience. We summarize what we found through the table 2 (below).

This table highlights that the Experience becomes a User Experience when considering the designed Artifact in the global system. Furthermore, it also highlights that the Artifact is bringing several interesting characteristics in the User Experience: interaction, action and interface are some of the defended fields that the Artifact is involving. Indeed, the scope of fields surrounding the Artifact is broad, thanks to the number of characteristics that the relation between the user and the Product involves. Indeed, we perform activities with them, we express part of our identity with them, and

USER EXPERIENCE						
	Definition of User Experience	Involves a user?	Involves an artifact?	Involves a product?	Involves an interaction?	Involves an interface?
[22] Desmet and Hekkert	A change in state affect that is attributed to human-product interaction	yes	yes	yes	yes	not necessarily
[56] Roto	Involves a product or a service	yes	yes	yes	yes	yes (feedback)
[37] Hassenzahl	UX is a consequence of a user's internal state, the characteristics of the designed system and the context, within the interaction occurs	yes	yes	yes	yes	not necessarily
[1] Ortiz Nicolás & Aurisicchio	The overall appraisal, judgment or evaluation of the subjective and conscious encounter that the user has with an artifact through interaction, occurring in a particular context and time	yes	yes	yes	yes	not necessarily
[53] Hassenzahl & Tractinsky	User internal states plus characteristics of the designed system	yes	yes	yes	yes	not necessarily
[50] Mäkelä & Fulton Suri	A result of motivated action in a certain context	yes	yes	yes	yes	not necessarily
[18] Gentner	Subjective and affective outcome of a situation in which a user interacts with a product or service in a defined environment	yes	yes	yes	yes	not necessarily
[46] Norman	User experience encompasses all aspects of the end-user's interaction with the company, its services, and its products.	yes	yes	yes	yes	not necessarily
[55] Law & al	User experience focuses on the interaction between a person and something that has a user interface	yes	yes	yes	yes	yes
[54] Forlizzi and Battarbee	User experience focuses on the interaction between people and products, and the experience that results	yes	yes	yes	yes	not necessarily
[22] Desmet and Hekkert	Product experience is used to refer to all possible affective experience involved in human-product interaction	yes	yes	yes	yes	not necessarily
[40] Allen	All the aspects of how people use an interactive product (starting from their training, how and they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it)	yes	yes	yes	yes	yes
[58] Sheldoff, online	The overall experience, in general or specific, a user, customer, or audience member has with a product, service, or event	yes	yes	yes	yes	not necessarily
[49] IJOC	Every aspect of the user's interaction with a product, service, or company that make up the user's perceptions of the whole	yes	yes	yes	yes	not necessarily
[59] Nielsen-Norman group	All aspects of the end-user's interaction with the company, its services, and its products.	yes	yes	yes	yes	not necessarily
[60] Wikipedia	The overall experience and satisfaction a user has when using a product or system	yes	yes	yes	yes	not necessarily
[53] Hekkert and Schillestein	An experience is subjective: it depends of psychological effects elicited by the interaction with the product.	yes	yes	yes	yes	not necessarily
[51] Krippendorff & Butler	We experience artifacts by interacting with them	yes	yes	yes	yes	yes

Table 2: User Experience components

we use them as a mean to interact with other people. According to Susi and Ziemke, the role of artifact cannot be ignored when looking at human activity [15]

In the previous chapter we already approached the notion of Kansei through kansei Engineering and Kansei Science. Here, in this chapter mainly dedicated to product, and so to conception, we can approach the Kansei Design understanding. We admit in our study that Design information consists of different levels: high-level (values, semantic words, analogy, and style), middle-level (sector name, context, and function), and low-level information (color, form, and texture) [28]. Thus, Kansei is a subjective process that enables to link high-level information with low-level information [17;18;28]. So our goal is to work on how to reflect and translate Kansei understanding into product design experience. In order to do so, identifying how products affect, physically or virtually, our experience through interactions in early design is a decisive challenge for both the industrial and the academic world. Indeed, according to Hassenzahl and Tractinsky [51], the objective of Interaction Design in the future is to contribute to our quality of life by designing for pleasure rather than absence of pain. Interactions in User Experience is all about this idea.

To conclude this section, we admit that what differs from Experience to User Experience, is the addition of a designed product, with the entire set of effect that this interaction implies.

The following part focuses on this Interaction's part, as the core of the User Experience.

#### **4. Interaction Design**

As described previously through Ortiz & Aurisicchio [1] User Experience is the link between User, Artifact and the Context in which they all take place. We also saw that this User Experience is considered as subjective and holistic thanks to Overbekke researches (and supported by many other such as Desmet and Hekkert [22], Norman [40]...) because it is both composed of high-level information with low-level information [17;28]. Furthermore we also highlight the temporal dimension based on Krippendorff [29]. Some recent works have made a concrete link between User Experience and Interaction [18;57]. Nevertheless, the relation between User Experience and Interaction is still difficult to identify, because of its youthfulness. So

how to define interaction in order to state on the right balance between User Experience and Interaction?

Interaction is the action accomplished by the user or by the artifact on each other that influences or modifies the User's motor, perceptive, cognitive, and affective systems [20]. Interaction can be physical, (driving a car) or non-physical (contemplating a car) [51]. Interaction binds User, Artifact and even the Context [18;62]. Furthermore, according to Desmet and Hekkert, interaction refers to instrumental interaction (function), but also to non-instrumental (no function), and even to non-physical interaction (no touch). Because each of these consequences can generate physiological, motivational or motor's responses [22;63]. So, we consider interaction as a dialogue between user and product (service or a system), in a particular context. And this dialogue is not specifically based on the use of an advanced technology. Interaction surrounds the Design process which creates a way to make it easily usable, useful, desirable and profitable relation with product. During the early stages of design, designers tried to respond to a given design brief, and find the good conception. It is because the product plays a critical role as a precursor to consumers' cognitive and affective responses [64].

Thus, if the User Experience is defined by the Interaction between the User and the Product, understanding how interactions are living by the User is decisive for product's conception. The following part highlights and considers independently the two dimensions of products in interaction the physicality and the virtuality through the notion of Interfaces. Indeed, as our research focuses on the two notions of Hardware and Software in interaction, we inevitably define the notion of 'interface'. Because 'Interface' means, at the origin, a surface as a frontier between two bodies according to Vial [31].

##### **4.1 Interfaces**

Even if this expression is global, it is often used in informatics terms to define the junction between two systems. This device determines concrete conditions of this interaction between human and machine (HCI: Human Computer Interaction). It refers to the exact place where two systems are sharing information, communicating and so, interacting. These conditions include physical (screen, mouse, joystick...) and digital

elements (programs, application, Operating system...). The relation between hardware (physical) and software (digital) is transcribed through interfaces (Graphic User Interfaces) [31].

Computers are the most complicated machines ever created. Its complexity is so huge that Human created an interface to be able to interact with them. Thus, screens have been created because of our inability to interact directly with computer. So how are we supposed to see the future of screen? Recent progress in hardware technology has brought that computers are small enough to be carry or even worn. These new computers, however, preclude traditional user-interface techniques such as Graphical User Interface or desktop metaphor [65]. « How sad that our connection to computers is 'sensory deprived and physically limited'. Visual displays are gradually improving, but our sense of touch is limited for most of the time to the feel of the keyboard and mouse (...) Can we go beyond x, y and z and make more use of the time dimension? » [52]. Recent researches have approached new ways to interact through our senses. For example Mousette [66] proposes haptic interfaces; recent MIT researches define new sound desktop; smell research are already approach in User-experience and marketing... and even new way to feel and experience are developed through our back sensors [67]...

Thus, Interaction in User Experience is approached as a field materialized through interfaces and opportunities to capture our senses. Through this research, we approach every human sense by focusing on the relation between physical and digital parameters.

#### **4.2 Tangible and Digital Interfaces, a first approach**

What about things "able of being perceived, especially by the sense of touch" '**Tangible**' things [68]. This term refers to interfaces influencing human sensations of an engagement with the physical world. The realm of tangible includes both haptic, visual, and audible engagement with graspable physical things, as well as ambient senses of light, warmth, vibration, motion, and so forth [66]. Tangible entities, which physically embody the digital information and interfaces, they represent. For example Ullmer [69] worked on the concept of physical icon or "phicon". It physically embodies both the digital content and the means for manipulation of its digital associations; thus seamlessly coupling virtuality and physicality by embodying both at once[69].

Today, interactions with digital information are now largely confined to Graphical User Interfaces (GUIs), thanks to Xerox 8010 Star System [70]. However, interactions with pixels on these Graphic User Interfaces are inconsistent with our interactions with the rest of the physical environment where we live. When we interact with the Graphic User Interfaces world, we cannot take advantage of our dexterity or utilize our skills to manipulate various physical objects. So our User Experiences with digital products are limited, until we address the notion of physicality in user interfaces.

#### **4.3 Tangible User Interfaces**

Tangible User Interfaces (TUIs) are built upon those skills and situate the physically-embodied digital information in physical space. The design challenge is a seamless extension of the physical affordances of the objects into the digital domain [71].

Tangible User Interfaces aim at taking advantage of these haptic interaction skills, which are a significantly different approach from Graphic User Interface. The key idea of Tangible User Interfaces is to give physical forms to digital information [72-73]. The physical forms serve as both representations and controls to their digital counterparts (see Hiroshi models of GUI and TUI). Tangible User Interface uses tangible physical forms that can fit seamlessly into users' physical environment [74]. Furthermore, the tangible field of products encompasses other strong fields of research such as 'peripheral interaction' [75-76]; 'Shape changing interfaces'[78]; 'Haptics' [66]; Or even 'Radical Atoms' [74]...

Following this opposition of tangibility versus virtuality, it is clear that tangible interface is an opportunity to increase User Experience. However, we have learned that Tangible User Interfaces are limited by the rigidity of "atoms" in comparison with the fluidity of "bits" [78]. In order to face this challenge of creating 'physical virtuality', they presented the vision of « Radical Atoms ». Radical Atoms is a computationally transformable and reconfigurable material coupling with digital model and dynamic physical forms. They also present in their work a 'requirements list' for Radical Atoms development. It shall be able to transform its shape; to conform to constraints, and finally to inform their ability, in order to utilize dynamic affordance as a medium for representation, while allowing bidirectional input

to control the shape and thus the underlying computational model [78].

Thus, the relation between Physical and Digital Interaction is a broad field of research, encompassing many notions borrowed to Affective Computing, Kansei Design, Emotional Design, ergonomic, Interaction, User Experience, Neuroscience, psychology and other strong fields of research...

## 5. Discussion

In the last century, developments in material science, fabrication processes, and electronic miniaturization have dramatically altered the types of objects and environments we can construct [79]. Today more than ever, interaction is becoming a real challenge for industry. In this section we discuss the future of interaction both in the industrial context as in the academic one. Firstly we suppose a natural evolution of interaction in our daily lives, and finally we try to understand how new ways of interacting can improve new User Experiences.

### 5.1: Natural evolution of interaction

Product is central in our User experience. Years after years our languages to interact with products have evolved. We propose hereafter a parallel between dimensions of how the world is made and our language of interactions. The 'one dimension' (1D) is about words and poetry. The 'two dimensions' (2D) states on physical elements like painting, typography... and digital elements like screens with diagrams and icons... The 'three dimensions' (3D) is languages of physical, sculptural form and augmented product by coupling bits with physical objects. These 'three dimensions' is a good start for us to understand the link between physicality and virtuality. And then there is the 'four dimensions' (4D). Here is about physicality and time. It includes sound, films, animations, movement and changing states. These 'four dimensions' bring us closed to Lakatos and Ishii's thoughts about products in their ability to change their shape and evolve physically in the same way as pixels are evolving. Could these 'four dimensions' be an evolution for interfaces?

After this dimensional reviewed through interaction, we observe that the possible evolution of interaction could be bind to 'tangible interfaces'. Recently, tangible interfaces have started to make use of shape change

as a way to embody digital information. While most of these interfaces provide interesting interactive possibilities, we have just begun to scratch the surface of how to use form transformation as a tool for communication and expression [80]. This new generation of shape-changing materials is materials that undergo a mechanical deformation under the influence of direct or indirect electrical stimuli. These new generation of products are dynamic by nature, in addition to the static properties that we find in other conventional polymers or alloys. That is why their nature and their capacity of being one thing then an other open a huge area of opportunities to rethink the way we interact with technological products.

### 5.2: Tangible interaction to improve user experience

In the field of Human Machine Interface, the perspective of interacting with tangible interfaces is a way to consider material as pixel. Few years earlier, materials were seen by Polhem as static substrates from where to build complex systems, rather than dynamic and responsive elements, which could change their properties on demand and adapt themselves to ever-changing design requirements [81]. Today, forms and their ability to change their nature are the result of a harmonious orchestration between elements with disparate and changing physical properties. This ability allows the human being to have an access to more than one sense during interactions. What Moggridge deplored when he was speaking of interaction « How sad that our connection to computers is 'sensory deprived and physically limited' », could be over. The relation with tangible interfaces could metamorphose the way we dialogue with product by including senses of touch, gestures, feelings, enclosure, manipulations... etc... improving and developing feedback, sound, environment adaptation...etc... These modifications of our relation to interfaces could also improve and increase our emotions during interaction. That is a major intention for Industrial early design, and especially for Kansei Design process.

## 6. Conclusion

This paper is our references' organization based on several researches, models, and definitions. The framework of product experience that was proposed in this paper states on User + Artifact + Environment,

where Interaction is the core of our system. It supposed that Interaction can be considered as an Experience is: holistic, subjective, affective, cognitive and temporal. Thus, we propose to consider Interaction as a decisive way to increase the User Experience in terms of emotions and sensations. This view of interaction is a broader way to consider the field of research dedicated to User Experience.

We will conclude this paper with the following analogy: the first time a man has decided to fly, he used the language of birds, and today, the human race has found its own one. We think that our way of interacting with technological product is still in the equivalent stage than early aviation. Instead of using the 'bits', let's create our own language based on our full senses.

### Acknowledgment

This research is supported by the CPI Laboratory of Arts et Métiers Paristech and the Kansei department of Toyota Motor Europe that I would like to thanks for their trust and support.

### References

- 1 Ortíz Nicolás, J.C., & Aurisicchio, M. 2011. A scenario of user experience. In S. J. Culley, B. J. Hicks, T. C. McAloone, T. J. Howard, and P. Badke-Schaub, *Proceedings of The 18th International Conference on Engineering Design (ICED 11), Impacting through Engineering Design: Vol. 7. Human Behaviour in Design* (182-193).
- 2 Desmet, P.M.A., & Hekkert, P. 2007. Framework of product experience. *International Journal of Design*, 1 (1), 57-66
- 3 Parrish P 2008; A Design and Research Framework for Learning Experience; The COMET Program Brent G. Wilson; University of Colorado Denver
- 4 Cross, Robert G. 1997. *Revue Management: hardcore tactics for market domination*, Broadway Books.
- 5 Fenko, A., Schifferstein, H.N.J., & Hekkert, P. (2010). Shift in sensory dominance between various stages of user-product interaction, *Applied Ergonomics*, 41, 34-40.
- 6 Hekkert, P. & Schifferstein, H. N. J. 2008. Introducing Product Experience. In Schifferstein H. N. J. and Hekkert P. (Eds.), *Product Experience*. Amsterdam, The Netherlands: Elsevier.
- 7 Overbeeke, C J, Djajadiningrat, J P, Hummels, C C M and Wenseen, S A G (2002) Beauty in usability: forget about ease of use! in W S Green and P W Jordan (eds) *Pleasure with products: beyond usability* Taylor & Francis, London, UK pp 9e18
- 8 Nurkka, P., The role of values and emotions in user experience. *Design and Emotion Conference*, Hong Kong, China, October 6-9, 2008.
- 9 Wright, P., Wallace, J. and McCarthy, J., 2008. Aesthetics and experience-centered design. *ACM Transactions on Computer-Human Interaction*, 15(4), pp.1-21.
- 10 Hassenzahl, M., Diefenbach, S. and Göritz, A., Needs, affect, and interactive products – Facets of user experience. *Interacting with Computers*, 22(5), pp.353-362, 2010
- 11 Govers, P.C.M. and Mugge, R., I love my jeep, because it's tough like me: the effect of product-personality congruence on product attachment. In *Proceedings of the Fourth International Conference on Design and Emotion*, 2004, Ankara
- 12 Carroll, J. M. and Thomas, J. C., Fun, *SIGCHI Bulletin*, 19, 21–24, 1988
- 13 Mugge, R., Schifferstein, H.N.J. and Schoormans, J.P.L., Product attachment and satisfaction: understanding consumers' post-purchase behavior. *Journal of Consumer Marketing*, 27(3), pp.271-282, 2010.
- 14 Helander, M., Khalid, H. (2006). Affective and pleasurable design. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics*. New York, NY: John Wiley & Sons.
- 15 Susi, T. and Ziemke, T., Social cognition, artefacts, and stigmergy: A comparative analysis of theoretical frameworks for the understanding of artefact-mediated collaborative activity. *Cognitive Systems Research*, 2(4), pp.273-290, 2001
- 16 Forlizzi, J. and Battarbee, K., 2004, Understanding experience in interactive systems. In *Proceedings of the 2004 conference on Designing Interactive Systems (DIS 04): processes, practices, methods, and techniques* (New York: ACM), p. 261
- 17 Kim, J.E. (2011). Modeling cognitive and affective processes of designers in the early stages of design: Mental categorization of information processing (Doctoral dissertation), Arts&Métiers ParisTech, Paris, France.
- 18 Gentner (Alexandre) 2014 thesis Definition and representation of user experience intentions in the early phase of the industrial design process: a focus on the kansei process
- 19 Overbeeke: G.J.F. Smets, C.J. Overbeeke (1995), Expression taste in package, in *design studies* Volume 16 issue 3: July 1995, Pages 349–365
- 20 Gil, S. (2009). Comment mesurer les émotions en laboratoire ? *Revue électronique de Psychologie Sociale*, 4, 15-24.
- 21 Hekkert, P. & Schifferstein, H. N. J. 2008. Introducing Product Experience. In Schifferstein H. N. J. and Hekkert P. (Eds.), *Product Experience*. Amsterdam, The Netherlands: Elsevier.



- 22 Norman, D. 2004. *Emotional Design: Why we love (or hate) everyday things*. New York, NY: Basic Books.
- 23 Picard, Ferguson; Eckhardt 2014; A Platform for Creating Stories Across Digital and Physical Boundaries
- 24 Levy Pierre, (2013) *Beyond Kansei engineering: The emancipation of Kansei Design*. International Conference on Kansei Engineering and Emotion Research. Paris, France : LCPI A&M Paristech
- 25 Harada, A. (2003). Promotion of kansei science research. In H. Aoki (Ed.), *Proceedings of the 6th Asian Design Conference* (pp. 49-51). Tsukuba, Japan: Institute of Art and Design, University of Tsukuba.
- 26 Nagamachi, M. (2011). *Kansei/affective engineering*. Boca Raton, FL: CRC Press.
- 27 Schütte, S., Eklund, J., Axelsson, J., & Nagamachi, M.(2004). Concepts, methods and tools in kansei engineering. *Theoretical Issues in Ergonomics Science*, 5(3), 214-231.
- 28 Bouchard, C., Kim, J.E., & Aoussat, A. (2009). Kansei Information Processing in Design. In *Proceedings of IASDR conference* (3327–3337).
- 29 Krippendorff, K. (2006). *The Semantic Turn: A New Foundation for Design*. New York, NY: Taylor & Francis.
- 30 Poole, M.S. Folger, J.P. (1981). Modes of observation and the validation of Interaction analysis schemes . *Small Group Behavior*, 12(4), 477-493
- 31 Vial (Stephane) *Court traité du design* Presses Universitaires de France, Collection «Travaux pratiques» 2014
- 32 Kelly in Bill Moggridge 2006 *Designing Interactions* , The MIT Press, 2006
- 33 Koskinen, H., Karvonen, H., Tokkonen, H. (2013), "User Experience Targets as Design Drivers: A Case Study on the Development of a Remote Crane Operation Station", in: *Proceedings of 31st European Conference on Cognitive Ergonomics (ECCE2013)*, Toulouse, France: ECCE.
- 34 Karvonen, H., Koskinen, H., Haggren, J. (2012), "Defining user experience goals for future concepts. A case study", in: *Proceedings of 7th Nordic Conference on Human-Computer Interaction (NordiCHI2012)*, UX goals 2012 Workshop – How to Utilize User Experience Goals in Design?. Tampere, Finland: TUT Publication series.
- 35 Wahlström, M., Karvonen, H., Norros, L., Jokinen, J., Koskinen, H. (2014), "Radical Innovation by Theoretical Abstraction – a Challenge for Design Anthropologists", Manuscript in peer-review.
- 36 Mok, C. (1996). *Designing business*. San Jose, CA: Adobe Press.
- 37 Tractinsky, N., & Zmiri, D. (2006). Exploring Attributes of Skins as Potential Antecedents of Emotion in HCI. In P. Fishwick (Ed.), *Aesthetic Computing* (pp. 405-422). Cambridge, MA: MIT Press.
- 38 Crilly, N., Maier A., and Clarkson P.J., Representing artefacts as media: Modelling the relationship between designer intent and consumer experience. *International Journal of Design* 2, no. 3: 15–27, 2008
- 39 Hassenzahl, M. (2004). The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human-Computer Interaction* , 19 (4), 319-349.
- 40 Minge, M., Riedel, L. & Thuring, M., *Modulare Evaluation von Technik. Entwicklung und Validierung des meCUE Fragebogens zur Messung der User Experience*. In Proc. 10. Berliner Werkstatt Mensch-Maschine-Systeme Universitätsverlag TU Berlin (2013).
- 41 Dias, R. A. (2009). "Percepção dos materiais pelos usuários: modelo de avaliação Permatius". 352 p. Doctoral thesis, Engineering and Knowledge Management, UFSC, Florianópolis.
- 42 Dias, R. A.; Gontijo, L. A. (2013). "Aspectos ergonômicos relacionados aos materiais". *Ergodesign & HCI*, v. 1, p. 22-33.
- 43 Mahut, T., Bouchard, C., Favart, C., *Experience and interaction in early Design*, CONFERE 2014, Sibenik, Croatie, 2014.
- 44 Amid G.Ho, *Exploring the Role of Emotion in the Design Cycle 2014* in *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014*, Kraków, Poland 19-23 July 2014 Edited by T. Ahram, W. Karwowski and T. Marek
- 45 Gibson, J. J. (1983). *The senses considered as perceptual systems* (p. 335). Greenwood Press.
- 46 Norman, D. A. (2004). *Emotional Design: Why we love (or hate) everyday things*. New York: Basic Books, pp.63-98.
- 47 Jordan, P. W., *Designing pleasurable products*, 2000 (Taylor and Francis, London)
- 48 Alben, L. 1996, *Quality of Experience: Defining the Criteria for Effective Interaction Design*. *Interactions*, 3, 3, pp. 11-15
- 49 UPA (Usability Professionals' Association): "Usability Body of Knowledge", <http://www.usabilitybok.org/glossary> (23.5.2006).
- 50 Mäkelä, A., Fulton Suri, J. 2001, *Supporting Users' Creativity: Design to Induce Pleasurable Experiences*. *Proceedings of the International Conference on Affective Human Factors Design*, pp. 387-394
- 51 Hassenzahl & Tractinsky 2006: User experience - a research agenda, *Behaviour & Information Technology*, 25:2, 91-97
- 52 Moggridge 2006 *Designing Interactions* , The MIT Press, 2006

- 53 Hekkert, P. & Schifferstein, H. N. J. 2008. Introducing Product Experience. In Schifferstein H. N. J. and Hekkert P. (Eds.), *Product Experience*. Amsterdam, The Netherlands: Elsevier.
- 54 Forlizzi, J. and Battarbee, K., 2004, Understanding experience in interactive systems. In *Proceedings of the 2004 conference on Designing Interactive Systems (DIS 04): processes, practices, methods, and techniques* (New York: ACM), p. 261
- 55 Law, E.L., Roto, V., Hassenzahl, M., Vermeeren, A.P., Kort, J., 2009. Understanding, scoping and defining user experience: a survey approach. In: *Proceedings of CHI '09*. ACM, New York, NY, pp. 719–728.
- 56 Roto, V. 2006. *Web Browsing on Mobile Phones – Characteristics of User Experience*. Doctoral dissertation, Helsinki University of Technology. [http://research.nokia.com/people/virpi\\_roto/dissertation.html](http://research.nokia.com/people/virpi_roto/dissertation.html)
- 57 Hassenzahl M (2011) User experience and experience design. In: Soegaard M, & Dam RF (eds.) *Encyclopedia of Human-Computer Interaction*. The Interaction-Design.org Foundation. Available: [http://www.interaction-design.org/encyclopedia/user\\_experience\\_and\\_experience\\_design.html](http://www.interaction-design.org/encyclopedia/user_experience_and_experience_design.html).
- 58 Shedroff, N. *An Evolving Glossary of Experience Design*, online glossary at <http://www.nathan.com/ed/glossary/> (23.5.2006).
- 59 Nielsen-Norman Group, *Our Definition of User Experience*. <http://www.nngroup.com/about/userexperience.html> (28.6.2007).
- 60 Wikipedia, *User Experience Design*. [http://en.wikipedia.org/wiki/User\\_experience\\_design](http://en.wikipedia.org/wiki/User_experience_design) (18.02.2015)
- 61 Krippendorff, K and Butter, R 'Product semantics: exploring the symbolic qualities of form' *Innovation: The Journal of the Industrial Designers Society of America* Vol 3 No 2 (1984) 4–9
- 62 Thompson D (1992) *On growth and form*. In: Bonner JT (ed) Cambridge University Press, Cambridge, UK
- 63 Kerstin Bongard. *Bringing the user experience to early product conception : From idea generation to idea evaluation*. Other. Ecole nationale superieure d'arts et metiers - ENSAM, 2013. English. <NNT : 2013ENAM0068>. <pastel-00936893>
- 64 Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. *Design Studies* , 25, 547-577.
- 65 Rekimoto 1995 Rekimoto, J., and Nagao, K. *The World through the Computer: Computer Augmented Interaction with Real World Environments*. Proc. of UIST'95, pp. 29-36.
- 66 Moussette 2012 Simple Haptics, Sketching perspectives for the design interaction
- 67 Eagleman (2015) *Can we create new senses for humans?* ted talk 2015
- 68 Webster 1997, Merriam-Webster's Collegiate, Tenth Edition. Online edition, <http://www.eb.com:180/>.
- 69 Ullmer; Brygg Anders Ullmer; *Models and Mechanisms for Tangible User Interfaces*, 1997, Massachusetts Institute of Technology
- 70 Xerox star system: Smith, D. *Designing the Star User Interface*, Byte, (1982), 242-282.
- 71 Ishii & Ullmer. 1997. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the SIGCHI conference on Human factors in computing systems(CHI '97)*
- 72 Holmquist, L., Redström, J. and Ljungstrand, P. *Token-Based Access to Digital Information*, 1999.
- 73 Fishkin, K.P. *A taxonomy for and analysis of tangible interfaces*. *Personal Ubiquitous Computing*, 8
- 74 Zgelbaum, Kumpf, Vasquez, Ishii 2008; Slurp: Tangibility, Spatiality, and an eyedropper; CHI 2008, April 10, 2008, Florence, Italy
- 75 Haussen (2013), doctoral dissertation, *Peripheral Interaction, exploring the design space* Eindhoven University of Technology Library
- 76 Bakker (2013) thesis *Design for peripheral interaction;* doctoral dissertation, Eindhoven University of Technology Library
- 77 Zigelbaum (2010); Marcelo Coelho • Jamie Zigelbaum: *Shape-changing interfaces*; MIT media lab
- 78 Ishii, Lakatos, Bonanni, and Labrune. 2012. *Radical atoms: beyond tangible bits, toward transformable materials*. *interactions* 19, 1 (January 2012), 38-51
- 79 Coelho, M. and Maes, P. *Sprout I/O: a texturally rich interface*. In *Proc. TEI '08*. ACM Press (2008), 221-222.
- 80 Poupyrev I, Nashida T, Okabe M (2007) *Actuation and tangible user interfaces: the vaucanson duck, robots, and shape displays*. In: *Proceedings of TEI'07*. ACM, pp 205–212
- 81 Strandh S (1988) *Christopher polhem and his mechanical alphabet*. *Tech cult* 10:143–168

# Haptic Beats: Designing for Rich Haptic Interaction in a Music Controller

## Abstract

This paper describes the design of Haptic Beats, a tangible interface that addresses two functionalities in music control: volume change and affective shuffle through playlists and songs. Through reflections on the iterative design process we discuss how to design for rich haptic interaction. By layering different types of haptic feed forward modules, we developed an interface with rich haptic interaction. Haptic Beats enables users to fully attune to a continuous loop of action and feed forward, triggering them to use cognitive, emotional as well as perceptual-motor skills by addressing their tactile sense. The prototype demonstrates how haptics could enrich future products and support aesthetic interaction.

## Keywords

Haptic Interaction Design, Interaction Frogger Framework, Remote control, Music Control

## 1 Introduction

Despite rapid changes in technology, most electronic products hardly changed in terms of user-product interaction. For 60 years remote controls have been boxes with buttons. Although they afford various actions such as shaking or tilting, these do not have any effect on its output. Instead of considering these actions as useless, we argue that they are expressions of human skills and by not addressing them; remote controls

illustrate the lack of human focus in most interfaces.

We believe that the quality of an interaction is achieved in products that address the beauty of being human. Therefore, we intend to transform actions, which are generally perceived as useless in human-product interaction into aesthetic interactions. Overbeeke et al. [1] indicate that aesthetic product interaction can be achieved by facilitating human-product interaction that engages all human skills, cognitive, emotional and perceptual-motor. This is summarized in what Frens [2, p.177] names rich interaction: *“A paradigm for interactive consumer products that results in a unity of form, interaction, and function and taps human skills (perceptual-motor skills, cognitive skills, and emotional skills) for information-for-use thereby setting the stage for aesthetic interaction.”*

When considering the perceptual-motor skills involved in the above-mentioned actions with a remote control, the main sensory system through which we perceive and act is that of touch. All aspects of the tactile sense, such as the sense of touch, relate to the field of haptics [3]. Haptics have been studied in various fields, ranging from physiology to robotics, and haptic interaction has been coined particularly in the research fields related to virtual reality. Haptics can offer a new layer that enriches the experience of interactive products, it can par excellence support the design for rich interaction as it extends and strengthens the human skill through its sensitivity. For example, the haptic

sense is 20 times faster than vision and is able to sense small displacements [4]. The subtle feedback of haptics could put the user-product interaction in a continuous loop of action and feedback [5], the zu-handen effect [6, p. 109]. There is a continuous coupling between the user's action and the actuators which respond by haptic feedback back onto the sensor, resulting in new computational input to the actuator creating an interaction loop which is just outside of the control of the user and yet is affected by the user's actions. This mechanism, defined as hybrid materiality [7] supports rich interaction [2], as it triggers users to explore products through all human skills.

Wensveen et al. argue that inherent properties of a product aesthetically enrich the interaction. Therefore, to understand how rich interaction could be applied in the context of haptics we build upon the Interaction Frogger Framework they propose [8]. This framework is based on six notions that stimulate a continuous coupling between user's action and product's feedback: time, the user's action and product's feedback are synchronous in time; location, the user's action and product's feedback happen on the same location; direction, the movement of the user's action is coupled to the movement of the product feedback; dynamics, the speed of the user's action is coupled to the speed of the product's feedback; modality, the user's sensorial action should fit the product's sensorial feedback; and expression, the expression of the user's action should be an image of the product's feedback expression. If the integration of haptics in current consumer-electronics is explored through the Interaction Frogger Framework, one can observe that haptics are mainly used for upgrading existing interactions, e.g. the Lexus remote control by Immersion [9] is an upgrade of a joystick and the Samsung phone [10] adds a new dimension to feeling what is on the screen by enabling air gestures. These solutions do not fully respect the user's skills, as they decouple location, direction or expression in the user-product interaction. Furthermore, the interaction still relies predominantly on screen-based interaction instead of physicality and does not bring forward the rich qualities of haptics. As a consequence, we define two guidelines, which we believe are necessary when designing for a rich haptic interaction. In terms of the Interaction Frogger Framework [8], the notion of location should

be combined with the notion of modality. Having a common location for the user's tactile actions and product's haptic feedback enriches the quality of the interaction. Furthermore, the notion of expression and direction are also missing within the interaction of haptic products and should be further explored while designing for rich haptic interaction. Consequently, the goal of this paper is to explore haptic interactions and how these could enrich human-product interaction in an aesthetic way. By offering insight on how to design for rich haptic interactions, we aim to define guidelines that contribute to the democratization of haptics in interaction design as ambitioned by Hayward and McLean [11].

## 2 Method

Moussette and Banks [12] argue that designers have to *"refine their mastery and develop a heightened sensitivity to haptics only if their work with and through the material"* [13, p. 279]. Simple Haptics [13] shows as an approach to expose the value and possibilities of haptics within the field of interaction design. The proposed method allows designers to sketch out uncomplicated low-tech prototypes to experience haptics. Various researchers have employed building experience prototypes [14] to explore haptics [15, 16]. With an explorative hands-on approach, myriad of possibilities for haptics in design are exposed. Furthermore, the strength of Simple Haptics is in the integration of design research with design practice, reflected in the tangible prototypes built to assess the value of haptics within the field of design practice. Similarly but adding the context of sound, Özcan and Sonneveld argue that action, acting out, being involved, being aware of the body, and experiencing the real world are important strategies in the conceptual phase of the design process [17]. Thus, in order to research the context of haptic interaction, designers have to explore through the act of making and designing.

To tackle a research question and respect the abovementioned designerly skills, we take a research-through-design approach, which favors the development of artifacts [18, p. 498]. Research-through-design is a form of action research and requires an iterative evolutionary design process involving discussion, trialing of ideas, reflection, evaluation, and action to address undefined challenges [19]. The designer should make his or her implicit process explicit to support the

development of knowledge and understanding. Within research-through-design we consider the Lab approach and use a prototype to validate whether and how haptic feedback could enrich interaction in an aesthetic way. Koskinen et al. [20, p.51- 65] describe how the lab-approach centers design research around the human perspective, by confronting society through a physical hypothesis. The physical hypothesis is embodied in a realistic consumer product, although it is often limited in its functionality to only address the core of the research question.

### 3 Tangible music control

We chose the context of navigation through music libraries to explore our research question. With the digitalization of music, various researchers have explored how to control and browse through large amounts of music by means of gestures [e.g. 21, 22, 23, 24]. In this paper we take this control one step further, by adding rich haptic feedback. Therefore, we present Haptic Beats, an interface that enables shuffling through songs and playlists and allows for volume control through gestures while providing haptic feedback. We limited the functionality of our music controller, as it is not the music controller itself that we wish to design, but the concept of incorporating haptics. We extend our knowledge on rich haptic interaction by showing and reflecting upon the iterations of how we designed, build and tested experiential prototypes of haptic interactions. Throughout the process over 30 designs and prototypes were made, which we summarize in four main iterations.

Fig. 1. Different haptic explorations within the haptic toolkit, showing a piezo sensor; a pressure pad; a slider mapped to vibration motor; a potentiometer and a magnetic force button

#### 3.1 Iteration 1 – Understanding haptics

To appreciate the concept of haptics it is important to gain experience with technologies that address the tactile sense. Similar to the conceptual phase for sound and touch design [17], in discovering haptics a parallel can be made with learning to sketch as it enables designers to think, reason, create, share, and discuss [25]. As in sketching designers first need to learn the basics before starting any implementation. Therefore, a set of haptic explorations was developed to discover haptics, which are depicted in Fig. 1. To assess the value of these explorations, a haptic toolkit was developed and explored during an informal user session with interaction designers. The toolkit consists of a piezo sensor, a pressure-pad, a slider, a vibration motor, a potentiometer and a magnetic force button.

As individuals fully attune to haptics, this learning curve establishes a coupling between the user's action and product's feedback. It illustrates the necessity of a continuous coupling between the two for rich interaction. To respect this learning curve, two major elements should be taken into account. Firstly, the user's action should take place at the same location as the product's feedback. In this case the action should be tactile and the feedback haptic. Secondly, noise created by the haptic actuators, for example sound, should be filtered out. This unnecessary feedback disrupts the coupling between action and feedback, resulting in wrongly interpreted feedback.

#### 3.2 Iteration 2 – Implementing haptics

To implement the six notion of coupling [8] within a clear context, a motorized slider was chosen as a means of exploration. This slider is capable of detecting slider movement as well as emitting force feedback. Regarding the notion of location combined with modality, the

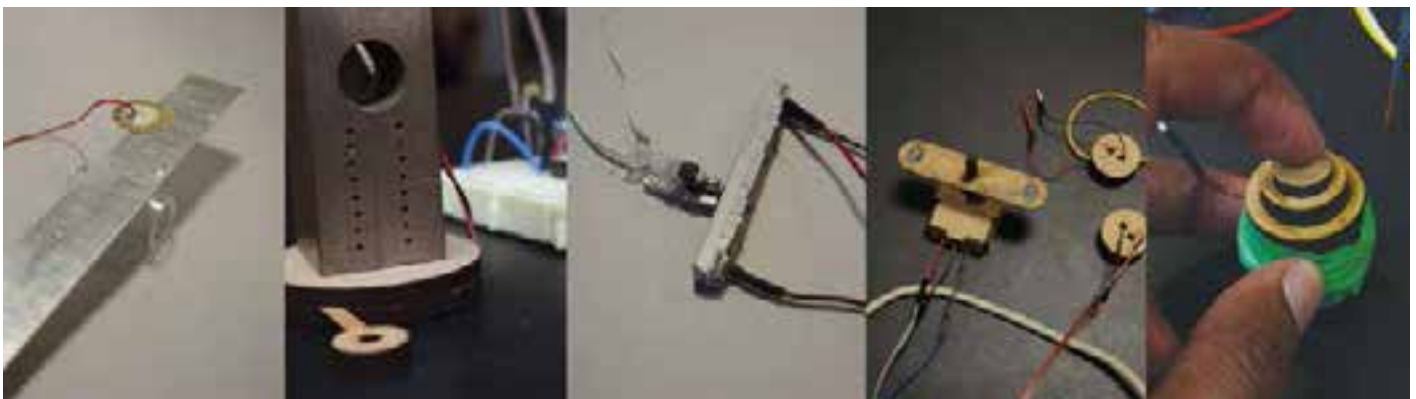




Fig. 2. Motorized slider

slider couples tactile input to haptic output at a common location. Fig. 2 depicts the slider that was used to explore different behaviors. The first behavior was based on a radio tuner in which the noise between the channels was replaced by haptic feedback mapped to the beat of the song. With the second behavior, songs can be selected based on the beat. In the middle of the slider, the beat can be experienced. By moving to the left, the beat can be changed. By moving to the right, the songs can be played. In the third exploration, different expressions of gestures lead to different songs. The first two explorations highlighted the notion of location and direction and the third was more grounded on the notion of expression in combination with dynamics. Even though the beat in the first two iterations somehow could be felt when interacting with the device, it remained too complex to understand through haptics, thereby causing confusion and eventually a decoupling between the user's action and the product's feedback. Wei and Körding describe

this phenomenon as a causal inference: “When cues are very different from one another in space and time, the nervous system will infer that they are not related and thus should be processed separately. Thus the estimation of the relevance of sensory cues determines whether and how the nervous system combines cues” [26, p. 655]. This iteration highlights the urge for simplicity in feedback, as this will support the continuous loop between action and feedback. Therefore, the highest potential was evidenced by the third exploration, as it could implement the notion of expression in the user-product interaction together with understandable feedback.

### 3.3 Iteration 3 – Haptic Beats version I

Haptic Beats is a music shuffle interface controlled by expressive haptic gestures, which builds upon the results of the previous iterations. The current version provides two functions based on the emotional states of pleasure or displeasure. Because the notion of expression closely relates to human emotion, Russell's Circumplex model of Affect [27] was applied for mapping a universal expression for shuffle. Haptic Beats functions as follows, if the played song is liked (pleasure) another song can be played within the genre by making a *Like* gesture, a slow movement with the slider to the right. When the song is disliked (displeasure) a song from a different category can be selected by making a *Dislike* gesture, a rough high force movement to the right. Furthermore, feedback was given within Haptic Beats through a *Music Skyline*, a unique haptic texture for each music genre. When moving the slider, this texture can be felt, e.g. classic has a smooth, soul a scratchy and rock a rough texture.

During an informal user session, participants were asked to explore a collection of songs with the product. The observations showed that participants were able to develop sensitivity towards the interface through

Fig. 3. The three haptic modules used in the evaluation



exploration. The most interesting observation was that participants were in a constant loop of action and feedback, as they closed their eyes and attuned to the haptic feedback while listening to the music. However, the *Music Skyline* was misinterpreted, as participants were not able to couple the feedback to an action. This coincides with the observation found in iteration two, describing the concept of causal interference [26]. Therefore, it is fair to argue that this additional layer of feedback does not add value to the continuous loop of action and feedback and should consequently be eliminated as part of the interaction with the music controller.

### 3.4 Iteration 4 – Universal Haptic control

In the previous iterations, the capabilities of the motorized slider were explored within the context of music. This exploration highlighted that simplicity in feedback is required to support a better coupling between user's action and product's feedback. Consequently, we explored how to apply the characteristic of simple feedback and common location of tactile input with haptic output with other haptic actuators. Therefore, different modules were developed of which three were selected (Fig. 3) that support the implementation of both rich characteristics. Artifact A has two embedded vibration motors, which are coupled to a 2-axis accelerometer. Enabling the artifact to vibrate faster in the back corner when rotating to the back and faster in the front corner when turning to the front. Artifact B is a handheld version of Haptic Beats version I. When the slider-knob is moved from the back to front, the force will quickly grow until the middle is reached. From this position the force will slowly decrease, until the knob is released. Finally, artifact C is a guitar string coupled to a vibration motor. The intensity of the force exercised on the string is mapped to the strength of the vibration pulse. These different modules could be considered as universal examples that mark the development for a rich haptic interaction, as they were developed based upon the lessons learned from the previous iterations.

## 4 Evaluation

An experiment was conducted with the three modules depicted in Fig. 3, to determine which actions support the continuous coupling of action and feedback in haptic user-product interaction. Through this experiment we

explored the user's interpretation regarding expressive gestures. The functions are extracted from Haptic Beats version I, regarding *Like* and *Dislike* actions when shuffling. Furthermore, the functionality of Volume change was added to the interaction.

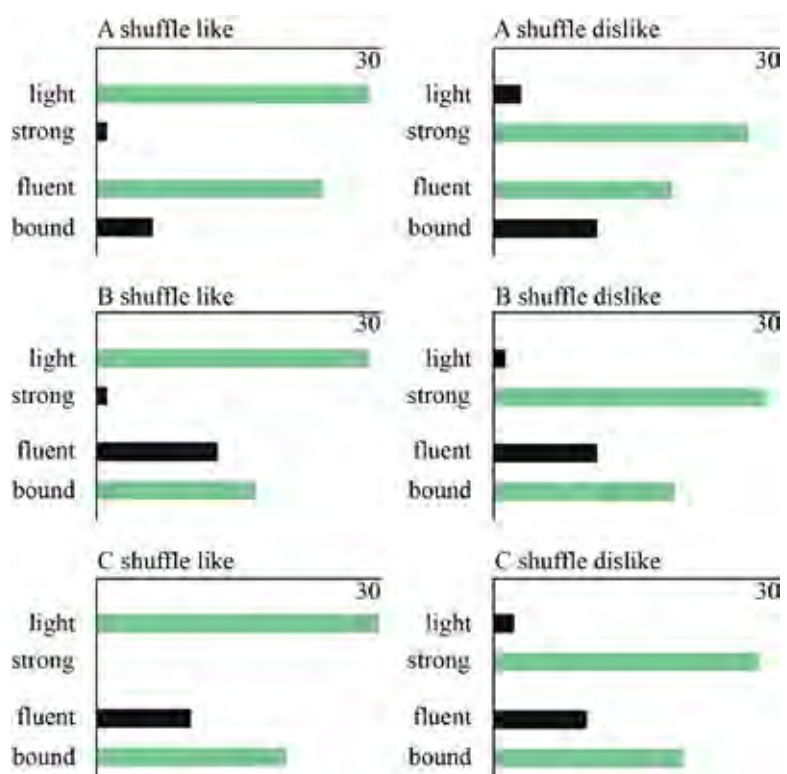
### 4.1 Participants

30 industrial design students (15 males, 15 females; age 17-26) participated in this experiment. An experimental session took 15-20 minutes and consisted of three stages.

### 4.2 Setup

The first stage consisted of a short introduction in which participants were informed that the experiment focused on haptic interaction. To understand the meaning of haptic interaction, participants were asked to explore the three artifacts, until they understood the influence of their input in relation to the haptic feedback. During the second phase participants were told that the project related to the development of a haptic musical interface. Consequently, participants were asked to indicate which gesture they would make for *Like*, *Dislike* and Volume change for each artifact.

Fig. 4. Results for the two types of shuffle mapped to Laban's dynamic qualities of weight and flow



In the final phase, participants were asked to give a score for their proposed gestures on a scale of 1-10 for Shuffle, and Volume as well as an Overall score for each interface. Before closing the session, they were asked which combination of two artifacts they preferred. The 30 sessions were digitally recorded and the footage of the second stage was analyzed by means of Laban's dimensions of effort as described by Fagerberg et al. [28, p.59]. Laban's parameters (space, weight, time and flow) enable the observations of dynamic qualities for the individually interpreted gestures. By analyzing the different interpretations we intend to find the dynamic qualities that define the differences between *Like*, *Dislike* and Volume change.

### 4.3 Results

During the second stage clear tendencies were observed between the individual interpretations. The most notable findings address the outcome of the Like and Dislike gestures mapped to Laban's dynamic qualities weight (light and strong) and flow (fluent and bound) (Fig. 4). These show a clear difference in the scale weight between the Like and Dislike gestures over all artifacts. Like is often characterized by a light movement, while the Dislike is often executed with a strong dynamic movement. Furthermore, there is coherence between the different Volume interpretations, as all are direct, light, sustained and fluent gestures. Finally there is a clear difference between the artifacts, as A provokes more fluent movement, while B and C tend to be more bound in dynamic quality.

### 4.4 Discussion

From the observations, Volume can be considered as fluent in quality, as the participants often expressed it as a fluent sustained movement on a clear rotational axis. Shuffle is more discrete, characterized by a quick bound movement. During the experiment, participants had difficulty in understanding artifact C, which is probably caused by the decoupling of the notions of time and modality. Through the high sensitivity of artifact C, the guitar string reacted even to the smallest vibrations. For example, when the artifact is moved, it also emits a vibration pulse, causing unnecessary feedback. The notion of time comes in play, as the string does react when it is released, causing the feel of delay. This complexity is also observable from the given scores, as C scores the lowest overall score.

Thus, the results indicate that artifact C was unable to establish a continuous loop of action and feedback. Artifacts A and B on the other hand were able to address the six notions of coupling. The strength of Shuffle is in the notion of expression as it connects emotion to expression. For Volume the strength is in the direction, which is perfectly coupled to the haptic feedback. Therefore, to summarize which actions support the continuous coupling of action and feedback, it is clear that the actions for Volume should be a combination of the dynamic qualities direct, sustained, light and fluent. As a consequence, artifact A suits these requirements best as users are triggered through the feedback to perform an action based on these qualities. With respect to the two Shuffle types, we observed a clear difference. The quality of weight grows when a genre is disliked. Artifact B scores similarly high for Shuffle as artifact A. However, given that its bound characteristic fits more to the weight shift from light to strong, triggering participants to express their emotion with the slider, the preference for shuffle is on artifact B.



Fig. 5. Haptic Beats

## 5. Final design

Haptic Beats version II is a rich haptic interface that enables users to shuffle and adjust the volume of their personal music library (Fig. 5 and <http://youtu.be/61Truh6YZb8>). Regarding the Like and Dislike gestures, the actions remain the same as Haptic Beats version I and is similarly generated by a motorized slider. However, in this second version the feedback has changed as it is directed towards simplicity to discard causal inference [26]. The slider movement is mapped to force feedback, as moving the slider to the center of the device increases the strength of the force feedback exponentially; by moving the slider from the center



to the end, the strength of the force feedback slowly decreases.

The function Volume can be controlled by means of a vertical movement to the front, to increase volume and a vertical movement to the back, to decrease volume. Two vibration motors in the back and front of the device embed the haptic feedback. The motor in the back vibrates faster with an increased forward rotation, while the motor in the front vibrates faster with an increased backward rotation. To support wireless interaction we had to give in to the form factor, as the prototype was build of off-the-shelf components. Therefore, it is approximately 150 percent larger than intended.

## 5.1 Rich haptic interaction

Haptic Beats version II demonstrates how rich haptic interaction can be implemented within the context of music. The first guideline for designing for rich haptic interaction, addresses the combination of the notions location and modality. As discussed in the introduction, a continuous coupling between the user's action and product's feedback is defined by a connection between the tactile sense and the haptic feedback, the combination of which is perceived and acted upon at the same location. Haptic Beats translates the user's tactile action to haptic feedback that can be perceived directly. The second guideline is based on the simplicity of feedback and strongly relates to the causal inference [26]. In the second iteration, complex feedback was connected to causal inference and thereby decoupled action from feedback. However, Haptic Beats version II provides simple haptic feedback, by means of force and vibrotactile feedback. Finally regarding the design for rich interaction, both the feedback and action should be rich. By combining Laban Dynamic Qualities with the notions of the Interaction Frogger Framework [8] more expression was achieved in the interaction with Haptic Beats.

## 6 Discussion

An aesthetic interaction should consider richness in appearance, actions, and role [29]. To design for rich haptic interaction we suggest three guidelines: simplicity within the feedback, coupling of time, modality and location, and affording expressive actions. We describe the process of coupling by mapping Haptic Beats to the Interaction Frogger Framework [8] shown in Fig. 6.



Fig. 6. Haptic Beats explained through the Interaction Frogger Framework

There is a continuous coupling of action and the combination of functional feedback and inherent feed forward, which is the result of the interactive materiality [29]. This interactive materiality, which creates a continuous coupling between the user's action and the actuators, clearly applies to the context of haptics as it as it responds to the user through haptic feedback. The three stages in the Interaction Frogger Framework relate to the movements made by the user (action), i.e. moving the slider or tilting the device; the result on the music (functional feedback), i.e. changing of song or playlist, or in volume; perceived and the haptic feedback perceived by the user (inherent feed forward), i.e. the friction on the slider or the vibration at the front or back end. Inherent feed forward replaces feedback in this model, because the haptic feedback is always a trigger for another action within a continuous coupling of user's action and product's reaction [29]. In the case of Haptic Beats, the transition of vibration triggers for more action as the interaction moves towards a new action of the user, based on the notions of direction, dynamics and expression.

Thus for rich haptic interaction, the feed forward may need to be coupled in time, i.e. at the same moment that the action occurs; furthermore, we believe that modality should be coupled through the tactile input and haptic output, and this should happen at the same location. As the interaction happens before the actual functional feedback, it allows users to express themselves towards the device by changing the direction and dynamics of their movements. The haptic feed forward enables them to explore the context-of-use with the artifact to extract the information-for-use [2].

Thereby, the haptic feedback respects all bodily skills as users can express themselves through movement, they can express their emotions and at the same time learn which gestures serve which functions.

We propose that rich haptic feedback can be achieved by layering different types of haptic feedback modules in the prototypes. This approach enabled us to explore how to incorporate rich haptics into a physical product as exemplified in Haptic Beats. The layers of rich interaction, respect the six notions of coupling, which are described in the Interaction Frogger Framework [8]. Furthermore, they support the continuous coupling of the user's action with the product's feed forward in the user-product interaction. This interactive materiality in haptic interaction opposes the trend of decoupled location and incremental haptics [9, 10] and thereby supports the design for rich haptic interaction. Finally, the research question aimed to define the guidelines that are important in the design for rich haptic interaction and was explored by means of an iterative research-through-design process. By taking a hand-on approach, different layers of complexity were combined in our exploration of rich haptic interaction. This process highlights the strength of using physical prototypes, as they enable to experience the hypothesis and support in addressing the research question. Reflecting upon the physical prototypes makes it more intuitive for the designer to argue whether certain behaviors are rich or not. Especially in the design for bodily interaction, an intuitive approach is recommended, as these can only be evaluated through experience.

## 7 Conclusion

This paper discusses how to embed rich haptic interaction into electronic products to support aesthetic interaction, through a research-through-design approach. It suggests addressing three key elements: simplicity in feed forward; conformity in time, location, and modality through tactile input and haptic output; and affording expressive actions to create a continuous coupling between actions and feed forward. It illustrates how rich haptic interaction can be achieved by layering different types of haptic feed forward. Finally, the iterative and reflective design process illustrates how a designerly approach enables the exploration of the value of designing for rich haptic interactions, and stimulates to expand to different contexts.

## Acknowledgements

For this study we want to thank Jacques Terken, Berry Eggen, Steffen Pauws, Stephan Wensveen and Jelle Stienstra for their expert feedback during the research. Furthermore, we thank the students who have participated in the experiments and supported the process. This work has been supported by the EC within the 7th framework programme through the FET Open scheme under grant agreement no. 309191 for the GHOST (generic, highly-organic shape-changing interfaces) project.

## References

1. Overbeeke, C.J., Djajadiningrat, J.P., Hummels, C.C.M. and Wensveen, S.A.G.: Beauty in usability: forget about ease of use! In: W.S. Green & P.W. Jordan (Eds.), *Pleasure with products: beyond usability* (pp. 9-18). Taylor and Francis, London, UK (2002)
2. Frens, J.W.: *Designing for Rich Interaction: Integrating Form, Interaction, and Function*. Unpublished Doctoral Dissertation, TU Eindhoven, The Netherlands (2006)
3. Grunwald, M.: *Human Haptic Perception Basics and Applications*. Birkhäuser, Berlin, Germany (2008)
4. Jones, M. and Marsden, G.: *Mobile Interaction Design* (p. 398). John Wiley & Sons, UK (2006)
5. Bruns Alonso, M., Hummels, C.C.M., Keyson, D.V., & Hekkert, P.P.M.: Measuring and adapting behavior during product interaction to influence affect. *Personal and Ubiquitous Computing*, 17(1), 81-91 (2013)
6. Dourish, P.: *Where the action is*. 1st edition. MIT Press, Cambridge, MA (2001)
7. Parkes, A. and Ishii, H.: Bosu: a physical programmable design tool for transformability with soft mechanics. *DIS'10*, 189-198 (2010)
8. Wensveen, S.A.G., Djajadiningrat, J.P. and Overbeeke, C.J.: Interaction frogger: a design framework to couple action and function through feedback and feedforward. *DIS'04*, 177-184 (2004)
9. Immersion.com: Automotive: What Products Use Haptics? Retrieved February 4th, 2015, from <http://www.immersion.com/haptics-technology/haptics-in-use/automotive.html> (2015)
10. Immersion.com: Mobile: What Products Use Haptics? Retrieved February 4th, 2015, from <http://www.immersion.com/haptics-technology/haptics-in-use/index.html> (2015)
11. Hayward, V. and MacLean, K.E.: Do It Yourself Haptics, Part-I. *IEEE Robotics and Automation Magazine*, Vol. 14, No. 4, pp. 88-104 (2007)

12. Moussette, C. and Banks, R.: Designing through making: exploring the simple haptic design space. TEI'11, 279-282 (2011)
13. Moussette, C.: Simple haptics: Sketching perspectives for the design of haptic interactions. Unpublished Doctoral Dissertation, Umea Universitet, Sweden (2012).
14. Buchenau, M., and Suri, J. F.: Experience prototyping. DIS'03, 424-433 (2000)
15. Chang, A., Gouldstone, J., Zigelbaum, J., and Ishii, H.: Pragmatic haptics. TEI'02, 251-254 (2008)
16. Swindells, C., Maksakov, E., MacLean, K. E., and Chung, V.: The role of prototyping tools for haptic behavior design. Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, 161-168 (2006)
17. Özcan, E., and Sonneveld, M.: Embodied explorations of sound and touch in conceptual design. DeSForM'09, 173-181 (2009)
18. Zimmerman, J., Forlizzi, J. and Evenson, S.: Research through design as a method for interaction design research in HCI. CHI '07, 493-502 (2007)
19. Swann, C.: Action research and the practice of design. Design issues, 18(1), 49-61 (2002)
20. Koskinen, I., Zimmerman, J., Binder, T., Redström, J. and Wensveen, S.A.G. Design Research Through Practice: From the Lab, Field, and Showroom. Morgan Kauffman, Waltham, MA (2011)
21. Bruns Alonso, M. and, Keyson, D.V.: MusicCube: a Physical Experience With Digital Music. Personal and Ubiquitous Computing 10, 163-165 (2006)
22. Gallardo, D. and Jordà, S.: Tangible jukebox: back to palpable music. TEI'10, 199-202 (2010)
23. Keränen, J., Bergman, J. and Kauko, J.: Gravity sphere: gestural audiotactile interface for mobile music exploration. CHI'09, 1531-1534 (2009)
24. Xambó, A., Laney, R.C. and Dobbyn, C.H.: TOUCHtr4ck: democratic collaborative music. TEI'11, 309-312 (2011)
25. Ferguson, E. S.: Engineering and the mind's eye. MIT Press, Cambridge, MA (1992)
26. Wei, K. and Körding K.P.: Relevance of error: what drives motor adaptation? Journal of Neurophysiology 101(2), 655-664 (2009)
27. Russell, J.: A circumplex model of affect. Journal Of Personality And Social Psychology, 39(6), 1161 (1980)
28. Fagerberg, P., Ståhl, A. and Höök, K.: Designing gestures for affective input: an analysis of shape, effort and valence. MUM'03, 57-65 (2003)
29. Djajadiningrat, J. P., Gaver, W. W., & Fres, J. W.: Interaction relabeling and extreme characters: methods for exploring aesthetic interactions. DIS'03, 66-71 (2000)
30. Stienstra, J., Bruns Alonso, M., Wensveen, S., & Kuenen, S.: How to design for transformation of behavior through interactive materiality. NordiCHI'12, 21-30 (2012)

**Edgar R. Rodriguez Ramirez, Kah Chan, Simon Fraser,  
Keith Thurlow, Sebastien Voerman, Dana Fridman, Scott Brebner**

School of Design, Victoria University of Wellington, New Zealand

edgar.rodriguez@vuw.ac.nz, kah.chan@vuw.ac.nz, simon.fraser@vuw.ac.nz

thurlowproductions@gmail.com, sebastien.w.voerman@gmail.com, danabrandala@gmail.com, scotty.brebner@gmail.com

# 3D Printing Sensor-enabled Splints and Exergaming

## Abstract

This paper reports on experiments for the design of a system for intelligent, digitally manufactured, optimised, individualised and low-cost orthoses. The great skill shortage of orthopaedic technicians worldwide and the long hours of manual labour necessary to produce customised orthoses imply high costs and waiting times for health organisations and patients. Digital manufacture tools make it possible to develop a highly optimised and individualised smart system. We propose a system that digitally 3D scans patients' limbs; software that translates the scanned data into designed and optimised orthoses that can be 3D printed with embedded sensors; software to gather data from the sensors, inform clinicians about orthoses use and pressure sores, and motivate patients to follow therapy through appropriately designed games.

## Keywords

3D printing, sensors, serious games, 3D scanning

## Introduction

Currently, orthoses around the world are mostly manufactured manually. This incurs in high costs and low accessibility to the right kind of medical treatments for many people. Technicians currently make a negative plaster mould of the patient's limb, pour plaster into it to make a positive, heat-wrap plastic around the positive, cut the plastic to shape, then add joints and

straps. The system can be optimised at different stages of the process. Firstly, it is unnecessary to make the plaster moulds if the limbs can be 3D scanned digitally. Instead of making a plastic piece that needs to be cut into shape, the orthoses can subsequently be 3D printed, using only the material needed. The shape of the orthoses can also be calculated so that it creates optimal structures for its performance.

The use of CAD in the design of orthoses in use in a variety of clinical settings (Jerrell, 2006; Smith & Burgess, 2001) and its potential to be more accurate than manual measuring and fabrication has been highlighted (Telfer, Abbott, Steultjens, & Woodburn, 2013). However our research to date has revealed one application of this process, which is currently restricted to the field of podiatric orthotics (3Ders.org, 2014). The digital file generated by the CAD software can play an important role in monitoring physical fit and progress of therapies by providing a significantly more accurate datum than manually formed orthoses. An accurate and optimised datum is critical in progressing therapies and tracking the effectiveness of incremental modifications. It removes subjectivity from the review process as it is based on objective data as opposed to patient or clinic observation or comment. The data gathered by embedded pressure and movement sensors can also offer clinicians important information about the usage of the orthoses, including use compliance and pressure points.

The same embedded sensing capability that is used to monitor comfort and compliance could be combined with computer based game technology for interactive therapy. The orthosis can serve much the same purpose as a gaming console. While there is evidence that computer-based games can assist in keeping patients motivated to complete their exercises, in a search of EBSCO health databases we were unable to identify any articles which described the use of customised orthoses embedded with sensors which allow patients free-movement to control a computer game and provide feedback regarding performance.

### 3D scanning

3D body-surface scanning is poised to become a mainstream medical tool of major value (Treleven & Wells, 2007). 3D scanning is currently used for a variety of medical purposes including planning for facial surgery (Kovacs et al., 2006; Marmulla, Hassfeld, Luth, & Muhling, 2003), monitoring changes after orthodontic surgery (Verzé, Antonella, Schellino, & Ramieri, 2012), and for fabricating limb prostheses (Engsberg, Clynch, Lee, Allan, & Harder, 1992) dental models (Akyalcin, Dyer, English, & Cagla, 2013), and orthoses (Jerrell, 2006). Some experiments have been carried out to scan lower limbs to produce ankle foot orthoses (AFO) (Mavroidis et al., 2011; Palousek, Rosicky, Koutny, Stoklásek, & Navrat, 2013). However, there is no standard procedure or validated methodology for 3D scanning limbs and the knowledge of the best ways to measure the lower-limb to produce an AFO lies with orthotic technicians.

We suggest a 3D scanning system that defines the acceptable constraints and criteria for 3D scanning patients' limbs, including scan resolution, scan speed and topographical complexity of anatomy to be scanned. The system needs to consider dexterity in scanner manipulation, procedure acuity and set up, and image computation related to post-scan assembly.

In order to offer higher level of accuracy and fit than current processes, our system can accurately 3D scan limbs to produce a 3D model of the customers' limb. There are number of 3D scanning systems in the market, which we have analysed. Our key criteria was the "resolution" of the scans. This resolution is not defined by the density of the mesh, but rather the accuracy of the scan and it's relation to the actual foot. High, medium and low resolution refers to the fidelity of the scans.

### 123DCatch

123DCatch is a mobile app that creates 3D models using captured stills. 123DCatch functions by capturing multiple stills from different angles and processing these into 3D models. Compared to similar apps 123DCatch operates relatively quickly and its cloud-based processing operated in a timely manner. This speed and non-existent entry cost comes at the price of fidelity. 123DCatch is a low cost entry into low resolution scanning.

### SKanect

Skanect is designed to be used with either the Microsoft Kinect or the ASUS Xtion camera both of which feature stereo cameras. SKanect operates by capturing 3D video that is then converted into point cloud data. SKanect is a low cost entry into medium resolution 3D scanning.

### Artec Spider

Artec studio is a high-end 3D capturing suite compatible with stereo capable cameras. The Artec Spider is a high end scanner designed to be used specifically with Artec Studio. Unlike other 3D scanners the spider has a fairly close focusing range. This makes for high quality point cloud data that can be converted into high resolution 3D models at the cost of time scanning and processing.

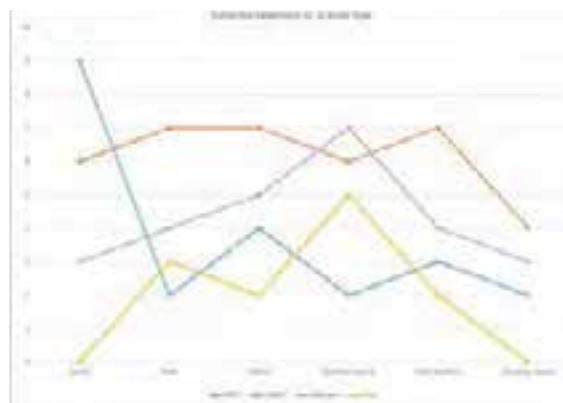


Figure 1. User experience analysis of scanning techniques

### Findings

The user experience differed greatly among the scanners, largely due to time spent still while scanning. 123DCatch was a fairly time intensive process and required the user to stay still. This difficulty was compounded by the device requiring a 360 degree scan of the foot meaning that the users had to orientate themselves so as not to interfere captures while staying still.



Figure 2. Sample orthosis render from Grasshopper. Rhino and Grasshopper

The stereo scanners fared better in this regard thanks to not needing a perfect 360-degree capture to complete the model. The fidelity of 123DCatch could not be relied upon for an accurate representation of a patient's foot at this point in time.

The SKanect software was easy to use and the user spent roughly three to five minutes staying still. Some difficulty was faced when the scanner had to pass close the user while maintaining focus on the foot. This could be remedied by lowering the minimum focus distance of the scanners. The capture quality of Skanect was accurate enough for our means. Artec Studio and the Artec Spider provided a moderate user experience. The process was slow taking around 30 minutes to complete a scan. The close focal distance of the Artec did allow for easier navigation around the users foot. A technician would need to be trained in Artec operation to use its software.

### Producing a parametric model

Recent research has experimented with 3D printing orthoses from 3D scans (Palousek et al., 2013). However, these early attempts still rely on a technician processing and translating the 3D scanned polygonal data into a parametric surface and assembling the surface through a commercial and difficult to learn CAD software before printing it. Once printed, the orthosis still needs manual assembly for all other pieces. Our hypothesis is that software can intuitively guide technicians and clinicians through the process of defining the technical specifications of orthoses with little training. Some of the technical software challenges to overcome include the fact that a typical smart orthosis would be made through the integration of several different surfaces: The scanned surface from the patient's limbs, an external surface determined by the mechanical properties the orthosis must have and aesthetic modifications made by the clinician or patient, different material considerations related to comfort, and surfaces for a variety of different sensing surfaces to be

integrated. All these surfaces need to be merged into a seamless whole, as any gaps between the surfaces will prevent 3D printing. At the same time, these surfaces need to be separately identifiable by a 3D printer in order to use the appropriate material.

The scanning process produces a 3D file is then used to generate the 3D model of the individualised splint. The 3D model of the splint needs to wrap around the 3D scan while keeping its own features: thickness, clasps, height, etc. We prototyped a system that allows clinicians to manipulate the digital splint, wrap it around the 3D scanned file and individualise it.

The 3D model of user's foot is imported into rhino and simple constraints are defined by the clinician i.e. coverage of the lower foot, how far up the calf the cast extends and the desired point of rotation.



Figure 3. Early printed orthosis and strength analysis

Using these definitions grasshopper parametrically generates a model of the cast around the users 3D scanned foot. This model is ready to be printed and immediately fitted to the user. Sensors are automatically modeled into the cast and won't require user input unless desired. Adjustments can be made at any point. The clinician can see changes to the parametric model against the 3D scanned foot.

Further customisation of the cast and its shape are possible both aesthetically and functionally using simple sliders within the Grasshopper definition. Stiffness and loading of the patients' dorsiflexion and plantar flexion can be controlled. The primary limitation of the process is the requirement of an accurate and watertight 3D scan for Grasshopper to build around.

### 3D printing

The goal of orthotic prescription is to improve a patient's level of function and quality of life (Heinemann, Bode, & O'Reilly, 2003). Treatment success depends upon the patient's subjective satisfaction with the orthosis. If a patient is dissatisfied with their orthosis they will wear it less often, incorrectly, or not at all, decreasing the overall effectiveness of treatment (Peaco et al., 2011). Patient satisfaction is multi-dimensional and encompasses comfort, ease-of-use, cosmesis, stigma attached, cost, function, aesthetics, weight, and durability (Heinemann et al., 2003; Peaco et al., 2011). These factors depend upon manufacturing variables such as the materials used, how well they fit, the cost of production, the ability of the technician, the time it takes for an orthosis to be fabricated and its design. Currently, the production of orthoses is highly technical, manual labour intensive, requiring specialists and long manufacturing times (Hellweg & Johannes, 2008). As the number of qualified technicians falls short of meeting demand (Walden, Personal communication), we suggest a high-value manufacturing process to 3D print orthoses that is strongly based on clinicians' and patients' needs and input. This could decrease the time and level of expertise taken to fabricate an orthosis, and which will improve patient satisfaction and health outcomes. The 3D model of the splint produced through the scanning and CAD processing can be 3D printed to produce a functional splint. We are exploring the use of fused deposition modeling (FDM) technology and ABS plastic because of its high strength, impact resistance, low flexibility and low cost of manufacture.

The way the splints have been designed has been defined by a collection of variables, most notably the intentions of the stakeholders, followed closely by the spatial capabilities of our 3D printer. The thicknesses of the splint were designed so as to be lightweight while still durable. Using Solidworks stress testing, we were able to identify the various weak points of the splint, as well as establish the way it would move under stress. In future designs, we will consider defining weak points in the parametric rules for the splint generation, in order to allow the program to thicken and strengthen various areas of the splint automatically. Allowing for usability was also important, hence the addition of the strap slots.

### 3D printed sensors

By 3D printing sensors, we can make them fit exactly into the shape of highly individualised and complex applications, including orthoses. This will make it possible to produce a functional electronic object in one print: sensing capabilities can be arranged in multiple planes to more accurately reflect complex forces; freedom of design can help avoid stigma in medical applications; and the problems of bending flat arrays of sensors can be overcome. While some experiments have been done to 3D print sensors using conductive materials (Leigh, Bradley, Pursell, Billson, & Hutchins, 2012; Ogawa et al., 2011; Tongrod, Lokavee, Watthanawisuth, Tuantranont, & Kerdcharoen, 2013), there has been no systematic and validated system to produce complex 3D printed sensors. In this project, we experimented with 3D printing piezoresistive sensors using conductive ABS in a FDM 3D printer. Presently, we have only conducted small-scale experiments with printing sensors. Initially we wanted the sensors to relay information based off an increase in resistance due to the compression of the sensors. However, after tests on the conductive ABS sensors, the change in resistance from a pressure differential was minute. We decided to experiment with bending the sensors, which stretches the outer edge of the bend on the sensor. This stretching increases the distance between the conductive particles across the bend, resulting in a 125% increase of resistance on a solid piece of ABS filament (50mm long) across a 45-degree bend. The resistance scaled from ~50 k $\Omega$  to ~120 k $\Omega$ , and reverted to original values as long as bending did not damage the ABS. Whether these results are repeatable and consistent over time is still to be researched.

## Exergames

Our hypothesis is that the smarter, more responsive technology can be applied to motivate patients, particularly children, to complete physiotherapy exercises. A lack of motivation has been identified as a major barrier in the treatment of children with conditions such as cerebral palsy even during one-on-one sessions with a therapist (Bartlett & Palisano, 2002; Yasukawa, 1990). There is evidence that computer-based games can motivate patients to complete their exercises (Levac, Miller, & Missiuna, 2012). The same technology could be used to record performance and progress with their therapy. In the case of children with hemiplegia as the result of a stroke or cerebral palsy, a sensitive splint fitted to the hemiplegic limb and linked to a gaming console may be an alternative to constraint-induced therapy.

The instant feedback loop provided by sensor-enabled orthoses empowers patients to have more autonomy over their therapy: providing an abstracted challenge that functions as a motivator (Fogg, 2003) to perform what are more mundane exercises. The digital component will also be tailored to the specific abilities of a patient, progressing in difficulty to match the patient's progress (Burke et al., 2009; Orvis, Horn, & Belanich, 2008; Sampayo-Vargas, Cope, He, & Byrne, 2013).

## Games overview

The smart splint provides a simple input in which these games are customized to make patient's physical rehabilitation easy and enjoyable. We based the first set of games to respond to the user sitting down and lifting the front of their foot, while the heel touches the ground. This is the most common exercise for wearers of splints. The games mechanics have to reflect the simple inputs provided by the splint. Our response to this challenge is to create games with progressive difficulty and leaderboard mechanics to motivate patients to beat their own scores or overcome challenges of varying complexity to encourage replayability (Koster, 2006).

## Little Wing

Little Wing is a simple with a core focus on high scores as a motivating factor. The game is played on the iPad utilizing the gyroscope as a means of directional input while the splint is connected via Bluetooth providing the rehabilitation input. Patients can perform exercises in



Figure 4. Little Wings interaction mechanics

comfort with little restriction on location using the iPad. The patient plays as Little Wing, a small pterodactyl who while unable to physically fly by himself.

Determined to fly it uses a giant slingshot to launch into the sky. The patient initially charges up the launch velocity by raising the splint for 10-15 seconds. This moves Little Wing backwards to gain tension with the slingshot. Once the patient's foot is brought back down to resting level Little Wing will be launched into the air. Launch velocity is calculated by the time the splint is held in up. When Little Wing is launched, patients face a linear level design which they navigate using the tilt control of the iPad.

Additionally patients are encouraged to keep up the exercises as they play. Every 10-15 second hold they perform after the initial launch will charge up a single wing flap which will give Little Wing a small increase in speed and altitude which can potentially give the patient the boost they need to reach the next heat geyser. The aim of the game is to navigate the level using wing flaps to glide as far as possible from the original launch location. Patient progression can be easily mapped to how far they get on each run as well as the time they can hold their foot up for and how many times they produce a wing flap before the exercise becomes too much.

## TodTec

TodTec is a building block simulator designed to turn a child's rehabilitative exercises into a creative outlet. The target audience is as young as three years of age. The core mechanic of the game translates motion from the splint (lifting the front of the foot) into a vertical crane that lifts building blocks given to the patient to construct predetermined architecture. The longer the patient raises the splint, the higher the block is lifted. A gradual difficulty curve is established by structures that require blocks to be lifted higher and more often. Like Little Wing, TodTec is also targeted at the iPad platform.



## Basic Interactions

The crane pans across the screen to the touch of the patient and releases blocks when tapped or the block is placed in the correct zone. Once a patient has successfully built a structure they are able to strike it down with a swipe across the screen, recreating the joyful duality of construction/destruction that blocks so often provide for small children. A “free-build” mode is available for the sake of more creative and slightly older children where the patient is free to summon a range of blocks to construct whatever they please.



Figure 5. TodTec interaction mechanics

## Conclusion

This paper describes steps towards a system to digitally manufacture smart orthoses. Our experiments show that it is possible to 3D scan patients' limbs and 3D print the actual orthoses. The limitations of this research include the fact that our process still involves manual editing of the 3D scanned files to convert them into the CAD models of an orthosis to be 3D printed. Our system of using Rhino and Grasshopper for generating the 3D model of splints has drastically reduced the need for manual modelling. These experiments fulfill several of the criteria for this project, which include:

- 3D scans patients' limbs
- Convert the 3D scanned meshes into 3D models of splints
- The 3D printed splint offers aesthetic opportunities and variations
- The 3D printed splint shape is optimised to offer different structural strength where it is necessary
- The 3D printed splint is washable

However, there are still areas to investigate, particularly in the area of embedding sensors to the splints, monitoring and designing games that encourage

adherence to medical therapies. Further research should also investigate how sensors can be embedded into the 3D printed splints, in order to track pressure points that can become pressure sores. Our current sensors measure only bend of the ankle joint. The pressure sensors could be connected to exergames that help patients carry out their therapies and increase adherence. Also, software needs to be developed to convert the 3D scanned meshes into designs of orthoses automatically, without the need of manual editing of the meshes by a qualified technician.

## Acknowledgments

This project was part-funded by the Product Accelerator. We would like to thank students and summer scholars from Victoria University of Wellington who contributed to this research: Holly Bradshaw-Clegg, Katherine Campbell-Hunt, Matt Everitt, Joe Dixon, Nicholas Wellwood, Max Kerr-Hislop, Warren Ariston-Smith.

## References

- Akyalcin, Sercan, David J. Dyer, Jeryl D. English, and Cagla Sar. "Comparison of 3-Dimensional Dental Models from Different Sources: Diagnostic Accuracy and Surface Registration Analysis." *American Journal of Orthodontics and Dentofacial Orthopedics* 144, no. 6 (December 2013): 831–37. doi:10.1016/j.ajodo.2013.08.014.
- Bartlett, D. J., and R. J. Palisano. "Physical Therapists' Perceptions of Factors Influencing the Acquisition of Motor Abilities of Children with Cerebral Palsy: Implications for Clinical Reasoning." *Physical Therapy* 82, no. 3 (2002).
- Burke, J. W., M. D. J. McNeill, D. K. Charles, P. J. Morrow, J. H. Crosbie, and S. M. McDonough. "Optimising Engagement for Stroke Rehabilitation Using Serious Games." *The Visual Computer* 25, no. 12 (August 27, 2009): 1085–99. doi:10.1007/s00371-009-0387-4.
- Engsberg, J. R., G. S. Clynch, A. G. Lee, J. S. Allan, and J. A. Harder. "A CAD CAM Method for Custom below-Knee Sockets." *Prosthetics and Orthotics International* 16 (1992).
- Fogg, B.J. *Persuasive Technology: Using Computers to Change What We Think and Do*. San Francisco: Morgan Kaufmann Publishers, 2003.
- Heinemann, A. W., R. K. Bode, and C. O'Reilly. "Development and Measurement Properties of the Orthotics and Prosthetics Users' Survey (OPUS): A Comprehensive Set of Clinical Outcome Instruments." *Prosthetics and Orthotics International* 27 (2003).

- Hellweg, S., and S. Johannes. "Physiotherapy after Traumatic Brain Injury: A Systematic Review of the Literature." *Brain Injury* 22, no. 5 (2008).
- Jerrell, M. L. "CAD/CAM in the O&P Industry." *O & P Business News* 15, no. 15 (n.d.).
- Koster, Raph. *A Theory of Fun for Game Design*. Scottsdale, Arizona: Paraglyph Press, 2006.
- Kovacs, L., A. Zimmermann, G. Brockmann, M. Gühring, H. Baurecht, N.A. Papadopoulos, K. Schwenzer-Zimmerer, R. Sader, E. Biemer, and H.F. Zeilhofer. "Three-Dimensional Recording of the Human Face with a 3D Laser Scanner." *Journal of Plastic, Reconstructive & Aesthetic Surgery* 59, no. 11 (November 2006): 1193–1202. doi:10.1016/j.bjps.2005.10.025.
- Leigh, Simon J., Robert J. Bradley, Christopher P. Purcell, Duncan R. Billson, and David A. Hutchins. "A Simple, Low-Cost Conductive Composite Material for 3D Printing of Electronic Sensors." Edited by Jeongmin Hong. *PLoS ONE* 7, no. 11 (November 21, 2012): e49365. doi:10.1371/journal.pone.0049365.
- Levac, D., P. Miller, and C. Missiuna. "Usual and Virtual Reality Video Game-Based Physiotherapy for Children and Youth with Acquired Brain Injuries." *Physical and Occupational Therapy in Pediatric* 32, no. 2 (2012). doi:10.3109/01942638.2011.616266.
- Marmulla, Rüdiger, Stefan Hassfeld, Tim Lüth, and Joachim Mühling. "Laser-Scan-Based Navigation in Cranio-Maxillofacial Surgery." *Journal of Cranio-Maxillofacial Surgery* 31, no. 5 (October 2003): 267–77. doi:10.1016/S1010-5182(03)00056-8.
- Mavroidis, Constantinos, Richard G Ranky, Mark L Sivak, Benjamin L Patritti, Joseph DiPisa, Alyssa Caddle, Kara Gilhooly, et al. "Patient Specific Ankle-Foot Orthoses Using Rapid Prototyping." *Journal of NeuroEngineering and Rehabilitation* 8, no. 1 (2011): 1. doi:10.1186/1743-0003-8-1.
- Movroidis, C., R. G. Ranky, M. L. Sivak, B. L. Patritti, J. DiPisa, and A. Caddle. "Patient Specific Ankle-Foot Orthoses Using Rapid Prototyping." *Journal of Neuroengineering and Rehabilitation* 8 (2011).
- Ogawa, M., K. Motoi, T. Yamakoshi, M. Nogawa, T. Yamakoshi, M. Shibata, and Y. Yamakoshi. "A New Proposal of Tailored Bioinstrumentation Using Rapid Prototyping and Three-Dimensional CAD - First Trial to Develop Individually Designed Cuff-Units for Continuous Blood Pressure Measurement." 30th Annual International IEEE EMBS Conference, Vancouver, British Columbia, Canada, n.d.
- Orvis, Karin A., Daniel B. Horn, and James Belanich. "The Roles of Task Difficulty and Prior Videogame Experience on Performance and Motivation in Instructional Videogames." *Computers in Human Behavior* 24, no. 5 (September 2008): 2415–33. doi:10.1016/j.chb.2008.02.016.
- Palousek, David, Jiri Rosicky, Daniel Koutny, Pavel Stoklásek, and Tomas Navrat. "Pilot Study of the Wrist Orthosis Design Process." *Rapid Prototyping Journal* 20, no. 1 (2013): 27–32. doi:10.1108/RPJ-03-2012-0027.
- Peaco, B. S., E. Halsne, and B. J. Hafner. "Assessing Satisfaction with Orthotic Devices and Services: A Systematic Literature Review." *Journal of Prosthetics and Orthotics* 23, no. 2 (2011).
- Sampayo-Vargas, Sandra, Chris J. Cope, Zhen He, and Graeme J. Byrne. "The Effectiveness of Adaptive Difficulty Adjustments on Students' Motivation and Learning in an Educational Computer Game." *Computers & Education* 69 (November 2013): 452–62. doi:10.1016/j.compedu.2013.07.004.
- Smith, D. G., and E. M. Burgess. "The Use of CAD/CAM Technology in Prosthetics and Orthotics - Current Clinical Models and a View to the Future." *Journal of Rehabilitation Research and Development* 38, no. 3 (2001).
- Telfer, Scott, Mandy Abbott, Martijn P. M. Steultjens, and James Woodburn. "Dose-response Effects of Customised Foot Orthoses on Lower Limb Kinematics and Kinetics in Pronated Foot Type." *Journal of Biomechanics* 46, no. 9 (May 31, 2013): 1489–95. doi:10.1016/j.jbiomech.2013.03.036.
- Tongrod, Nattapong, Shongpun Lokavee, Natthapol Watthanawisuth, Adisorn Tuantranont, and Teerakiat Kerdcharoen. "Design and Development of Data Glove Based on Printed Polymeric Sensors and Zigbee Networks for Human-Computer Interface." *Disability and Rehabilitation: Assistive Technology* 8, no. 2 (March 2013): 115–20. doi:10.3109/17483107.2012.737540.
- Treleaven, Philip, and Jonathan Wells. "3D Body Scanning and Healthcare Applications." *Computer* 40, no. 7 (July 2007): 28–34. doi:10.1109/MC.2007.225.
- Verzé, Laura, Francesca Antonella Bianchi, Eleonora Schellino, and Guglielmo Ramieri. "Soft Tissue Changes After Orthodontic Surgical Correction of Jaws Asymmetry Evaluated by Three-Dimensional Surface Laser Scanner." *Journal of Craniofacial Surgery* 23, no. 5 (September 2012): 1448–52. doi:10.1097/SCS.0b013e31824e25fc.
- "World's First Commercially Available 3D Printed Custom Orthotics Launches." 3Ders.org, 2014. <http://www.3ders.org/articles/20140113-world-first-commercially-available-3d-printed-custom-orthotics-launches.html>.
- Yasukawa, A. "Upper Extremity Casting: Adjunct Treatment for a Child with Cerebral Palsy Hemiplegia." *The American Journal of Occupational Therapy* 44, no. 9 (1990).

**M. Pillan**

Design Department, Politecnico di Milano, Italy

# Aesthetic and ethic issues in interaction design

## Aesthetics and interaction design

The role of designers and, between the others, of interaction designers, does not simply consist in the facilitation of the innovation processes, but can also be provocative and open new directions of development, beyond stereotyped solutions, indicating new perspectives of intending contexts and solve project questions.

In the disruptive evolution and spreading of digital technologies, the academic communities engaged in research for interaction design should not restrict the discussion to the topics of design methodologies and education approaches, but they can also offer a relevant contribution to the innovation of the discipline, developing original directions of research, and promoting the critical thinking about the potential scenarios made possible by the technical innovation.

In doing this, we may refer to the tradition of industrial design that has always found its cornerstones in technical and language experimentations, in the most comprehensive quest for quality as well as in social commitment, and in the courage to exercise a critical analysis of the dominant trends, also proposing meaningful and paradigmatic alternatives. To this respect, the growing interest aroused by aesthetic issues in the community of interaction designers can be interpreted as a sign of maturity of a discipline that, in the lapse of a few decades, progressed from the discussion about usability and user centred methodologies, to the design of emotions supported by the neurosciences, to finally land to aesthetics.

The topic of aesthetics is quite vast and the word itself is employed with a variety of different meanings [1].

The aim of making digital products and systems more pleasurable and desirable is and remains a very relevant issue; on the other hand, we can profit of the discussion about aesthetics to better clarify and reinforce the specificities of the role played by industrial designers in the project of technology based solutions and to highlight their original contribution with respect to other actors involved in projects. The aesthetics issue supports a renegotiation of the importance attributed to formal factors with respect to functional ones, since the research about formal qualities is indeed a research about human needs, perception phenomena, ways of involvement, and so on, that can be very difficult to describe in terms of objective statements. The formal attributes of a product or of a service have a value on its own, and should not be considered only as a means to support the access to functions.

The reasoning about aesthetics is, therefore, a discussion about quality or, better, about the possible ways to intend quality in interaction design and it is possible to refer to aesthetics theories to find new ways to investigate quality

factors that cannot be expressed in terms of rational and measurable elements even if their relevance can be clearly and unmistakably experienced in subjective ways.

As an example, we can go back to the origins and take as a starting point the invention of the word itself, aesthetics, by the German philosopher Alexander Gottlieb Baumgarten who claimed for a science of sensations as complementary and independent from logic sciences [2]. While philosophers as Leibniz, Christian Wolff, Kant [3], differently referred to aesthetics in the need of discussing the nature of clear sensible knowledge as opposed to logics and scientific exploration of the world, other authors considered aesthetics mainly as theoretical discussion on art, and others, such as Gernot Böhme, as a theory of perception [4].

In the time, the theoretical discussion about art generated reflections around beauty, taste and subjective evaluations, and produced the popular use of the word as synonymous of formal quality and beauty. But when we talk of aesthetics we should not only focus on the characteristics of the artefacts, but better, we focus on the kind of experience that the artefacts can produce.

The Italian professor of aesthetics Paolo D'Angelo calls aesthetic experience [3] a specific state of mind that can be elicited by the contemplation of artworks (even if the contemplation of a piece of art does not guarantee in itself the state of aesthetic experience), but also by other circumstances not related to art; a state of mind capable to deeply involve us both from the cognitive and emotional points of view, a state that we are neither able to fully untangle in its complexity nor to rationally explain, but that we clearly and unmistakably experience as something intense, meaningful and capable to produce relevant changes in ourselves.

If we take this definition as a reference, the research about the aesthetic of interaction should deal with the ability to create new languages based on the shaping of the interactive processes; in order to produce meaningful experience through interaction, we need to experiment different ways of engagement, also investigating the sides of human perception that appear as confused, uneasy, contradictory and dark, as artists have always been able to do, going beyond beauty and pleasantness. Through the research about the aesthetic of interaction, we should be able to investigate the different states of mind that can be produce in human minds through the interaction with digital solutions.

If we refer to the specific of industrial design culture and, as an instance, to the Italian masters of design, the reference to aesthetics as theoretical issue is seldom explicit while most of designers instead reflected on art and on the relationship between art and their personal work as designers. Authors such as Bruno Munari considered themselves as an applied artist and a pragmatic explorer of the expressive potentialities of fabrication techniques. In his book "Arte come mestiere", Munari claimed: "a person employing an object designed by a designer can feel the presence of an artist who worked also for him/her, so to improve his/her life and favour the change in his/her relationship with aesthetics" [5].

Enzo Mari remarked that industrial design is the unique discipline that faces three different cultural horizons: production technologies, scientific knowledge of natural phenomena, and expression. He stated that the formal quality of a designed artefact must be the outcome from the synthesis of deep knowledge or of motivations experienced as deeply involving. Again, the aesthetic issue is presented as a way to embrace human complexity also on the base of subjective readings of contexts and project questions; designers should be conscious that in their work, they have to produce the best synthesis between functional and formal goals, and the two have the same dignity [6]. The masters of traditional industrial design have always been quite conscious of the power of formal qualities of material products as means to convey meanings and messages, and of their ability to produce deep and relevant effects by shaping the form of their artefacts. Gropius aimed to the production of good forms so to translate life processes into images; he considered psychological needs as basic and primary, while interpreted the technical elements as tools to realize non-tangible effects through tangible solutions [7]; with a similar vision, Breuer got to the point of ideating a chair made of a flux of air as the sitting process was taken as more relevant than the chair in itself [8]. This awareness implied and should always imply a sense of responsibility connected to the profession of designer: the good form of tangible and non-tangible artefacts can induce emotions, fulfil psychological needs, communicate messages, induce value changes. From the market point of view, design can be seen as a way to add value to material products making them more attractive; on the other hand, the discussion about formal characteristics of products is

indeed a discussion about social concerns and ethics; the form of every kind of artefact we produce, has effect in terms of communication and meta-communication [9] and has an active role in the shaping of physical and virtual environments.

Interaction design is, for excellence, the domain of collaborative and multidisciplinary projects, mainly based on robust methodologies requiring data collection, ethnographic research and behaviour modelling; the discussions about the aesthetic of interaction can be therefore interpreted as a kind of provocation: a claim that now is the time to experiment new design approaches, to better investigate new forms of fulfilment and to redefine the ways we perform evaluation.

Furthermore, the issue of aesthetics also proposes the focus on art as a research approach; it indicates the relevance of investigate unproductive activities, emphasizes the analysis of subjective evaluations in their complexity and of the exploration of ambiguity as fundamentals of research methodologies. On the other hand, digital technologies offer opportunities of creating forms of experiences that are completely new in human history, most of which have only partially experimented and studied. As well documented in her book, *Aesthetic of Interaction in Digital Art* by Katja Kwastek [10], we can learn very much through the study of the modes of art and media engagement that produce the hybridization of physical world, digital information and interactive mechanics. The domain we explore is the new urban space that is generated by architectures based on these three elements.

In the tradition of industrial design, the formal attributes depend on material features of products; on the other hand, in interaction design the fulcrum of the discussion about aesthetics is based on the awareness that interaction is a dimension of human experience that humans perceive as relevant in itself. More: the shaping of the interactive dynamical processes offers the opportunity of creating new and engaging languages.

In industrial design, designers can create languages, elicit emotions, produce messages by acting on the form and colours of material objects; in the same way, by shaping the dynamics and mechanics of an interactive process, we can produce messages, stimulate emotional and cognitive processes, provide meanings and engage far beyond the simply optimization of affordance with respect to functions.

Every human activity and, consequently, every interactive process are inseparably based on the perception through the senses and therefore depend on the material factors of the material solutions enabling the interaction. Nevertheless, interaction is something that transcends and surpasses the perception of the characteristics of the material world with which we interact, and is developed through the implementation of the possibility of action that the relationship with the materiality sensitive makes possible. While we experiment new forms of interaction, we can actually investigate states of mind that are enabled by the interactive process.

To clarify this concept, we can opportunistically quote the German philosopher Gernot Böhme who employs the concept of atmosphere and states that seeing a tree is a very different experience than seeking shelter from the rain or the heat under the crown of a large tree [4]. In the search of a shelter under a tree, while we escape from a sudden rain or we search relief from the heat of the summer sun, our experience is clearly related to the formal qualities of the tree enabling the event, but, undeniably, the core of the experience itself is connected to the dynamics of the event (i.e. the change of state produced by entering into the protective cover of the tree) and to a tangle of other factors such as the physical characteristics of the tree (its dimensions, the shape and texture of leaves and trunk, the space defined by the shadow casted by the tree), the state of our active involvement (body and brain), and the way we perceive ourselves with respect to the features of the tree, as we see the potential shelter and begin to move toward it as a solution to a maybe unspoken problem, so experiencing a mental activity that we can describe in terms of (physical) problem solving. More, going back to the now disused concept of affordance, we could say that the only way to know a tree is through the exploration of all the possible interaction we could enact with it: getting shelter under it, climbing on it, building through it and so on.

When we design interactive processes, the shape is related to the physical design of the interactive solution, but also (mainly) to the mechanics of interaction and to the kind of affordances (i.e. the freedom of action) made available to the user. As we can do with the material shape of objects, in interaction design we can create languages acting on the form of the interactive process, and we can play with archetypes; we can overlap functions, meanings

and sensations; even in games, we can make strict procedures or, instead, encourage personal approaches [11], and we can play with ambiguity.

As designers, we can shape the interaction only designing artefacts that support or induce activities through the use of the solutions we design; on the other hand, as technology offers a growing number of opportunities to reduce the materiality of the devices involved in the interactive processes by producing electronic sensors and actuators that do not need touch or typing, we should develop the ability to reify interactive processes so to be able to play with forms of experience even when the material elements involved in the interaction have not a significant shape in their own.

## **Design and critical thinking**

The dynamic and interactive processes can be quite powerful in producing emotions but also in transmitting and make acceptable metaphors and paradigms; the involvement produced by interactive solutions can be much intriguing and even convincing just for the kind of involvement associated to being active part of a process. Some research already use the understanding on how interactive processes can be employed to convey messages, to produce effective experiences capable to modify opinions and attitudes [12].

If we accept the assumption that by shaping interaction we also produce meanings and messages in voluntary and involuntary ways, we should also acknowledge that the discussion about the quality of interactive products and systems is a matter of ethics as well as of aesthetics. The effort to gain the awareness about the implicit messages carried by the formal attributes of the artefacts we design is mandatory.

The adoption of digital technologies is transforming the ways we search for information, the perception of time and space, the use we do of our personal memory; also our mental frames and our brain-senses perception strategies change with the use of technologies, and the innovative communication tools we use modify the way we socially interact with other people and the way we intend priorities, hierarchies and roles, personal rights and privacy. On the other hand we must be very conscious that, in the design of technological devices and services, we have often a limited ability to fully govern the messages conveyed by the artefacts designed by us, and it is very difficult to predict *ex ante* the social consequences of an innovative solution. Quite often, even when technology is employed to support traditional and apparently unmodified functions, the amount and nature of the changes induced by technical innovation are predictable only in a limited way during the design process, and the full understanding *ex post* of the long term consequences on individuals and social systems connected to the use of a digital solution can be often performed only in time. To this respect it is important to invest in the critical analysis of the changes induced by the adoption of digital technologies and on the emerging scenarios, as performed, for example, by the authors that contributed to the book edited by Ulrik Ekman [13].

Back in 1999, Alan Cooper wrote a successful book entitled “The inmates are running the asylum” where he introduced his Personas and declared that “we need to radically rethink the interaction between humans and machines” [Cooper]. In this book, Cooper described technological solutions with the metaphor of a dancing bear: when we see a dancing bear we are so amazed by the fact that it is a dance performed by a bear that we tend not to notice that there is not a real quality in the dance itself.

After almost twenty years during which digital technologies evolved and became pervasive, still we often have a complacent attitude with respect to the final quality of technological solutions, and often we do not evaluate them at the light of their actual implementation, but our judgements tend to make allowances since we consider that tolerance is due to novelties. Digital innovation is always radical innovation, and we are still exploring the real beginning of the digital era. To produce knowledge in this exploration, there is no other way than to experiment, prototype, test and evaluate, on the other hand, we should pay more attention to the task of critical evaluation of the solutions we design and the directions to respect with we exert the evaluation: very often the changes induced in social rules by the adoption of digital technologies are implicit and therefore are not fully discussed in their final

consequences. Now we know that the technology should be designed to fit humans and not, the other way round, that humans should adapt to technological solutions, but we tend to consider the disadvantages provided by the introduction of technologies in process as temporary effects. The technological structures and systems are the new virtual urban environments in which we will live, and as such we should take care of them.

In order to carry on a relevant and effective discussion about the quality of interactive products and systems, we can go back to the history of design and inspire ourselves by the example of masters of design who, in their search for absolute quality, did not make scruples in expressing their severe critics, most of which were not “scientific” but mainly based on subjective sensations.

In 1997, in the early stages of the digital era, the genial Thomas Maldonado wrote a book named “Critica della ragione informatica” [14] in which he anticipated a number of relevant issues related to the spreading of computers and of digital solutions. At that time cd-rom were still considered as innovative supports of information, and some authors argued that the turn of interest from passive media (i.e. television), toward the new interactive information and entertainment solutions made available by internet and multimedia pc was quite uncertain since they supported the idea that human beings are naturally attracted by media requiring low level of active involvement.

Really, the awareness of interaction as a dimension of expression was still far away, nevertheless, in his survey on the tangle of issues related to the construction of the then called cyberspace, Maldonado was quite conscious that the realm of digital technologies was something unique and new with respect to the tradition of industrial design; the peculiarity of digital technologies in the shaping of the future requires a more complex and articulated modelling of human mind and perception processes. To this purpose, Maldonado called in scientists such as V. Ramachandran and S. Zeki to indicate the need of acquiring new knowledge to face the digital change and the related project opportunities.

The book framed some questions that are still relevant: How the new technological inventions are going to modify human organization systems? Which innovative urban scenarios are made possible by the spreading of internet and of computers? How human perception is going to be modified by the intensive use of digital prosthesis? How will we manage an unprecedented amount of information? How cognitive and emotional processes will change in the new environments created by the intersection of physical and digital spaces? Which changes will be produced by technologies on language, personal identity, sense of self, sense of personal freedom and rights? And more: which forces, beyond the market and the economical interests can orient the innovation toward a sustainable and desirable future? The book of Maldonado is still fascinating as it conserves the ingenuity and clairvoyance associated with the reflections developed at the dawn of a great change. His questions cannot find a final answer but should accompany us in the development of future solutions and scenarios so to maintain the perspective we had of the future when we were moving the first steps into the digital space. More, we should be able to afford in a more direct and explicit way the discussion on the real desirability of digitization of processes, case by case, and in some circumstances, we should be brave enough to oppose against the use of indiscriminate adoption of technological solutions when this is not supported by real progress.

## **A drawing through dots**

The challenge posed by the DeSForM Topic entitled “From smart to wise: toward a new conception of digital products and services” focused the call on the differences between two words, innovation and progress, that we should try to maintain distinguished.

The papers collected in the track propose different approaches to the topic and offer an interesting map of the state of the art of research. Each of them enlightens, from a specific and original perspective, the efforts addressed toward new ways to intend quality in interaction design.

Elif Özcan, in his paper entitled “Toward wise experiences: The role of wisdom in design for well-being” deals with relevant definitions of wisdom coming from psychology, phenomenology and philosophy, and he extracts from them a conceptual system useful in the design of products and in their evaluation with respect to well-being.

The paper “Examining Sensorial Interfaces as the Stimuli for remote Affective Communication” by Xinchu Zhang,

Lois Frankel and Audrey Girouard presents a study of communication activities in families; the analysis deals with emotional factors such as concern, sense of togetherness, memory, and provides insights for the design of innovative communication solutions.

Jacklynn Pham wrote “Expanding the Palette of Digital Interaction”, a paper reporting a design exercise based on a tool intensively employing reflectivity in the design process so to widen creative potentials.

In their writing entitled “ The delicacy of handshakes: reflection on the aesthetic of interaction”, Marc Hassenzahl, Eva Lenz, Sarah Diefenbach and Nigel Geh Keong Teck investigate interaction at the intersection between material and immaterial experiences and present a design philosophy focused on experience, based on design practices, conceptual thinking, and experimental findings.

Bin Zhu, Yanqing Zhang, Xiaojuan Ma and Haibo Li offer a reasoning about the evaluation criteria in interaction design from the perspective of cultural specificity and explore the contribution that the Chinese culture about aesthetics can provide to the reasoning about the topic in interaction design. Their paper is entitled “Bringing Chinese Aesthetics into Designing the experience of Personal Information for Wellbeing”.

In “Social Shopping in Smart spaces” Shushu He focuses on social shopping, discusses the main issues in this field, and indicates the relevance of acting on factors such information asymmetry in the purchase process, of trust-forming policies and evaluation criteria.

Marco Spadafora presents a design tool supporting the creation of innovative concepts interactive products, and while he focuses on the dialogue between users and machines, he refers to aesthetic values in design to get out of the constraints of efficiency; the paper is entitled “ Object’s Personality, a Tool to Chase Aesthetic Approach in the Design of Smart Objects”.

The last three papers of the track refer to the domain of game design but with different perspectives.

Ilaria Mariani and Ida Talelbasic, in their paper: “The reverse Engineering of Emotions”, introduce the idea of employing serious game in reverse modelling of emotions as a preliminary activity in the design of NFC based solutions for daily applications so to investigate the emotional pattern of users involved in the interactive processes. The paper “In Search of the Right Design Abstraction for Designing Persuasive Affordance towards a Flourished Society”, Mizuki Sakamoto and Tatsuo Nakajima deals with interactive digital rhetoric and outline an investigation of its influence on human behaviours.

Annamaria Andrea Vitali in “Play Design and Sense-making: players and games as digital Interactive Contexts for Effects of Sense” bases her writing on case-study analysis and design experiences, and investigates sense-making effects on the base of semiotics theories.

## References

- [1] Mersch, D. (2015) Epistemologies of Aesthetics. Think Art, Diaphanes.
- [2] Baumgarten, A. G., (written in 1735, reference print 1999) *Riflessioni sulla poesia*, curatorship Pinpinella, P., Tedesco, S., Aesthetica.
- [3] D’Angelo, P. (2011) *Estetica*, Laterza
- [4] Bhöme, G. (2001, reference print 2010) *Atmosfera, estasi, messe in scena. L’estetica come teoria generale della percezione*, Marinotti-Percezioni. *Estetica&fenomenologia*.
- [5] Munari, B. (1966, reference print 2003) *Arte come mestiere*. Editori Laterza.
- [6] Mari, E. (2001) *Progetto e passione*, Bollati Boringhieri.
- [7] Gropius, W. (1943, reference print 2007) *Scope of total Architecture*, It.ed., Abscondita s.r.l., p.46.
- [8] Fiedler, J. (2006) *Bauhaus*, Tandem Verlag GmbH.
- [9] Maiocchi, M., Pillan, M. (2009) *Design e comunicazione*, Alinea.
- [10] Kwastek, K. (2013) *Aesthetics of Interaction Design in Digital art*, The MIT Press.
- [11] Righi Riva, P., Pillan, M. (2012) *The Unimportance of Flawless Game Mechanics*, 4th International Conference on Games and Virtual Worlds for Serious Applications(VS-GAMES’12), *Procedia Computer Science* 15.
- [12] Laschke, M., Hassenzahl, M., Diefenbach, S. (2011) *Things with attitude: Transformational Products*. In: *Proceedings of Create11 Conference*.
- [13] Ekman, U. (editor) (2013) *Throughout. Art and Culture Emerging with Ubiquitous Computing*. MIT Press.
- [14] Maldonado, T. (1999) *Critica della ragione informatica*, Feltrinelli.



# The delicacy of handshakes: Reflections on the aesthetics of interaction

## Abstract

Nowadays, consuming activities, ideas, and experiences become more important than cherishing possessions. This apparent shift from the tangible, material to the intangible, immaterial poses a serious challenge for contemporary product design and industrial design. At the heart of designing the immaterial (i.e., experiences) is interaction. Interaction is actually the go-between the immaterial and the material, providing form to an immaterial experience in the physical world. Consequently, questions of what constitutes a “good”, “pleasurable”, or “beautiful” interaction become more and more important. While there is a vivid discussion about the aesthetics of interaction among interaction designers, most approaches focus either on the experiences and emotions to be created or on the sensomotoric attributes of interaction itself. An open and pressing question, however, is how to bridge the gap between these levels, i.e., how to deliberately design interaction to materialize a specific experience. This paper gives an overview of our approach to the aesthetics of interaction and experience design. It provides the general philosophy, concepts and findings and two in-depth examples of our design praxis from the area of interpersonal verbal and non-verbal communication (i.e., relatedness experiences).

## Keywords

Experience design, aesthetics of interaction, relatedness

## 1 Experiences and “stuff” – new challenges for design

In *Up in the Air*, George Clooney plays a corporate downsizing expert, flying from city to city for 320 days a year, living in hotels, out of his suitcase. Most of the time, he is firing people, but now and then, he gives motivational speeches of how to relieve one's life of excess physical (and emotional) baggage. Of course, such lifestyles exist not only in the movies. Bardhi and colleagues [1] recently interviewed modern elitist nomads about their “physical baggage”, that is, their relationship to possessions. They found nomads to eschew the identity-building “function” of the material. As one interviewee put it “I also realized that they're [his possessions] just things. They didn't really define who I am. So since then, I'm quite a bit detached from any particular items. So I don't haul things around for sentimental reasons” (p. 518). Instead, nomads form liquid relationships to things marked by a focus on situational value, use value, and immateriality. For nomads, “stuff” is only temporarily significant, and if, mainly for the experience it provides access to or mediates. Nomads travel “light”. They consume activities, ideas, and experiences, rather than cherish possessions.

The global elitist nomads studied by Bardhi and colleagues [1] are certainly not average consumers. But they may be glimpses of the type of consumers to come. One may, for example, understand “lightness”, a general

disenchantment with material possessions, as a crucial element of a sustainable lifestyle. When relationships to possessions become liquid, we no longer need to possess a car as identity-marker, but rather use it when necessary.

Changing focus from stuff to experience poses a challenge for many design disciplines, especially product design and industrial design [8]. It shifts attention from the material, tangible, to the immaterial, intangible. Of course, the symbolic, identity-building value of artifacts is immaterial, too, and contemporary design long mastered this aspect in theory and practice (e.g., [14]). But an experiential perspective is about a different kind of immateriality. It is about creating experiences through sustained interaction with the material. It is actually about doing rather than possessing. The material itself is merely a mediator, providing accesses to experiences and shaping them. To give an example: A handshake can create a positive moment of mutual appreciation and feeling close to each other. Hands play a significant role in shaping the experience. A “successful” handshake is all about the pressure applied, the moisture of the skin, the velocity of arm movements. Variations of these parameters will inevitably impact the beauty of a handshake and, thus, the experience. But without the experience, the material becomes meaningless. (Note, that this does not render the hand useless without handshakes.) To give a further example from the domain of “stuff” – for people, who travel a lot, the mobile phone is an important possession. It links the traveler to her loved one's at home; it provides access to the experience of feeling related to significant others; it offers ways to fulfill a fundamental psychological need for togetherness, belonging, relatedness (e.g., [16]). The potential relatedness experiences created and mediated by a mobile phone are its true value. Obviously, if mobile phones merely grant access, it doesn't matter which phone one uses – the relationship to the phone becomes liquid. But in fact this is only half of the story: Through its very physical design, that is, the technology, form, and functionality used, the mobile phone inscribes particular uses and forms of interaction, which in turn impacts the experience. Thus, an experience- and interaction-oriented design of “stuff” focuses on the way materiality has to be configured to make experiences positive and meaningful. This differs immensely from the primarily identity-building approach of contemporary product design and industrial

design [19]. Today, mobile phones are offered in myriad configurations, sizes, materials – all basically employing the same type of communication experience. In the future, we may offer a myriad different ways of feeling close [9]. To give an example: *The Whisper Pillow* [3] supports messaging among couples, who live together, but do not spend much time with each other due to asynchronous daily routines, for example, because of shift work. The *Pillow* features a pocket for a short audio message (Figure 1). If the pocket is empty and opened, a recording starts, capturing brief messages, whispered into the pocket. Simultaneously, the end of the *Pillow* inflates and creates an impression of being “filled” with the message. The recording ends with closing the pocket. If a “full” pocket is opened, the message is played back, deleted, and the *Pillow* deflates.



Fig. 1. The Whisper Pillow (Source: [3])

In this example, the interaction for leaving and receiving a message was deliberately designed to suggest intimacy and emotional expression. The *Pillow* puts the user into a body posture reminiscent of intimate practices, such as embracing or pillow talk. The pocket as well as the quite sensitive microphone implies speaking in a tender, whispering voice. The need to hold the pillow close to the ear to listen to a message ensures attention and implies respect for the partner's message. The *Pillow* is a materialization of a particular relatedness experience, designed to invoke and shape the experience through interaction.

In our view, the *experience* itself (the *Why* and the *What*) as well as its *materialization* (the *How*) are arenas for design. The design of an *experience* is conceptual. Designers detail the needs to be fulfilled in and through the experience (e.g., feeling related to family when travelling). Typically, people engage in concrete activities

or “social practices” [15] to fulfill their psychological needs (e.g., kissing, hugging, making a telephone call, or something completely different, dreamt up by the experience designer, such as messaging through a pillow). The practice is context-dependent (situation, culture), and in many cases, the most pressing question for experience design is to create a version of a practice, which perfectly fits the intended emotional-cognitive outcome as well as the particular circumstances (situation, culture).

While the experience remains conceptual, intangible, its *materialization* brings it to life. The materialization suggests a particular course of interaction, designed to create the desired experience for the “user”. In this sense, the experience is designed and then embedded into a material configuration by the designer. Through interaction (i.e., “use”), the experience (need fulfillment, feelings, thoughts) is (re)created for the user. This is of course not a one-to-one process; experience not always re-emerges as inscribed. In the case of the *Whisper Pillow*, some couples used it as intended, others found new uses, that is, appropriated the *Pillow* [3]. Nevertheless, the emergence of the intended experience through interaction is – at least for us – a sign of design quality. This differs from other approaches, which celebrate open-endedness and ambiguity [5].

In our view, the experiential and the material are closely intertwined. But in a conceptual sense, it is helpful to see them on two different levels: one constituting the immaterial part of the artifact, the other its particular materialization. At its heart are interaction and its design. Interaction is the go-between the immaterial and the material. It is at the same time derived from the intended experience and brought into world through the material. Consequently, interaction design is much more than the design of efficient, effective, visually stunning, sleek and novel interfaces – there is an *aesthetic* to it. Not in the sense of aesthetic as a fancy word for the visually beautiful, but as a normative system describing principles of “good” interaction.

## 2 Our view of an Aesthetics of Interaction

The notion of an *aesthetics of interaction* is around for some time now [13]. In a recent systematic review of 19 published approaches to the aesthetics of interaction, we found two distinct groups [12]. One dealt with low-level description and specification, i.e., spatio-

temporal attributes of interaction sequences (e.g., movement speed, precision, duration). This is where interaction design is crafted from the material and requires decisions on concrete physical parameters – is the interaction fast or slow, precise or fuzzy, direct or indirect? The other group of approaches addressed high-level experiences, desired emotions and meanings (e.g., thrill, challenge, trust) rather than the interaction itself. In fact, attributes on the “experience-level” broadly referred to psychological needs, such as competence, relatedness, stimulation [7,18]. As said above, psychological need fulfillment is the ultimate source of pleasure and meaning. In other words, this notion of two levels, one dealing with the experience, the immaterial, and one with its materialization, is clearly reflected in contemporary theorizing about the aesthetics of interaction.

We argued that while conceptually different, both levels need to be closely intertwined. Surprisingly, only two of the reviewed approaches addressed both levels simultaneously, making an explicit link between the interaction enabled by the material and the attributes and “shape” of the intended experience. The question of how to bridge the gap between experience and the material remains open. We believe that this question is essential to the theory and praxis of (aesthetic) interaction design. In fact, we argue that the overarching principle of aesthetic interaction is the match between the way the material shapes interaction and the practices and needs to be fulfilled through this interaction. Like in the *Whisper Pillow*, intended experiences and interaction must match.

Over the last three years, we sought to better understand how the material and the immaterial relate to each other and to develop strategies to bridge the gap between both. A first step was to study a broad sample of already existing artifacts/products [11]. Participants (n=38) chose an interactive product from their daily life. They first described their product’s “interaction profile” with the *interaction vocabulary* [4]. The interaction vocabulary is a systematically derived set of attributes, useful for describing interaction on a concrete motor-level, but in a modality- and technology-free way (e.g., slow-fast, stepwise-fluent, instant-delayed). Participants then reflected on how concrete interaction relates to the experience. Though based on experiences with quite different products (e.g., coffee maker, smartphone app, electric drill),

participants' reports revealed a striking consistency with regard to the high-level experiential consequences of particular low-level interaction attributes. For example, stepwise interaction was described as rewarding, providing emphasis on progress and advancement of the process, approaching a goal step-by-step (need for competence), fast interaction was described as animating, stimulating, and activating (need for stimulation), and constant interaction as well as spatial proximity were associated with safety (need for security).

Another approach was to study mundane interactions. While most available interactive products (e.g., smartphones, music players) are quite limited in the interaction they offer, interaction in daily life (e.g., pulling up the blinds, rolling a ball, cutting vegetables) as well as interaction between people (e.g., hugging, shaking hands) are rich and leave room for variations. A hug can be performed slow or fast, gentle or powerful, with more or less precision – interacting with a contemporary smartphone is less flexible. If variation is possible, people will tend to adjust interaction to what feels good, meaningful, just “right” for them in a particular situation. In a recent unpublished study (N=214), we first identified typical practices, which fulfill different psychological needs in daily life. People, for example, felt competent, when parking their car into an especially tight space or when opening a bottle with a lighter. Obviously, these practices are culturally and situationally bound, nevertheless, they are repeatedly mentioned, that is, shared, and can be consciously linked to a need. We then selected a number of practices, described them to a new sample of people, and asked them to vividly imagine having done the respective activity, that is, to imagine the interaction. They described their experience with a questionnaire on need fulfillment [7, 18] and the interaction with the interaction vocabulary [4]. In addition, we asked them to rate, how positive the experience had been overall. Correlational analyses revealed that indeed particular practices were linked to particular needs. More importantly, need-specific practices were related to specific interaction attributes. Despite serving different functionalities, “good” competence-related interaction was typically described as stepwise rather than fluent, “good” stimulation-related interaction (e.g., “opening a surprise package”) was described as fast rather than slow, and “good” security-related interaction

(e.g., “snuggling under a blanket”) was described as constant and of high spatial proximity. This knowledge can be used to assist the identification of interactions appropriate for a specific experience.

In sum, our work so far suggests that in daily life, psychological needs are fulfilled through particular practices. The interaction implied by all the practices belonging to a particular need, in turn, are – while of course being diverse – marked by typical interaction attributes. In this sense, we suggest that the overarching principle of an aesthetic interaction is the match between the experience to be created (the Why and What) and the interaction actually suggested through the material to create and mediate this experience (the How). In the remainder of the paper, we further explore this notion of designing aesthetic interaction through our design praxis.

### 3 Design praxis 1: The handshake

The conceptual understanding outlined above enables a rich design praxis. Let us illustrate this with an example from a course of “experience and interaction design” at the Folkwang University of Arts. One of the first assignments is to design a hand-shake. The handshake is one of the myriad practices, people established to experience relatedness. While the psychological need for relatedness is rather universal (e.g., [16]), it remains an abstract concept. A handshake, on the other hand, is a concrete way to *practice* relatedness in everyday life. This practice, of course, is situationally and culturally bound. The handshake is foremost a form of greeting. Typically, two people extend their arms, grab each other's right hand, hold it firm for some seconds, and often move their arms slightly up and down. This practice is rich in meaning. It, for example, expresses a certain desired intensity of relatedness. While it becomes an intimate gesture through the touch of hands, it differs from other forms of greetings, such as an embrace, a peck on the cheek, or a kiss. Sennet [17] calls it a “low-intensity exchange” (p. 88). In other words, the (desired, appropriate) intensity of the feeling of relatedness to be experienced is expressed by the practice chosen, which in turn “materializes” this intensity (intimacy) through spatial proximity and physical contact. A handshake creates a moment of bodily contact, synchronicity and mutual appreciation, but still keeps people at arm's length. It also expresses a desire for peace. It is said to have been invented by



Fig. 2. A redesigned, more hygienic handshake (Source: Authors)

the Greeks to show that the hands hold no weapons ([17], p. 88). In addition, in many Western cultures, the handshake seals contracts, thus, connoting trust. Where is the potential objective of design, when it comes to handshakes? There are at least three: polishing the practice, redesigning the practice to adjust it to a given situation, and (mis)using the practice to fulfill a need different from relatedness.

*Polishing.* A handshake is an interaction between two people, intended to create a particular experience, which gets its meaning through fulfilling the need for relatedness in a particular intensity. In this sense, a handshake becomes a subject of interaction design. Which “parameters” of a handshake have to be tweaked to make it perfectly pleasant? “Perfect” and “pleasant” become a consequence of “designing” the handshake in a way to invoke the exact intensity of relatedness that seems appropriate and desired – reflecting our notion of a match between the experience and its materialization. As designers of handshakes, we have a number of parameters to consider: spatial aspects, such as the proximity between the two individuals or their exact position to each other; physical aspects, such as the strength of grip or the dampness of the palms; temporal aspects, such as the length of holding each other's hands or the number and timing of up-and-down movements. Considering these parameters, many things can go wrong. In some countries, a weak grip – especially for men – has a negative connotation, similar to damp hands. One should also not forget to look the other straight into the eye during the short moment of shaking hands. And we all know the archetypal situation, when a slightly overeager opposite just does not seem to stop pumping one's arm. “Wrong” means that the feeling of relatedness to be invoked by the handshake is

not realized or even turned into the opposite. To define the parameters for creating a particularly polished version of a practice is, from our point of view, an act of experience and interaction design. Note, that this does not involve “stuff” (i.e., objects, products, technology), but still has clear immaterial as well as material aspects to be deliberately arranged (i.e., designed).

*Redesigning.* While polishing a practice can be a purpose of design, the more common is the redesign of a practice to avoid potentially negative consequences. The handshake, for example, is not as innocent as one may think. Handshakes (as forms of physical contact) are among the prime risks for infections, such as a cold or gastro-enteritis [2]. Typically, over the course of the day, peoples' hands touch many surfaces and other people, as well as the own mouth, nose, and eyes. Of course, one can try to avoid handshakes at all [10]. Another possibility would be to design an especially hygienic handshake (for example, grabbing the forearms rather than the hand) (Figure 2). The design requires to create as much relatedness as possible, but at the same time limiting physical contact to less problematic body parts.

In the case of hygiene, people have the opportunity to touch each other, but try to avoid or limit physical contact. A more extreme case, often apparent in technology-oriented interaction design, assumes that a practice cannot be carried out directly, but needs to be completely mediated by a technology. In the case of relatedness, people may simply not be in the same location, such as in the case of long distance relationships. In a review of 143 concepts for technology-mediated relatedness, “physicalness” – the mediation of physical intimacy – was a strategy used in 13%. The concepts were either about transmitting

secondary effects of physical proximity, such as body heat or heartbeats, or about gestures (practices), such as hugging. To recreate a hug over a distance [6] requires the careful translation of the defining aspects of a hug into material configurations (e.g., an inflatable vest) and technical parameters (e.g., the speed of inflating the vest). The technology allows to “transmit” a hug, by mimicking input and output of the practice. In this sense, to design a handshake over the distance would require the materialization of all the parameters (spatial, temporal) of an appropriate handshake. This is certainly a difficult endeavor in terms of materialization, but less challenging conceptually.

It gets more interesting, when we deliberately redesign practices, such as when finding a more hygienic version of a handshake. Obviously, this can have different reasons and can take different forms. For Marc Hassenzahl a handshake is too formal, too much associated with contracts and the business world, to express sympathy in an informal setting. In line with other cultures, he favors an embrace, a hug. However, for some people, a hug expresses the wrong level of intimacy. Especially among men, hugging is not yet a completely accepted practice in Marc’s reference group. To overcome this, he “designed” a – for some of his contemporaries annoying – greeting. Typically, upon meeting, the “handshake” person extends his arm and offers the hand. Marc starts with reciprocating this, but stops half way in the movement and pulls his hand back. He quickly opens his arms for an embrace, often accompanied by an “ach, come on”. Most of the time, this is then reciprocated and turns into a hug; of course, a manly hug, firm, with a lot of backslapping. The desired experience of relatedness is designed through



Fig. 3. Prank Handshake for littleBits (Source: <http://littlebits.cc/projects/prank-handshake>)

a particular interaction. Here, the design is not just the polishing of a given practice, but the deliberate design of a new form of greeting, which aims at transforming the level of intimacy. It mixes two practices and provides a transition between both.

*(Mis)Using.* Finally, note that a practice can also be (mis) used to fulfill completely different needs. In the starter kit of the littleBits system, one of the first projects is the *Prank Handshake*. Figure 3 shows the setup.

A button is attached to the palm and connected with a buzzer. Upon shaking hands, the button is pressed and the buzzer makes a terrible sound. The receiver of the handshake is, of course, frightened out of her wits, and the giver indulges in *schaden-freude*. The experience for the giver is one of being stimulated, victimizing the receiver to some extent, but in a lighthearted way. Obviously, this is quite different from the typical experience of shaking hands. Marc’s daughter tried it out and had a lot of fun with it (Figure 4).

Fig. 4. A technology-mediated practical joke (Source: Marc Hassenzahl)







Fig. 5. ANAlog – recording (first row), "impression" (second row) and enjoying an impression (third row)  
(Source: Nigel Geh Keong Teck)

In this example, the practice of a handshake is “misused” by making an unexpected addition to a familiar interaction. Done on a material level (realized with *littleBits*), the slight rescripting of the interaction led to profound changes on the experiential level. Or to put it more correctly, starting from the practice of “practical jokes”, the designer (the daughter) redesigned a handshake by manipulating the interaction on a material level. Again experience is made possible and “good” through the close match of both levels.

#### 4 Design praxis 2: ANAlog

Nigel Geh’s concept *ANAlog* is another example of our design approach in praxis. *ANAlog* is a smartphone application to record visual impressions and then share them with a lover over the distance. While being an exchange student in Germany, about thirteen thousand kilometers from home, he tried many ways to share new impressions, sights and places with his partner. Picture sharing was one important practice. But sharing pictures through services such as *Facebook* or *Pinterest* remained emotionally “flat”. Just clicking through photos had nothing in common with the original situation and the photographer’s feelings in that situation. Obviously, a click is an interaction carried out countless times a

day, for tasks ranging from deleting spam mail to saving an important document. Nigel wanted to show his partner the places he found to feel close to her and “designed” an according experience. He envisioned a situation, where lovers stand side-by-side in a meaningful, beautiful, stunning place. They take a look around, slowly moving their heads from left to right, in sync with each other, fully immersed in the scene, while one partner points out particularly interesting views or tells a little story. This is the envisioned experience. Unfortunately, there was the little inconvenience of 13.000 kilometers distance in between the two lovebirds. Similarly to the *Hug* [6] discussed above, the design challenge was to create the envisioned experience asynchronously and over a distance. To achieve this, *ANAlog* allows to record an “impression” by moving a smartphone in exactly the way (direction, pace), the “photographer” feels appropriate. While doing so, sound of the surroundings is recorded and one can comment on what is seen (Figure 5, first and second row). Imagine standing in the harbor, slowly moving the smartphone from right to left, panning over the old market hall, the ferry, resting some final moments on the entrance of the harbor. It is a mindfully executed “look around”.

Upon receiving this “impression”, the Nigel's definite other puts her smartphone in a specifically designed cardboard peeking box (Figure 5, third row; for a concept video see <https://vimeo.com/125439661>). This is meant to make her forget the fact that she is actually in a different place. To play back the “impression” the viewer has to move the way the photographer has moved, that is, in the original pace and direction. Differences between the movements of the photographer and the viewer are signaled through image and sound. If, for example, the original movement was from left to right, but the viewer watches from right to left, everything is played backwards. Through this, *ANALog* only shows the impression exactly the same way as recorded, if the viewer recreates the same movements as the photographer. This creates an impression of synchronicity, of taking this look around together, standing side-by-side, rather than being separated by thousands of kilometers. In line with our general approach, relatedness was linked to a practice (i.e., being at a relevant place, side-by-side, sharing the perspective, and commenting on the surroundings), which in turn was materialized through interaction and technology to overcome the problem of physical separation. The resulting interaction is both, derived from the relatedness to be fulfilled and the envisioned practice, but shaped to convey this by careful materialization (i.e., through the way of recording an impression, way of viewing the impression, the cardboard box to increase the immersion in the impression).

## 5 Conclusion

Experience is an important future arena for industrial design and product design. Through its intimate link to need fulfillment and positive affect, experience emphasizes individual wellbeing and health. Through its focus on the immaterial, innovations-of-use rather than innovations-of-things, experience is a strategy for less resource-consumption. In our view, understanding and designing experiences is an important building block for post-materialistic, post-growth lifestyles marked by sufficiency in the material, but experiential richness in everyday life.

But experience is only the story. It has to be told. Here, interaction becomes crucial. It is the go-between the immaterial (i.e., experiential) and the material world. Interaction is an important carrier of meaning, at the

same time constituting a particular practice (e.g., a handshake is nothing more than an interaction, made of a sequence of actions and reactions) and being realized through material configurations (e.g., shaped by sizes of palms, moisture of skin, strength of grip etc.). In our view, designers need to do both: design the experience and materialize it through interaction with the material. Since interaction plays a crucial role, there is obviously a need for an aesthetics of interaction, an understanding of what constitutes a “good”, “pleasurable”, “enjoyable”, “beautiful” interaction.

So far a number of approaches to the aesthetics of interaction were proposed (see [12]). They address issues on an experiential level by proposing important attributes of a meaningful, positive experience (e.g., feeling competent and in control), closely matching our own need-based approach. Others address issues of the minute description of interaction on a physical, sensomotoric level (e.g., pace of interaction). Only rarely, both levels are integrated. In our view, this is a serious omission. In fact, we believe that the match between the intended, desired experience and the interaction chosen to materialize it, constitutes the single, overarching principle of an aesthetics of interaction. Our design praxis and the present examples evolved around this theme of bridging the gap between experiences (i.e., the stories to be told) and physical interaction (i.e., the way the story is told). The designer in this sense becomes simultaneously author and director, the same way an author embeds abstract meaning into a particular play and a director chooses ways to materialize that play, to bring it to life.

## 6 Acknowledgement

This work was supported by the German Federal Ministry of Education and Research (BMBF), project NÄHE auf Distanz (Grant: 16SV7093K).

## 7 References

1. Bardhi, F., Eckhardt, G.M., and Arnould, E.J.: Liquid Relationship to Possessions. *Journal of Consumer Research* 39, 510–529 (2012)
2. Bloomfield, S.F., Aiello, A.E., Cookson, B., O'Boyle, C., and Larson, E.L.: The effectiveness of hand hygiene procedures in reducing the risks of infections in home and community settings including handwashing and alcohol-based hand sanitizers. *American Journal of Infection Control* 35, 27–64 (2007)



3. Chien, W.-C., Diefenbach, S., and Hassenzahl, M.: The whisper pillow: a study of technology-mediated emotional expression in close relationships. *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces - DPPI '13*, 51–59 (2013)
4. Diefenbach, S., Lenz, E., and Hassenzahl, M.: An interaction vocabulary. Describing the How of interaction. *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*, ACM Press, 607–612 (2013)
5. Gaver, W.W., Beaver, J., and Benford, S.: Ambiguity as a resource for design. *Proceedings of the conference on Human factors in computing systems - CHI '03*, 233–240 (2003)
6. Gemperle, F., Disalvo, C., Forlizzi, J. and Yonkers, W.: The Hug : a New Form for Communication. *Proceedings of the 2003 conference on Designing for user experiences - DUX '03*, 1–4 (2003)
7. Hassenzahl, M., Diefenbach, S., and Göritz, A.: Needs, affect, and interactive products – Facets of user experience. *Interacting with Computers* 22, 353–362, (2010)
8. Hassenzahl, M., Eckoldt, K., Diefenbach, S., Laschke, M., Lenz, E., and Kim, J.: Designing Moments of Meaning and Pleasure. *Experience Design and Happiness. International Journal of Design* 7, 21–31 (2013)
9. Hassenzahl, M., Heidecker, S., Eckoldt, K., Diefenbach, S., and Hillmann, U.: All You Need is Love: Current Strategies of Mediating Intimate Relationships through Technology. *ACM Transactions on Computer-Human Interaction (TOCHI)* 19, 30 (2012)
10. Kozlowski, L.T., Kiviniemi, M.T., and Ram, P.K.: Easier said than done: behavioral conflicts in following social-distancing recommendations for influenza prevention. *Public Health Reports* 125, 789–792 (2010)
11. Lenz, E., Diefenbach, S., and Hassenzahl, M.: Exploring relationships between interaction attributes and experience. *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces - DPPI '13*, 2013, 126–135.
12. Lenz, E., Diefenbach, S., and Hassenzahl, M.: Aesthetics of Interaction – A Literature Synthesis. *Proceedings of the 8th Nordic Conference on Human-Computer Interaction Fun, Fast, Foundational - NordiCHI '14*, 628–637 (2014)
13. Löwgren, J. and Stolterman, E.: *Thoughtful Interaction Design: A Design Perspective on Information Technology*. The MIT Press, Cambridge (2004)
14. Mugge, R., Schoormans, J.P., and Schifferstein, H.N.J.: Emotional bonding with personalised products. *Journal of Engineering Design* 20, 467–476 (2009)
15. Reckwitz, A.: Toward a Theory of Social Practices: A Development in Culturalist Theorizing. *European Journal of Social Theory* 5, 243–263 (2002)
16. Ryan, R.M. and Deci, E.L.: Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist* 55, 68–78 (2000)
17. Sennet, R.: *Together. The Rituals, Pleasures and Politics of Cooperation* [Kindle-Edition]. Allen Lane, Penguin (2012)
18. Sheldon, K.M., Elliot, A.J., Kim, Y., and Kasser, T.: What Is Satisfying About Satisfying Events ? Testing 10 Candidate Psychological Needs. *Journal of Personality and Social Psychology* 80, 325–339 (2001)
19. Sun, J., Chen, T., Xie, J., Li, F., and Wang, G.: When technology products meet social needs: Product pricing and design. Available at SSRN 2266115.

# The Social Shopping in Smart Space

## **Abstract**

Social shopping is one form of electronic business, it is not only a kind of online shopping behavior, but also a kind of unprompted social behavior among consumers, which brings advantages to consumer's shopping experience and efficiency for decision-making. This article starts from the general definition of social shopping, then analyzes and summarizes the features of current social shopping behaviors and deduced three essential conclusions: 1. The information asymmetry exists between buyer and seller. 2. Subjective feeling based trust. 3. Imbalance between consumer expectation and user evaluation. Based on these conclusions, this article discusses and explores the interaction features and future development of social shopping which is built on the Internet of Things. It also puts forward the concept of smart space with its task to provide more neutral information to consumers, to help them distinguish fake information, to reduce information asymmetry, promote trust formed on objectivity, and narrow the gap between consumer expectation and user evaluation. In this way social shopping modes can be improved, and encourage costumers participation in social shopping more actively.

## **Keywords**

Social Shopping, Smart space,  
Internet of Things

## **1 Introduction**

Social network service is prospering, and online transactions have become a mode of electronic business, which is the so-called Social Shopping. Social shopping builds up a real human relation in the Internet of Things, and economic behaviors are also embedded in social network throughout. Customers can enjoy both online and offline commercial environments and social business modes provided by social shopping. The Institute for Business Value of IBM conducted a survey on over 30 thousand consumers from three mature markets and three fast-developing markets [1]. The result shows that 33% of the customers would possibly follow retailers on social networks and exchange the experience [2]. A survey by Decision Step found that 72% of people would use social features if they were available to them whilst shopping [3]. The reason for consumers to collect information through social networks is to decrease information asymmetry while shopping, so as to realize profit maximization. Essentially, social shopping is a combination of social behavior and consuming behavior [4]. The earliest shopping behavior dates back to between 75 AD and 125 AD [5], and the modes and range develop and mature along with the progressing of the society. On the other hand, social shopping not only extends social network, it also assists consumers to acquire information for shopping [6]. In the meantime, successful shopping experiences provide more valuable

information for social shopping and consolidates the modes for social shopping. As purchasing power elevates and technology advances, social shopping modes become more complex. As a result, it is not appropriate to constrain the research on social shopping to the narrow concept under the Internet of things, more considerations are necessary regarding those in multi-situations.

To summarize, the article starts from the general concept of social shopping and analyzes the three main problems in current social shopping activities. On the basis of this analysis, it continues to discuss the advantages of smart space in the Internet of things. Smart space is capable of providing consumers with objective information and help them to acquire the sense of trust, balanced individual expectation, and user evaluation as well as narrowed information asymmetry. This article also intends to provide some valuable theoretical reference for the development of social shopping.

## **2 Problems in interpersonal relationship based social shopping**

It is deemed in present researches that the earliest concept for 'Social Commerce' is by Yahoo in 2005 [7]. Yahoo considers social commerce is social communities made up by sellers and its job is to provide more valuable information for consumers. Andrew T. Stephen and Olivier Toubia (2010) argued that, the general sense for social business and social shopping are both labeled with the attributes as social network and online shopping [8]. However, the difference between them lies in that social commerce links sellers, whereas social shopping links customers. The integration of social network service and electronic business modes creates the so-called social shopping. Such as on the brand homepage of Facebook, sellers and buyers are able to do direct or indirect interaction [9]. Through social shopping, consumers can acquire both tangible products and social values, like social interaction and social entertainment, which compensate the deficiency of value monotony in traditional electronic business. In addition, social shopping elevates the content created by consumers into a commercial attribute, so as to strengthen mutual trust, stimulate purchase will, and decrease customers' transaction cost and risks.

## **3 The foundation of social shopping is interpersonal relationships**

As social shopping is based on interpersonal relationships, and interpersonal relationships are of obvious psychological features, therefore customers purchasing decisions made through social means are subjective and filled with personal emotion. Consequently, in social shopping there are three main problems among consumers:

- 1) Information asymmetry exists between the buyer and seller.
- 2) Trust built on subjective feelings.
- 3) Imbalanced consumer expectation and the user evaluation.

### **3.1 Information Asymmetry between buyer and seller**

Consumers are trying to acquire as much information as possible to help them to make an appropriate purchasing decision. Mishra argued in his concept of 'relativity of information perception' [10], information relativity refers to whether an information gap exists between that perceived by consumers and that provided by sellers, which means buyers can fully utilize information from sellers to make proper decisions. In most situations of social shopping, buyers cannot acquire complete transaction information, and their capacity and means to get that information are limited. Thus, the buyer is usually at an information disadvantage, whereas the seller has the advantage. Because of this, information asymmetry is an impeding factor for social shopping development.

In the offline context, most of the products' information comes from consumers' in-person experience or sellers' recommendation, so it's hard for consumers to get abundant information about products. Malone, Yates, and Benjamin [11] suggested that the application of electronic means could decrease the cost of coordination when making deals and they anticipated that competition among sellers would become fiercer thereafter and the market force of a single seller would be weakened. In recent years, the fierce competition among Taobao, eBay, Amazon, and other electronic business platforms has proved this anticipation, whereas the information asymmetry hasn't been fixed thoroughly. On one hand, consumers get more information than they need and capable of perceiving,

and on the other hand, much repeated and tedious information that is hard to distinguish stops consumers from acquiring valid messages, so information asymmetry still exists in electronic business on the Internet. While Internet information transparency improves and consumers' ability to acquire valid information becomes stronger, the information gap in social shopping will be narrowed.

### 3.2 Consumers make purchase decisions according to subjective trust

Mutual trust is a premise in social shopping. The sense of trust significantly affects consumers' efficiency and satisfaction when making purchase decisions. Denise M. Rousseau made a definition for general trust in 1998 [12]: trust is an unprotected psychological state that the trustor makes a positive estimation on the trustee's intention and behavior. In the social shopping process, the consumer is the trustor, and the trustee are other participants involved in the social network, such as salespersons, other consumers, friends, relatives, and people who provide decisive advice. Trust built in social shopping is in essence a subjective anticipation of buyers on what sellers are going to sell. For instance, consumers trust the so-called super-big discount in shopping malls and go to buy their products, or consumer psychologically believe other buyers' comment on a piece of clothes as 'gorgeous style' and click the button 'buy now'. Trust of consumers is built in the process of social shopping (Fig.1). Consumers judge the reliability of information acquired through how much they trust the social interaction and the results, which affects consumers' purchase decisions of whether buying a product or not. As the information created in social networks and acquired by consumers is subjective cognition of products, such a kind of trust relationship is not stable.

### 3.3 Extreme evaluation made by consumers' imbalanced psychological expectation and user evaluation

In social shopping, consumers' psychological expectation on a product directly affects their evaluation of it. Their comment on the product has subtle influence on its potential to be recommended and other consumers' purchase decision. Consumers' psychological expectation is their comprehensive judgment on the product's expected performance and its

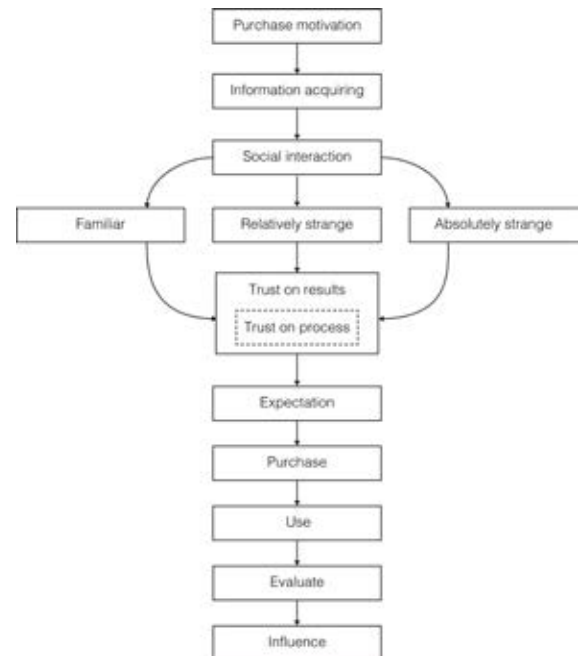


Fig. 1. Social shopping process

affordable price. Psychological expectation is formed in the process of social shopping, and it has become an important evaluation criterion for making a purchase decision. An evaluation is consumers' comments on a product according to their true feelings after consuming it. It is a subjective conclusion combining consumers' psychological expectation and user evaluation.

As is shown in Fig.2, in the process of social shopping, consumers will be influenced by people's comments and other factors, and then forms their psychological expectation for a product. If their expectations almost match their requirements, consumers will make a purchase decision. When they are using a product, consumers will form their own experience. Generally speaking, there will be certain differences between real experience and expectation. If the experience is next to the expectation, consumers will make negative or even underrated comments on the product, and they will subjectively agree that it is an unsatisfying shopping experience. On the contrary, if the experience excels psychological expectation, the evaluation will be positive or even overrated, and this shopping experience is deemed as successful and satisfying. However at the meantime, the evaluation will have a negative effect on social shopping. An unsuccessful shopping experience will damage consumers' trust on social

shopping, while a successful shopping experience will encourage consumers to participate more actively in social shopping. As a consequence, narrowing the gap between psychological expectation and real experience will strengthen consumers' trust on social shopping and maintain and optimize social shopping modes.

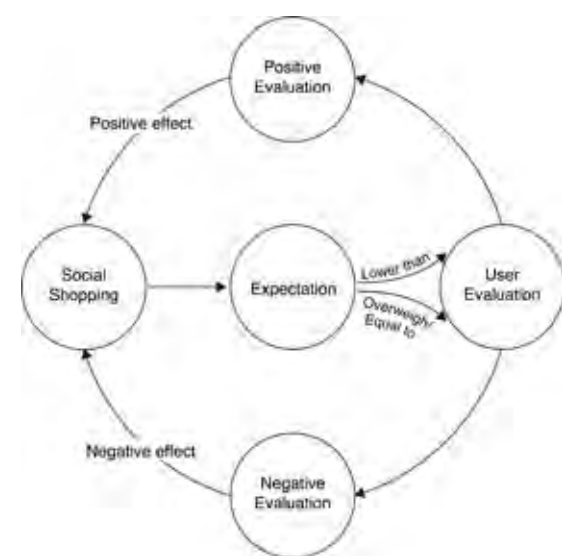


Fig. 2. Relationship between expectation and user evaluation

Consumers are at a disadvantage in information asymmetry. When it comes to the phase of making decisions, they are constrained by subjective trust. And then they are influenced by inconsistent psychological expectation and real experience when making evaluations. They are factors restricting the development of social shopping modes. Under this condition, new social shopping modes, such as social shopping in smart spaces, are ready to come out (around the corner).

#### 4 The advantages of social shopping in smart space

Smart space is a complicated and interactive intelligent system based on physical space of a certain area. It can fully utilize the means of information and information technological (means) to perceive, analyze, and integrate all relevant information about the core system running in this space and respond intelligently to people's demands in activities. In this system, novel application of Internet of Things and optimized allocation of other

resources work together on the digitalization and intelligentization of traditional physical space, so that interaction among people and things would be smarter. Therefore, activities in smart space will produce better experience.

Smart space is the advanced stage of physical space informationization. It is constructed on innovative applications of emerging hotspot technology, such as Indoor-positioning; cloud computing, mobile Internet, big data, iBeacon, etc. Smart space can provide users with smart mobile data experience, which enables users to acquaint with the surroundings very quickly, to build up a sound basis for subsequent operations like searching, GPS, and payment. The fast development of Internet of Things ignites the fire to construct intelligent systems among various companies. In Nov 2008, IBM proposed the concept of 'Smart Globe', and they did some fruitful investigation in 'smart electricity', 'smart treatment', 'smart city', 'smart transportation', 'smart supply train', 'smart bank', etc. [13] In China Shop 2014, Panasonic set up its topic as 'A smart, beautiful lifestyle with intelligent retail'. They designed their exhibition stand as real supermarkets and convenient stores, to exhibit their 'one-stop' solution in their retailing stores [14]. In addition, the vice president of eBay's mobile business, Steve Yankovich and his group are trying to combine wearable devices with electronic business. They named it as Zero Effort Commerce [15]. ZEC will collect individualized historical data to anticipate consumers' demands via smart devices and it works accordingly. The cases above show that famous terminal producers and electronic business companies have been making positive attempts in constructing smart space.

Innovative application has provided technological support for establishing a seamless combination of online and offline and this new circumstance will bring better social shopping experiences. Intelligent space can, to some extent, alleviate the current problems existing in social shopping and bring new interaction methods. Not only is smart technology vividly seen in smart space, but also individuals, as contact points, can actively join in this system. Consumers' interaction in smart space will transform from traditional third person singular to first person singular, which means, as a contact point, consumers will be involved in the whole interaction through social shopping.

#### 4.1 To reduce information asymmetry between buyers and sellers

In the stage of acquiring information, information asymmetry has existed for long, and it is one of the factors impeding the development of social shopping. In Fig. 3 of offline social shopping, only a part of the information provided by the seller overlaps that of the consumer's needs. For instance, when a salesperson is recommending a camera, he/she usually provides customers with information like some parameters, guarantee clauses, and price, however, except for price and guarantee clauses, customers also care much about imaging quality, main functions, and appearance. Because of inadequate information, the overlapped part becomes relevant product knowledge, which is not enough to help consumers make a wise decision. In online social shopping, the Internet provides customers more detailed information, far more than customers need. When a customer is selecting a camera online, after browsing the information on the Internet, the customer may refer to other buyers' comments and some evaluation articles on some professional photographic equipment websites. Therefore, the customer can acquire the meaning of each parameter, the configuration of different types, and information about reasonable prices. However, overloaded information creates chaos, and there will be some differences between the information perceived and information needed, so finally the efficiency to transform information into product knowledge is still low. Intelligent space rightly compensates the deficiency in online and offline information, where it regards appropriateness of information as its premise and stands between information perceived and information needed by customers. What's more, as this information is related to customers' shopping demands, they have to match the information they can perceive and that they need, so as to increase the efficiency of product knowledge transformation. In this way, smart space can reduce information asymmetry and simulate a positive development of social shopping towards equal trading.

#### 4.2 To help customers build up objective trust

In general, trust established in social shopping is customers' bounded rational cognition and subjective cognition, which adds to the instability of social shopping. No matter online or offline shopping, many customers would be influenced by sellers' seditious



Fig. 3. Demand for information from buyers

description, tones, and emotions, and change their original shopping decision. However, those seditious description, tones, and emotions are irrelevant with customers' shopping needs, but they build up trust among customers via emotional expression. If the experience is bad, customers will on one hand blame themselves for impulse buying, or on the other hand, they will have doubts' on sellers' creditability. Compared with words based on subjective feelings, objective data would be more persuasive among customers. As illustrated in Fig 4, technologies of Internet of things can explore and analyze mass information to assist decision-making. In the circumstance of smart space, after cloud computing on massive information, those irrelevant information could be excluded, and the information remained come to form the information net centered on customers' target commodity. By providing information objectively, customers can focus more on that useful information. First of all, objective information enables customers to calibrate product knowledge, so as to acquire a neutral image closer to objective fact. Second, high-quality information can reduce customers' burden in distinguishing information, so that product knowledge transformation could be more efficient.

As a consequent, the trust relation between buyer and seller can be built on product knowledge, which will help customers better anticipate future changes. As the information provided by smart space and acquired by customers are relatively objective, the trust relationship is more stable, and decisions made by customers are wiser.

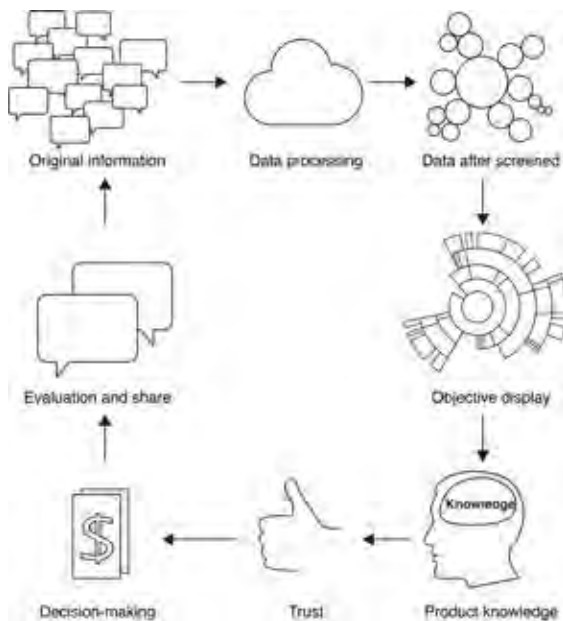


Fig. 4. The process of trust-establishing in smart space

#### 4.3 To balance psychological expectation and user evaluation

In current social shopping activities, consumers' psychological expectation and real experience are always different, which leads to extreme user evaluations. Imbalanced psychological expectation and user evaluation deeply affect customers' social shopping and buying decision-making.

Constrained by physical space and time, most of the information acquired by customers is from sellers and their time for decision-making is limited. Even though customers may feel unsatisfied after calculating the time, energy, and emotion spent on a product, they would buy it reluctantly. Therefore, if information is inadequate and time is limited, it is possible for customers to make an improper decision and the uncertainty of user evaluation increases.

In the process of online shopping, customers can get large amounts of information from sellers (websites, online customer service) and participator groups (other customers, third-party product evaluation), but that information may stop customers from formulating objective psychological expectation. What's more, customers can't see in-person the physical object, so information acquired can't be tested until customers

receive the product. Therefore, delayed user experience of online shopping further extends the difference between psychological experience and user evaluation.

Social shopping in smart space combines the real and virtual world. On one hand, customers can maintain their habits in offline social shopping while experience (see, touch, enquiry, etc.) and can distinguish among commodities via face-to-face social interaction with sellers. On the other hand, consumers can also follow their online shopping habits or even bring them into offline shopping activities. Moreover, while convenient wearable devices are developed, it's possible for smart social shopping to get rid of traditional handheld devices like smart phones, laptops, etc. The seamless combination of online and offline shopping enables objective information to be delivered from sellers or third parties to customers, and that information is selected and are relevant to purchasing demands. In addition, there are new technologies for exhibition utilized in smart space, like 3D printing, virtual reality, holographic laser projection, which can show more accurate product information. As customers couldn't see physical products in person, they can still verify the correspondence between product description and the real product. In addition, iBeacon technology and indoor positioning technology [16], [17], plus popularized mobile Internet [18], will bring great seamless online and offline shopping experiences to customers. Even in physical stores, consumers are still able to get adequate information via twitting, through comparison with physical products, and can make wise purchasing decisions.

Social interaction methods provided by smart space has transformed customers' social shopping activities that are aimed at acquiring information to activities that are aimed at verifying those information, so as to help customers to form more objective psychological expectations which are closer to real user experience. Such expectations are almost the same with user experience, and extreme comments that result from excessive difference between psychological expectation and real experience won't appear. A pertinent comment not only strengthens their confidence in social shopping, but also is able to give other social shopping participators more useful messages. Therefore, the

gradually narrowed psychological expectation and user evaluation in smart space will help balance them and stimulate the development of social shopping.

## 5 The advantages of social shopping in smart space

In social shopping, interpersonal relationship and the trust formed thereof are important means for acquiring product information. It has existed in social shopping of different stages of social development. People acquire information of high reliability via social shopping and make buying decisions of maximum benefits. Finally, a win-win outcome is created. Therefore, the development of social shopping is of practical significance. However, trust formed in social shopping comes from subjective feelings, not totally corresponding to real user experience. Owing to this, the balance is destroyed between consumers' psychological expectation and user evaluations, which negatively affect social shopping development. To conclude, social shopping has its pros and cons. These two sides are of obvious influences on shopping activities.

Compared with electronic business, the so-called social shopping in a narrow sense, this paper discussed in a macro perspective the shopping activities or transactions that are based on either social network or any specific social activities or events. The author started from the subjectivity and emotion of interpersonal interaction, and analyzed the reasons leading to information asymmetry, subjective trust of consumers in social shopping, and the loss of balance between expectation and user evaluations. After the explosion of communication network, the Internet of Things is the next productivity stimulating economic development. It will reform people's living style. Smart space has created a high-efficient and smart service system. It provides a social shopping platform for service providers and service participators to conduct interactions interactively among human beings and things. The smart space on an Internet of Things basis will benefit social shopping development from three aspects. First, the information provided by smart space can reduce information asymmetry between seller and buyer as those messages are selected, more demand-oriented, and more objective. Second, the trust relationship between buyer and seller in smart

space is on product knowledge trust basis, so as to encourage consumers to participate in social shopping more actively. Finally, smart space can transform social shopping activities that are aimed at acquiring information, to activities that are aimed at verifying information, by which the gap between psychological expectation and user evaluation can be narrowed, in case of extreme user evaluation. To summarize, provided the platform by Internet of Things, social shopping is able to elevate to a certain degree the objectivity of consumers' expectation, user experience, and commodity promotion. Meanwhile, smart space stimulates product suppliers, continue to improve quality and service, and push forward the development of social shopping. The social shopping experience of costumers is of great importance for increasing successful transaction, and the social shopping behavior model and social shopping evaluation model created are of great significance to electronics business. In the next step, our research will concentrate on the user interaction model and social shopping behavior model in smart space.

## References

1. Schaefer M, VanTine L. Meeting the demands of the smarter consumer [J]. IBM Institute for Business Value. January 2010.
2. Blanchard O. Social media ROI: Managing and measuring social media efforts in your organization [M]. Pearson Education, 2011.
3. Marsden P. eBranding and Social Commerce [M]//Brand Evolution. Gabler, 2011: 357-372.
4. Tian Yuqing. Summary of social e-commerce research [J](in Chinese). Beijing University of Posts and Telecommunications (Social Sciences), 2013 (4).
5. Oxy P. The Oxyrhynchus Papyri [J]. Published by the Egypt Exploration Society in Graeco-Roman Memoirs. London, 1898, 2007.
6. Li Zhicheng, Liu Mwilian. E-commerce environment, consumer behavior research [J] China Management Science, 2002, 10 (6): 88-91.
7. Curty R G, Zhang P. Social commerce: Looking back and forward [J]. Proceedings of the American Society for Information Science and Technology, 2011, 48(1): 1-10.
8. Stephen A T, Toubia O. Deriving value from social commerce networks [J]. Journal of marketing research, 2010, 47(2): 215-228.
9. Ng C S-P. Intention to purchase on social commerce websites across cultures across-regional study [J]. Information &



- Management, 2013,50(8).
10. Mishra S., Umesh U.N., Stem D.E. Antecedents of the attraction effect: an information processing approach [J]. Journal of Marketing Research, 1993, 30(8): 331-349.
  11. Malone T W, Yates J, Benjamin R I. Electronic markets and electronic hierarchies [J]. Communications of the ACM, 1987, 30(6): 484-497.
  12. Dennise. M. Rousseau, SimBSitkin, Colin Camerer. Not so different after all: across discipline view of trust [J]. Academy of Management Review, 1998, (3): 393-404.
  13. Zhu J, Fang X, Guo Z, et al. IBM cloud computing powering a smarter planet [M]//Cloud Computing. Springer Berlin Heidelberg, 2009: 621-625.
  14. Panasonic Supports Smart Retail at "CHINA SHOP 2014". [http://news.panasonic.net/archives/2014/1118\\_30125.html](http://news.panasonic.net/archives/2014/1118_30125.html), 2014.
  15. A Future Featuring Zero Effort Commerce. [http://www.ebayinc.com/in\\_the\\_news/story/future-featuring-zero-effort-commerce](http://www.ebayinc.com/in_the_news/story/future-featuring-zero-effort-commerce), 2014
  16. What is iBeacon? A guide to Beacons. <http://www.ibeacon.com/what-is-ibeacon-a-guide-to-beacons/>
  17. Gu Y, Lo A, Niemegeers I. A survey of indoor positioning systems for wireless personal networks [J]. Communications Surveys & Tutorials, IEEE, 2009, 11(1): 13-32.
  18. Murphy M, Meeker M. Top mobile Internet trends [J]. KPCB Relationship Capital, 2011.

# Towards wise experiences: The role of wisdom in design for well-being

## **Abstract**

Smart products make our lives easier, because we seek for efficiency in life. However, the concept of smartness can have shortcomings for the design contexts of well-being and health, which would require a more tactful approach to deal with sensitive situations. In this paper, wise products as a concept is presented as a natural evolution to smart products. The paper looks for a definition of wisdom suitable for the context of experience design by borrowing perspectives from philosophy, phenomenology, and psychology. The psychological processes underlying the experience of wisdom (cognitive, affective, reflective, and conative) are then mapped on to product experiences facilitating wisdom. With the findings, three forms of product experiences have been proposed. First, the product is inherently wise (knowledgeable & flexible); secondly, user becomes wise (self-determined & assertive) with the product; and finally, both user and product become wise (empathetic and supportive) through continuous interactions. The paper concludes with the suggestion that wise products with their rich properties offer ample opportunities for human flourishing and as a result make our lives better in the long-term.

## **Keywords**

Wisdom, wise products and experiences, human-product interactions, experience design, design for well-being.

## **1 Introduction**

Facilitating human lives has always been the focus of traditional and present-day product design strategies. From scissors to cars and from washing machines to smart phones, objects have been designed to compensate for the lack of human skills and capacity. More than 20 years ago, Norman [1] suggested that people needed smart products to feel smart and efficient. Nowadays, smart products support people almost in every aspect of daily practicalities and even in social contexts. Smart products and other designed objects make our lives easier; because, we feel more complete, capable, and autonomous with their presence and functionality [2][3]. However, does having an easy life equate to a better life? Do people still value being smart to have good quality of life? Are there other ways to improve the quality of life through design?

Design for subjective well-being, as a new design field, tries to answer questions such as above. According to Desmet and Pohlmeier [4], three high-level personal goals that underlie people's need for a better life are the main ingredients for design for subjective well-being. That is, people strive for *pleasure* (e.g., having fun, enjoying being free of problems, relaxing), *virtue* (e.g., giving the right decision, acting properly), and *personal significance* (e.g., being a resourceful person, achieving personally set goals). If all these factors are carefully considered and proficiently applied, the resulting designed objects can have a big impact in our long-term

happiness and well-being. Considering the current design approaches for well-being, perhaps what people need is not more products that make them smart, but products that empower them to achieve and maintain their full potential in a healthy way on physical, mental, and social accounts. Perhaps, people need new products that cultivate wisdom so that in return people can become a little wise too.

### 1.1 Shortcomings of smart products

As much as smart products support our modern life styles to a great extent, our experiences with them over the years indicate negative effects. By making products smart, designers also create product characteristics that can have unwanted effects on people. Imagine our daily interactions with products that have 'smart' qualities. For example, mobile phones, navigation devices, alarm clocks, televisions, ovens have intelligence embedded (with an operating system, chips, sensors, and memory), can sense activities, collect data, and autonomously take action when needed. As a result, such products demand that the user acts in a desired way; they *exhibit an obvious sense of righteousness* and *show authority* by insisting on drawing attention until the user responds; they are supportive for their own purpose but also very intrusive in the user's other daily rituals creating momentary discomfort while fulfilling their functions. These are short-term positive and negative effects encountered with smart products. While smart products aim to have immediate positive effects, their long-term negative effects should be considered in the design processes. For example, increased versions of autonomy or intelligence embedded in smart products can potentially harm users' act of judgment and sense of control of their lives. In the long-term, interactions with smart products can make users *lazy* in daily events and *less intuitive* towards the actions to be taken, insensitive to their surroundings, *distant* to basic functioning of life, and eventually *dependent* on products. While avoiding such unwanted effects, designers could also reconsider the supporting role of products in the long-term with topics such as wellbeing and healthy life-styles in mind.

### 1.2 An alternative view?

Imagine a digital alarm clock scenario with the Sleep Cycle (Figure 1), an app for smart phones with accelerometer, by which users again set the alarm clock

to wake up at a certain time. Sleep Cycle monitors users' movements during the nighttime in order to determine in which sleep phase people are in (light / deep sleep or dream state) and only wakes people up when they are in the lightest sleep. The user needs to be *flexible* with waking up times; because, by respecting the user's sleeping state, SleepCycle has a window of 30 minutes for its alarm sound to go off. As a result, the user is supposed to wake up *less grumpy* and start the day *more energetic*. Thus, the SleepCycle, as a smart product, is concerned with the user's immediate context of morning rituals and aims at a pleasurable experience. That is, waking up the person is not the most important function of the product but monitoring the best moment to wake the user up is the essential role of the product. Sleep Cycle is a step closer to becoming a *wise product* because of its *sympathetic*, *humble*, and *suggestive* interaction qualities, its *flexible* and *considerate* behaviour, and *positive* effects on users by making them *open for ambiguity* and *prepare them for uncertainty*.



Fig. 1. Sleep Cycle, an alarm clock app, analyses users' sleep cycle for the optimum wake-up time.

(Image courtesy of <http://www.sleepcycle.com>)

However, such a product concept, which is promising to be wise, can still be improved to be and act wise. Sleep Cycle could further consider the broader context of the user in addition to the user's morning rituals so that it has more insight into the user's current needs and emotional state. Sleep Cycle could eventually have a situation-based interaction with the user and choose behaviour apt for it; its effect on the user could go beyond immediate pleasure and tackle long-term happiness of the user. As a result, Sleep Cycle would offer the user an opportunity to take control

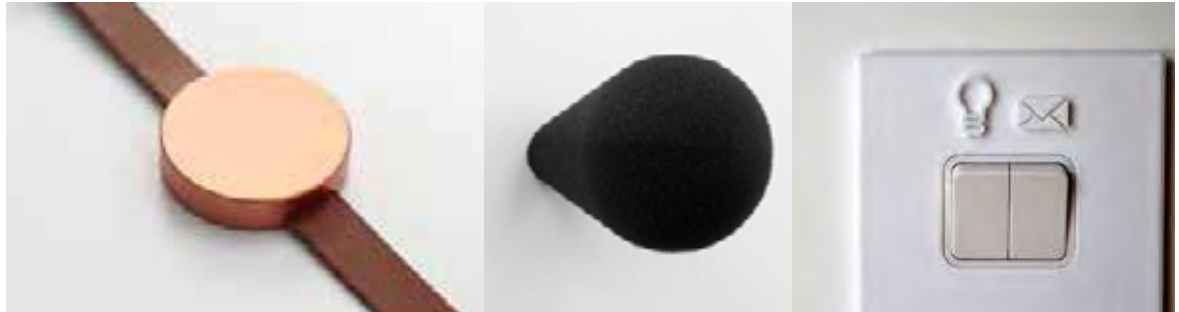


Fig. 2. Some examples for potentially wise products. From left to right: Durr; a shimmering bracelet by Skrekstore; Statistical clock by Dunne & Raby; and Nim, an email switch by Dawes. (image courtesy of <http://skreksto.re/products/durr>; <http://www.dunneandraby.co.uk>; <http://brendandawes.com/projects/sixmonkeys>)

of their lives by making them realize the importance of starting the day afresh and respecting their own biological rhythm. The wise Sleep Cycle would have a reflective role (as opposed to practical) in users' lives: to encourage users to reflect on the basics of life and on their priorities.

## 2 From smartness to smart products

The Oxford dictionary definition of 'smart' indicates two sub-concepts: being *quick* and having *intelligence*. That is, smartness pertains to quick-witted intelligence provided momentarily as a response to an external stimulus. Smart devices are those that contain digital intelligence and can therefore solve problems and/or autonomously take action when needed. The notion of smart products was introduced in the 1980s with digital alarm clocks, microwave ovens, video-recorders, fax machines or ATMs and in the 2000s smart products included navigation devices, PDAs, phones, autonomous vacuum cleaners, and thermostats. The main function of such products was merely utilitarian: Through user input or data collection and with limited capacity of data interpretation, smart products served a specific need, which was to complement human mental and physical faculties in order to make humans smart and efficient [1]. More importantly smartness was initially considered as an added attribute to the existing product categories. For example, an autonomous vacuum cleaner differed from a normal vacuum cleaner, because it had the ability to function independently of the user. However, with the advancement of technology in 2000s, smart products also existed as a separate product category (e.g., navigation devices, PDAs). These products contained complex information technology

systems and had embedded multi-functionality in order to support users with complex mental tasks and predict the future user-context. Thus, problem-solving nature of the intelligent/smart products has become less of a challenge and more of a mundane design task.

In the late 1990s, first scientific definitions of smart products were given [5][6][7]. Early definitions included key descriptors such as *electronic*, *high-tech*, or *intelligent*. Rijdsdijk and Hultink [8][9] defined *smart products* as products containing information technology in the form of micro-chips, software and sensors and therefore able to collect, process, and produce information. Rijdsdijk and Hultink further explained the role of smart products through seven dimensions: autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, human-like interaction, and personality. A smart product can possess one or more of these dimensions to a lesser / higher degree.

In the current decade with high access to connectivity (Wi-Fi, Bluetooth, or GPS systems or complex connected networks such as Internet of Things) and easy data collection through mobile devices and wearable technology, smart products have taken additional roles; i.e., to support people's physical, mental, and social health. Nowadays, people are carrying or wearing portable devices (smart phone apps, Nike+, Fitbit, AIRO) that monitor their physical activities, measure their stress levels, or help them socially connect. By doing so, intrinsic human needs such as competence, autonomy, and relatedness [3] become partially satisfied in the 21st century life styles. Thus, supporting subjective well-being and social development has become a central aspect in the design and development of smart products.

Furthermore, some critical design examples (see Figure 2) indicate simple and elegant solutions that emphasize a new function for smart devices, that is to make users *reflect on daily phenomena*. For example, Skrekstore has designed Durr, a shivering bracelet or in more common terms, a faceless watch that only indicates time through small vibrations every five minutes. The main function of Durr is to make people aware of time perception and train them to rely on their biological rhythm, which means that users will start to gain control of their body. Similarly, inter-connectability of objects (e.g., through Internet of Things) could also result in similar effects on the user. For example, Dunne & Raby, two design professors, came up with Statistical Clock, which checks BBC database for fatal traffic accidents and speaks out a number that indicates the fatalities in that given moment of life. Again, users are triggered to reflect on what the number heard represents in terms of the value of human lives. A third design example is from Brendan Dawes. Dawes designed Nim, which is essentially a light switch to physically turn email off when one leaves the office for home. Nim makes a person question the work-life balance and provides opportunities for people reflect on their priorities in life. Such designs with speculative nature exemplify a natural shift from smart products to wise products.

The aforementioned design examples are symptoms of the change in history of product design: i. not all products need to be designed for utilitarian functions, ii. daily practices and interactions with objects operate in alternative ways, and iii. a new domain for the use of available technology and the databases seems to be emerging. Let us further elaborate these changes. *First*, human needs have been shifting from psychological and safety needs to higher level needs such as belongingness, esteem, and self-actualization (see Maslow's hierarchy of basic human needs [2]). These needs are also in line with intrinsic motivations for people to engage in daily activities and objects such as competence, autonomy, and relatedness [3]. Furthermore, products' impact in our lives also goes further than the individual and concerns people in relationships and in communities. *Secondly*, people started to enjoy the presence of new technologies and what the technology allows them to do. People instantly document important aspects of their lives, publicly share them, wear high-tech devices, and demand immediate response from systems. As a result, our interactions with objects have become more

sophisticated but less intuitive. *Thirdly*, technologically speaking, our society has arrived at an age where collecting data is no longer an issue; people are even willing to help collect data through social media or wearable devices. However, data alone are meaningless. It is more interesting to turn data into information and then into knowledge, and even into wisdom (see Rowley's DIKW hierarchy, [10]). Ackoff [11], Zeleny [12], and Rowley [10], explain that *data* represent properties of objects, *information* is what the objects are, and *knowledge* is how those objects function life. According to these authors, current technologies can achieve until the interpretation of data as knowledge. However, there is a *wisdom* level, which elaborates why those objects exist in life and that level is the most challenging to currently achieve. Once achieved, data could turn into wisdom and systems, using wisdom-related knowledge, will be able to respond to the current trends in supporting well-being of people and societies. As exemplified, the notion of smartness associated to products and systems has come a long way since the 1980s as a result of the shift in and awareness to current human needs, daily practices with objects, and the advancement of technology. However, the philosophy behind the smart products dates back to the early days of smart products. For that reason, wisdom can be a new paradigm for smart products of the 21st century.

### 3 Wisdom and its role in well-being

According to the Oxford dictionary, wisdom pertains to *experience, knowledge, and good judgment*. Thus, wisdom is fundamentally different from smartness: Smartness relies on quick judgments based on intelligence whereas wisdom relies on the interpretation of multiple, repetitive, or longitudinal life experiences. Earliest studies on wisdom date back to the Aristotle, which relate wisdom to ethical decisions and being virtuous [13][14][15]. Baehr [16] discusses two types of wisdom, i.e., practical and theoretical. Theoretical wisdom concerns the accumulation of knowledge and experience and seeks truth in a universal sense; whereas practical wisdom (also known as 'prudence') is reaching excellence in decision making and acting on critical situations often through common sense regarding knowledge discerning good from bad. Thus, practical wisdom would help individuals flourish, cope with dilemmas or help them resourcefully explain their

knowledge on concrete life events. The experience of wisdom therefore is associated to intuition, values, and emotions, which should help an individual's process of wise decision-making.

Modern views on wisdom [15][17][18] do not focus on excelling as an ultimate human being and is more tolerant towards individuals and suggest that wisdom can be cultivated and acquired in the span of life. Similar to the ancient views, the acquisition of wisdom inherently requires time and effort; education (gaining knowledge and practice), personal experience, and reflections on highly emotional situations (e.g., dealing with dilemmas, uncertainty, or difficult life events) are fundamentally necessary [19]. As a result of such complex factors, people become knowledgeable, mature, tolerant, empathic, experienced, and intuitive. Furthermore, Glück, Bluck, Baron, and McAdams' [20] definition of wisdom is based people's daily experiences. According to Gluck et al. wisdom can have three forms: knowledge and flexibility, self-determination and assertion, and empathy and support. *Knowledge and flexibility* relies on the knowledge gained from experience and operates with the tolerance for both compromise and uncertainty. It concerns applying previously gained knowledge where possible but also accepting uncertainty and trade-offs. *Self-determination and assertion* relies on personal capacity and beliefs and concerns taking control of a situation, relying on intuition, and following one's goals or priorities. *Empathy and support* considers other peoples' perspectives and feelings, and offers or provides social support. The aforementioned human qualities pertaining to wise people are symptoms that cognitive, affective, reflective, and conative processes underlie experiences of wisdom [19][21]. *Cognitive processes* allow people to obtain knowledge. It is by experience of small and big life events that people gain knowledge about how objects, people, and places are related within a given situation. People learn to make links between cause and effect. Here, Rowley's [10] wisdom hierarchy explains the cognitive aspects of wisdom: not only the identity of the objects but also their role in life has to be understood in order to answer the 'why' questions related to them. *Affective processes* pertaining to wisdom favour eudaimonic rather than hedonic emotions. Thus, temporary feelings are learnt to be discarded in order for greater gain in life. Because, wisdom is most needed when people undergo important and emotional life

events that cause dilemma or have uncertainty (e.g., having to move to a different country for love, having to quit job after having children, or feeling depressed and worked up). As a result, emotion regulation is needed to have emotional mastery in such critical situations. Although affective processes are active in the experience of wisdom, the decision-making processes might be free of affect. The aim of wisdom is to regulate the emotion (e.g., reduce the intensity of the experienced negative emotion) again through reflection. As a result, action tendencies are motivated by cognitive and *reflective processes* not by emotion. Reflection is a process that evaluates and reappraises the current situation with past events for the purpose of predicting the future. The reason for emotion regulation through cognitive and reflective processes is to activate the *conative process*, i.e., to be able to properly act on critical situations. Baltes and Smith [19] propose a framework for how wisdom can be applied in the conduct and understanding of life. According to the authors, wisdom is applied to *life planning* (which future life goals to pursue and how?), *life management* (how to deal best with critical problems?), and *life review* (how best to make sense of our life history and past experiences). The multidimensional nature of the experience of wisdom should be able to help people in dealing with these categories of important actions in daily life. Bluck and Glück [22] also consider wisdom as a means to improve one's quality of life; people, by learning lessons in life, change their attitude towards life and focus more on how they see things rather than what they see. Ultimately, people strive to produce novel solutions to their problems or the critical situations in which they are involved.

All in all, the literature on wisdom supports the possible design directions envisioned for positive design and design for subjective well-being. The three components of positive design (design for virtue, pleasure, and personal significance) can be traced back to the components of the experience of wisdom. Essentially, human flourishing is at the heart of the theories for both positive design and wisdom. Thus, the design for wise products would fundamentally aim at fostering better and healthier lives by offering users the possibilities for personal development, increasing awareness in the self, others and environment, and becoming more sensitive towards the consequences of current events.

## 4 Prospective characteristics of wisdom implemented in product experiences

### 4.1 Situations

Critical situations during which users face difficulties to cope with will define the need for wise products. Critical situations may also vary. One way to recognise them would be to observe the emotional impact of critical events on people. For example, in one case, people could be simply stressed due to momentary complications or high-demand for attention; in another case, people may be overwhelmed because they are going through life-changing events or they have experienced a negative event [20]. Wise products do not aim to solve such critical and problematic situations, but rather help people prevent, avoid, predict, and overcome them and possibly regulate the occurring emotions through different approaches such as using empathy and expert knowledge on users' daily routine and life events.

### 4.2 Role

Wise products are intended to play an important role in fostering better lives (e.g., subjective wellbeing). That is, the concept of wise products is not driven by practical functionality as smart products often are (i.e., increasing performance and efficiency in life), but rather driven by motivational functionality (i.e., achieving intrinsic human values such as gaining self-confidence). As a result wise products tackle personal and social issues hindering well-being and human flourishing (e.g., personal development, mental and physical health, bodily awareness, social interactions). Therefore, the aim would be to support, encourage, and empower people in their quest for meaningful and long-term happiness.

### 4.3 Function

What procedural properties of wisdom are relevant to the human-product interactions and how can they be implemented in the function of wise products? Again, the mental and emotional activities underlying experience of wisdom observed in the literature review [19][21]) should be visible in the product experiences concerning wisdom. These activities include cognitive, affective, reflective, and conative processing of the critical situation or its components. The function of wise products then should be to trigger these mental and emotional activities during human-product

interactions. With *cognitive* processes, the user/product makes sense of the critical situation, identifies its components, and contextualizes the problem. With *affective* processes, the user/product recognizes and acknowledges the occurring emotion (and its magnitude) and tends to regulate it. With *reflective* processes, the user/product reappraises the negative meaning of the situation and tends to find positive motivations for the future impact of the critical situation. Finally, with *conative* processes, the user/product acts confidently on the situation. These processes are prerequisite and complementary to the experience of wisdom and thus should be active during the human product interactions pertaining to wisdom. Especially, the affective (i.e., emotion regulation) and reflective (i.e., reappraisal) processes are key to wise experiences.

### 4.4 Effects & Behaviour

The long-terms effects of wise product on users have been mentioned earlier in the paper. While the ultimate goal would be to cultivate wisdom in the society and incite human flourishing, this paper focuses on the positive contribution of wisdom on subjective well-being and physical, mental, and social health. In the short-term, wise products also have a direct effect on their users. During human-product interactions, wise products should make their users feel empowered, supported, knowledgeable, mature, tolerant, reflective, controlled, aware, and conscious (see also Ardel's [24] comparison between intelligence and wisdom for a detailed account). Furthermore, in order to have such effects, wise products' behaviour should be empathetic, sympathetic, suggestive, intuitive, flexible, motivating, autonomous, empowering, supportive, and caring.

## 5 Wise product experiences

So far, I have used the term 'wise products' quite loosely to present a new paradigm of products as opposed to 'smart products'. However, the objective of design for wisdom is not necessarily to design products that are wise, but to demonstrate that wisdom can emerge in the mutual experience between the product and the user.

### 5.1 Basic framework for wise product experiences

To be able to discuss the characteristics of wise product experiences, the framework in Figure 3 will be used. This figure essentially summarizes the basic factors that

influence user experiences with products [23] and it also frames the special conditions for wise experiences to happen. These factors will be further explained in detail below using the figure and later used for conceptualizing wise products experiences.

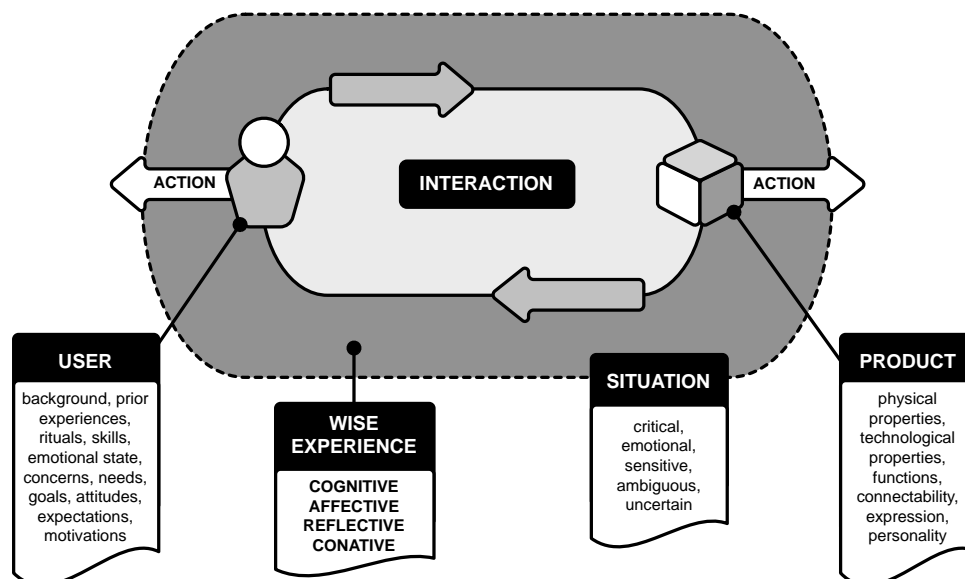
*Product* properties include sensory properties (e.g., shape, sound, materials, parts), functional properties (e.g., usability, actions, capacity, mechanisms, electronics), and meta properties that indirectly influence product experiences (e.g., situations, culture, locations, related products). Product related physical properties, function, and their roles in daily lives are deliberately designed. *User* related properties, however, are more complex and often idiosyncratic either to a specific user or a group of users that share the same concerns, goals, and attitudes. Users in general feel a certain need and have a clear motivation to use a product, which shape their expectations about the product properties described above. Furthermore, emotional state of the user, their background and prior experiences with products in particular and the world in general influence how they interact with and experience the product. *Interactions* depend on the user and product properties and result in basic *product experiences* (aesthetic, meaningful, and emotional). Users' interactions with product (its physical properties, parts, functionality, etc.) determine how they identify and build meaningful associations with inherent product

properties; consequently, the identified product affects the user either on an aesthetic or emotional level. Furthermore, context (e.g., specific situations, culture, communities) plays an important role to frame product experiences and further actions that need to be taken. In the case of wise product experiences, the context is named as *situations*, which are mainly critical but also emotional, sensitive, ambiguous, and uncertain. Finally, *wise product experiences* should occur within these critical situations. As mentioned above, a typical wise experience yields four stages of mental processing: cognitive, affective, reflective, and conative.

## 5.2 Three forms of wise product experiences

To summarize wise product experiences and their roles in our daily lives, the three forms of wisdom emerged in Glück et al.'s study [20] will be adopted to the design context (i.e., knowledge and flexibility; self-determination and assertion; and empathy and support). Products facilitating experiences of wisdom could possibly have these forms or emerge in situations that require these forms of wisdom. Each form of wisdom can tackle the components of human-product interactions and product experiences from different angles. The first form of wisdom, *knowledge and flexibility*, can be applied on the product. Because, this form of wisdom relies more on factual knowledge and a sagacious attitude for its utilization. Products can acquire wisdom

Fig. 3. Conceptual framework for wise product experiences





related knowledge (i.e., factual and experiential) rather easily thanks to the ICT technologies and smart systems, whereas for people acquiring factual and experiential knowledge takes long time. As a result, with this approach *product becomes wise*.

The second form of wisdom, *self-determination and assertion*, can be applied to nurture wisdom in users. Because, this form of wisdom concerns human values and helps people discover their individuality on mental, emotional, and physical accounts. As a result with this approach *user becomes wise* with the help of designed objects.

Finally, the third form of wisdom, *empathy and support*, can be applied both to the product and to the user. Because, this form of wisdom tackles social aspects such as communication, negotiation, and cooperation in which more than one entity needs to interact to understand different/opposing views. Therefore, with this approach *both the user and the product become wise* through their mutual experiences and human-product interactions. As a result, wisdom can be acquired, shared and experienced by both entities.

### 5.3 Three examples of wise product experiences

The aforementioned approaches can also be taken as design strategies to tackle wise product experiences. Below, I will exemplify these approaches in design context and use the basic framework to demonstrate the design interventions for eliciting wisdom. The design contexts used below are borrowed from ongoing student activities (i.e., master graduation projects) concerning design for wisdom (and well-being) at the Faculty of Industrial Design, TU Delft. The author is involved in the supervisory team of all the project ideas presented below.

**Product is inherently wise – knowledgeable and flexible.** This design context concerns the application of a digital unlocking system for domestic use. That is, users will be offered a digital key to unlock their house. The situation is critical (ambiguous/uncertain) because users may feel distrust towards the system or even feel threatened with hacking. The challenge for designers is to evoke trust in user that the system unlocks only for the authorized. Therefore, in this scenario, the product has properties of wisdom already embedded. The major components of wise experiences (cognitive, affective, reflective, conative) should operate on the

product level. That is, the product maps users' daily behaviour, pinpoints the problem, regulates users' emotions, reflects on the criticality of the situation, and finally takes action. The final action for the digital lock would be to open (or not) the door. Factual knowledge is embedded in the system by using existing data. Experiential knowledge is obtained through daily observations of the user by a network of connected products (e.g., IoT). With experiential and factual knowledge combined, the product becomes flexible in its decision-making process and following action.

**User becomes wise with the product - self-determined & assertive.** This design context concerns the application of a mobile app that promotes a healthier life-style for young seniors (55+). The health of this age group can deteriorate quite rapidly, especially if they cannot recognize the symptoms of aging. The situation is critical (emotional/sensitive) because aging is a life-changing event and accepting to live with it can be very confronting. The challenge for designers is to make the user self-aware about the current state of their health and conscious about future consequences for living an (in)active life. Therefore, the user needs to gain a wise attitude for preventing health issues. The user learns factual knowledge about health and functions of body offered by the product and relevant experiential knowledge through practices guided by the product. User emotions (e.g., hesitation or distrust) can be regulated by attributing positive meaning to health practices. Potential gains (e.g., long life-expectancy, agility) and losses (e.g., obesity, weak condition) can be reflected upon with the product's motivating intervention. With sufficient emotional and cognitive interventions, the user decides whether or not to act on preventing future health problems. As a result, the user becomes self-determined because s/he feels empowered by the impact of the app and also assertive to take bold steps to act on his/her health. Furthermore, the design of such a product can encompass the properties of a smart product, as long as its interaction qualities indicate confidence, openness, audacity, and willingness to communicate.

**Both user and product become wise through continuous interactions – empathetic and supportive.** This design context tackles a societal problem such as boredom through a product. Due to

busy social and professional activities, people never have time to be bored. Boredom (i.e., lack of meaningful activities/stimuli) can be beneficial to the organism because bored people, by disconnecting themselves from external stimuli, enter a voluntary reflective process. The situation is critical (emotional and ambiguous), because the person is overactive and has too many options for a desirable activity. The challenge for designers is to intrigue the user to do nothing (i.e., scheduled activities). In this scenario, both the user and product become wise. Product cannot rely much on factual knowledge but on experiential knowledge intrinsic to its user. User identifies daily overwhelming activities and relaxing activities with the support of the product. Both the user and the product exchange knowledge and emotional experiences. Then, both entities put these activities in daily context and life context and discover potential gains and losses. Acting is part of the dynamic relationship between the product and the user. The progressive exchange of experiential and factual knowledge requires behaviour change on both entities and flexibility to adapt to an updated situation. In fact, users become more empathetic with the product and their environment and product becomes more supportive throughout interactions.

#### 5.4 Discussion

The three forms of wise product experiences present us with ample opportunities for design for subjective well-being. The first form (wise product) is a step further from smart products. What is challenging here is the acquisition of factual and experiential knowledge and embedding it in the system providing wisdom to the product. Connectivity is essential for wise products and Internet of Things is a good direction to explore in the collection of wisdom-related knowledge. The second form (wise user) is a typical case of design for behaviour change. The aim of the product is to facilitate wisdom through human-product interactions. Such application of wisdom will have big impact on the physical, mental, and social health of the user. Users will observe a changed attitude towards life. The last form (wise product, wise user) is the most challenging for designers because the occurring interactions are dynamic and unpredictable. Moreover, both product and user change properties over time and desired effects can be observed in the long-term. This form may be more suitable for social issues that require

strong statements. The occurring products may have speculative nature with their novel functionality and aesthetic qualities.

#### 6 Conclusions

In the field of product design, smartness has been explored and adopted as a product attribute that supports people in their daily activities. In this paper, the extreme richness of wisdom as a concept has been illustrated from the modern perspectives of philosophy, phenomenology, (motivational) psychology, and current trends in experience design and societal needs. With a critical look into the literature, the prominent properties of wisdom has been selected and argued as suitable to be applied to the different components of product experiences. Finally, three design strategies for wisdom were presented within the contexts of physical, mental, and social health.

As much as smartness embedded in products would persist to exist for its own reasons, wise products/experiences, as a new paradigm, should have a special place in product design. That is, design objects of wisdom should aim to empower people in critical daily situations that require it. I further suggest that smartness and wisdom could co-exist because they are complementary concepts. Especially for the implementation of wisdom for subjective wellbeing, a product must first have properties of smartness such as intelligence, autonomy, reactivity, human-like interaction as a baseline, and in addition characteristic qualities of wisdom to have more positive and long-lasting effects on people. As a continuation of Norman's suggestion [1], I believe that current human needs require wise products to stimulate people to act wisely.

#### Acknowledgments

I would like to acknowledge the enthusiastic contribution of the industrial design engineering students at TU Delft to the topic of wise products during the 2014-2015 master courses (Context & Conceptualization; Product Use, Understanding, & Experience); special thanks to my graduation students Rene Schoumans, Leo van Beek, and Hiske Elferink. My gratitude also extends to my colleagues Rick Schifferstein, Marco Rozendaal, Arnold Vermeeren, and Elisa Giaccardi for the valuable discussions we had on the topic of 'wise products'.

## References

1. Norman, D.A. (1993). *Things that make us smart: Defending human attributes in the age of the machine*. New York: Basic Books.
2. Maslow, A. H. (1954). *Motivation and personality*. New York: Harper.
3. Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55, 68–78.
4. Desmet, P.M.A., & Pohlmeier, A.E. (2013). Positive design: An introduction to design for subjective well-being. *International Journal of Design*, 7(3), 5–19.
5. Feldman, L.P., 1995. Increasing the usability of high-tech products through design research. *Design Management Journal*, 5, 27–33.
6. Den Buurman, R. (1997). User-centered design of smart products. *Ergonomics* 40, 1159–1169.
7. Han, S.H., Yun, M.H., Kwahk, J., & Hong, S.W. (2001). Usability of consumer electronic products. *International Journal of Industrial Ergonomics*, 28, 143–151.
8. Rijdsdijk, S.A., Hultink, E.J. (2002). The impact of product smartness on consumer satisfaction through product advantage, compatibility, and complexity. *Proceedings of the 13th PDMA Research Conference, Orlando, USA*.
9. Rijdsdijk, S. and Hultink, E.J. 2009. How Today's Consumers Perceive Tomorrow's Smart Products. *Journal of Product Innovation Management*, 26(1), 24–42.
10. Rowley, J. (2007). The wisdom hierarchy: representations of the DIKW hierarchy. *Journal of Information Science*, 33(2), 163–180.
11. Ackoff, R.L. (1989). From data to wisdom. *Journal of Applied Systems Analysis*, 16, 3–9.
12. Zeleny, M. (1987). Management support systems: towards integrated knowledge management. *Human Systems Management*, 7(1), 59–70.
13. Taylor A.E. (1955). *Aristotle* (Rev. ed.). New York: Dover Publications.
14. Kekes J. (1983). Wisdom. *American Philosophical Quarterly*, 20, 277–286.
15. Nussbaum, J. F. (2013). The communication of wisdom: The nature and impact of communication and language change across the life span. *Journal of Language and Social Psychology*, 32, 243–260.
16. Baehr, J. (2012). Two types of wisdom. *Acta Analytica*, 27, 81–97.
17. Brugman, G. (2006). Wisdom and aging. In J.E. Birren & K.W. Schaie (Eds.), *Handbook of the psychology of aging* (6th ed., pp. 445–476). Amsterdam, The Netherlands: Academic Press.
18. Thiele, L.P. (2006). *The heart of judgment: Practical wisdom, neuroscience, and narrative*. Cambridge, United Kingdom: Cambridge University Press.
19. Baltes, P.B., Smith, J. (2008). The fascination of wisdom: Its nature, ontogeny, and function. *Perspectives on Psychological Science*, 3, 56–64.
20. Glück, J., Bluck, S., Baron, J., & McAdams, D.P. (2005). The wisdom of experience: Autobiographical narratives across adulthood. *International Journal of Behavioral Development*, 29, 197–208.
21. Birren, J.E. & Fisher, L.M. (1990). The elements of wisdom: overview and integration. In R.J. Sternberg (Ed.), *Wisdom, its nature, origins and development* (pp. 317–332). Cambridge: Cambridge University Press.
22. Bluck, S., & Glück, J. (2004). Making things better and learning a lesson: “Wisdom of experience” narratives across the lifespan. *Journal of Personality*, 72, 543–573.
23. Fokkinga, S.F., Desmet, P.M.A., Hekkert, P., Özcan, E. (2014). From Product to Effect: Towards a human-centered model of product impact. Paper presented at the 6th Design Research Society Conference, 16–19 June 2014, Umeå, Sweden.
24. Ardel, M. (2000). Intellectual versus wisdom-related knowledge: the case for a different kind of learning in the later years of life. *Educational Gerontology* 26, 771–789.

# The Reverse Engineering of Emotions

## Abstract

Technology is rapidly changing the way we perceive the world. In order to cope with this constant evolution, we reviewed in this paper the approach of Emotional Design, focusing on users' emotional response towards new technologies. We then propose to address Emotional Design from a different perspective, proposing a framework in which emotions are correlated through user experience and interaction. We introduce the concept of *Reverse Engineering of Emotions*, where emotions are considered as the starting points to depict the user experience pattern, and therefore to better design the interaction. We propose to apply the framework in a specific case study concerning the introduction of Near Field Communication (NFC) technology into everyday life. We outline the structure of a serious game through which it would be possible to test some future scenarios of use for this technology and obtain an emotional map thanks to users' self-reports; then we correlate emotions to user experience, interaction and needs.

## Keywords

Emotional response; human-interaction; user experience; NFC (Near Field Communication) technology; serious games

## 1. Introduction

Technology has a great influence on the way we live, simplifying it and providing solutions for human needs.

As a matter of fact, recent and breakthrough advances largely contribute to change the role of technology within society: it is no longer only a matter of problem-solution, but also of satisfying human psychological needs as well. To make a common example, the use of Internet mobility satisfies the need of belonging, allowing people to freely connect with their social networks.

Technology, in its whole meaning, is the encompassing knowledge involved to produce materials, artifacts and tools that convey innovation. Therefore, as Hassenzahl [1] stated, technology has frequently been proposed as an attempt to answer to human needs, a way to solve problems. We may indeed refer to technology as an extension of human sensory system, as McLuhan [2] asserted: "People approach the final phase of the extension of man – the technological simulation of consciousness, when the creative process of knowing will be collectively and corporately extended to the whole of human society, much as we have already extended our senses and our nerves by the various media". Human body can be extended through technology either in virtual or physical modality, at different levels (Fig. 1).

As seen extensively in the work of Shepard [4] technology is shifting from being tangible and physical to a pervasive and ubiquitous appearance. The body is slowly becoming the central element of interaction.

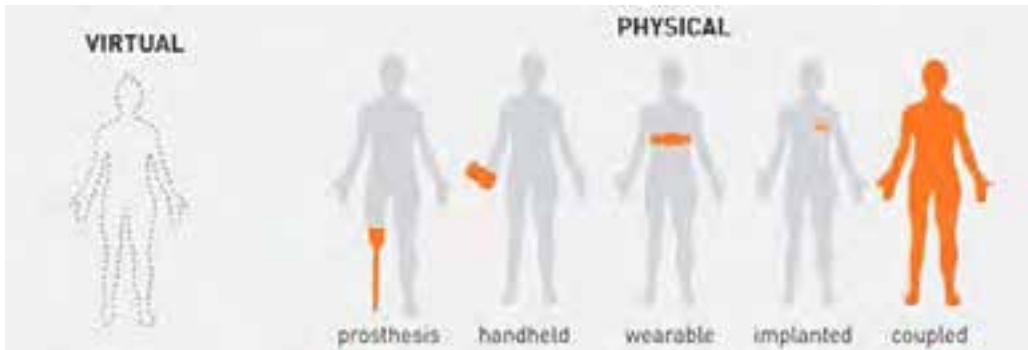


Fig. 1. The virtual and physical modalities of the human body (Credit to Secil Ugur) [3]

This transition from *handheld* to *wearable* to presumably future *implanted* technology requires not only conceptual inventions but also a phenomenological reflection. Keeping this in mind, designers should approach the design of technology, willing to meet usability needs and the consequences of embodied and intrusive technology, moreover it is fundamental to consider the pleasure in its whole meaning. Designing a pleasurable experience is not only an ethical issue, but also a necessity in order to make this shift in technological paradigms acceptable.

In this paper, we aim at investigating the emotional phenomena of human-technology interaction and how to increase the desirability of technological solutions, considering the users' emotional reactions. Donald Norman's seminal work [5] on the importance of users' emotions and personal needs in the design process has been considered as a crucial point in product design. We will address this complex topic by correlating emotions to user experience and product interaction, starting from the assumption of Hassenzahl [6], emotions are quite ephemeral, they themselves cannot be designed, due to their subjective and complex nature. In this perspective, we propose a framework aimed at designing technological solutions and improving their desirability.

The framework integrates three complementary perspectives: (1) Emotional Design, (2) Serious Game approach and (3) Service System Design. They equally contribute to building an environment within which users will simulate the experience of a technological product service system by playing a serious game. This allows us to depict users' emotions during the game, and therefore to understand the complete pattern

of a desirable experience within a precise context. Hence, the study is a qualitative research, including an iterative process of design, counting on cycles of experimentation and improvements according to the results achieved from the following methods: observation, data collection and user self-reporting.

Furthermore, we present the framework applied to a precise case study, which is the introduction of Near Field Communication (NFC) technology through implanted microchips into everyday life. The case of implanted technology, although available from a technical point of view, is hard to be accepted by people, because of its perceived intrusiveness. Nonetheless, we can encounter a challenge with several phenomenological aspects – the acceptability of technology and the socio-cultural meaning, just to mention a few – which ultimately identify it as a suitable case study for our proposal.

## 2. State of the Art

The importance of understanding users' emotions in design has been established by Donald Norman [5] who demonstrated the complex relation between humans and the objects of everyday life. Emotional Design has been defined as the discipline aiming to evoke or prevent the elicitation of certain emotions. Indeed, emotions affect not only the way we choose and buy products, but also the way we use them. Emotional Design pays specific attention to the subtle qualities and meanings of human-product interaction. The main issue, at first, has been to understand how to avoid potential commercial failures; a large amount of academic literature involves tools to measure/evaluate users' emotions towards a product. Lately, Emotional Design

started addressing several other issues, as explored in the dissertation of Colombo [7], such as how to design more engaging products, how to mediate intimacy and emotions through technology, how to convey messages through products, or ultimately, how to design starting from users' emotions as generative insights.

However, emotions are hard to define: Kleinginna & Kleinginna [8] compiled a list of 92 different definitions of emotions. It is possible to identify some basic components of emotions, such as: the elicitation by appraisal (the recognition of the event as relevant); changes in motor expressions (face, voice, body); motivational changes (action tendencies); physiological changes (heart rate, skin conductance) and subjective feelings [9]. The subjective aspect of emotions is what makes them so hard to define and measure: we may argue that an emotion is dependent on people's previous experiences and memories, and no emotion is like to another. Nevertheless, following the Basic Emotion Theory (BET), we are able to classify emotions through a set of basic emotions, including 7 different categories that correspond to specific neural patterns [10]: the Fear System (Fear), the Seeking System (Seeking), the Rage System (Rage), the Panic/Loss System (Panic/Grief), the Play System (Play), the Mating System (Lust), the Care System (Care). The BET is a controversial approach within social sciences: however, it proved to be the most usable and applicable in Emotional Design field because of its schematic attitude.

Over the recent years, Emotional Design triggered the core principles of the User Experience Design (UXD). UXD pays on the emotional and personal needs of the users as much attention as it does to the usability and practical matters, trying to depict the whole experience involving users [11]. Furthermore, Hassenzahl [6] outlined how putting an emphasis only on the emotional aspect of user experience may result in a misleading approach. Emotional Design should instead explore the interplay of cognition and emotion. In the model described by Crilly et al. [12], the affective state is just one out of three components that constitute the whole user experience. More specifically, the user's response elicited by a stimulus may result in a cognitive, affective or behavioral response. In another study, Ortony [13] agreed on the ephemeral quality of emotions; Wright and McCarthy [14] noted that it is not possible to

actually design an experience, only to design for an experience. Designers are able to create possibilities, but they cannot create certainties: products alone cannot guarantee an emotion. Emotional Design, as we defined before, is the discipline aiming to evoke or prevent the elicitation of certain emotions. How can we make these emotions more likely? In this paper, we present a framework in order to answer this question.

### 3. Reverse Engineering of Emotions

According to the considerations presented above, we can consider emotions as complex mental states, wherein users are not simply receptors of a given interaction, but are conductors of a given and defined process. This chain of expressions can be related to three consequential phases that are interlinked and dependent on each other, but also unpredictable at the same time in terms of what we can expect from a certain emotional process to attain.

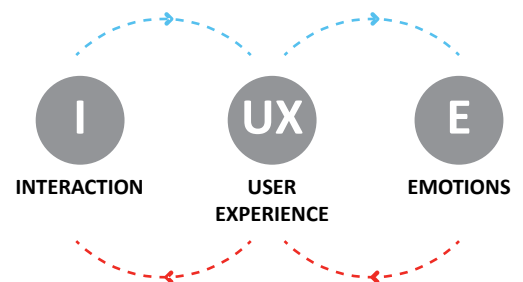


Fig. 2. Reverse Engineering of Emotions' steps

When we look at the steps in Fig. 2, we can clearly see the interaction, which in turn creates an experience for a user and then evokes an emotion. We are able to design this process, but are not capable of predicting the resulting emotion that will be felt by each different user. We are able to control different parameters of the interaction itself and create meaningful experiences that for the user will result in completely diverse emotional states. We therefore propose the concept of *Reverse Engineering of Emotions*. It aims to approach the experience analysis from a different point of view, assuming that neither emotions themselves can be designed, nor the user experiences, but what we can design is precisely the human-product interaction. In a reverse engineering modality, we propose to start from understanding emotions, in order to depict the complete pattern of user experience, and finally to

conceptually design the interaction itself. According to that, we propose the concept of *Reverse Engineering of Emotions*, where emotions are considered the starting point to discover the underlying principles eliciting them.

#### **4. The Microchip Implant: A Case Study**

In order to test the framework presented here, we introduce a case study that is an example of how we can start from emotions in order to understand how to make a new technology desirable and acceptable. The case study that we will focus on is the possible introduction of Near Field Communication (NFC) technology into everyday life through human-implanted devices. NFC is a technology able to establish radio communication among devices by bringing them into proximity, it can be used in contactless payment systems (similar to those currently used in credit cards and electronic ticket smartcards) and allows mobile payment to replace or supplement these systems. NFC reflects the ongoing tendencies of miniaturization and pervasiveness that computing devices are achieving [3]. This tendency is actually reflected in a variety of grants present in the Horizon 2020 program (<http://ec.europa.eu/programmes/horizon2020/>).

A human microchip implant is an extreme case study that opens up a whole series of problematic issues. An identifying integrated circuit device such as the implanted NFC microchip is a subtle indicator of our next future, where all our data could potentially be stored. Basically, it contains a unique ID number that is synchronized with an external database. It can contain information such as: personal data, contact details, bank accounts, medical records, allergies, etc. With this concept in mind, we may think of all the advantages that such product-service systems could encounter. But at the same time, we are forced to consider the extreme risks to skin disease; privacy policy and freedom of movement, not to speak in terms of the perceived intrusiveness this technology could impose. In fact, we should reflect on the huge impact that this shift in technological paradigm could actually have on users' perceptions. As a consequence, this defines the importance of focusing on the set of emotions this technology can provoke.

#### **A. Context: globalized world without boundaries**

Grasping the human microchip implant concept,

as a near-future reality, we can set the grounds for the arising challenges that we will need to face in understanding how this product can become part of our lives and what type of services it will provide. Will cognitive and interactive process be enabled through product-service-system that will respond to our needs and in turn reflect the emotional states of our future activities? This remains a polemic on whether this is something that will be accepted by several integrated interactions to save time, reduce additional production of products and create an ease of use. In addition, it is necessary to investigate the socio-cultural and psychological context that could be affected by NFC technology. As such, the designer's mediating role can facilitate and encourage the experience that emerges from using a new set of products, both from the point of view of emotion, aesthetic and meaning.

When we take a look to the global context today, we are witnessing a connected world arising from the interchange of products, ideas and cultural aspects. The Internet, being the major factor of globalization, has been responsible in generating greater interdependence in terms of economic, social and cultural flows [15]. These interactions are occurring simultaneously and information is being transmitted, using diverse devices between products, product-human and human-human.

#### **5. The Game Concept**

##### **A. The Serious Game approach**

In order to improve the desirability of NFC technology and to understand the desirable user experience to design, we propose to map users' emotions towards NFC using the ludic approach (as a way to directly experience in a safe and motivated way a reduction of reality) and the serious game in particular.

The ludic activity is something that belongs to human being and as such has its roots deeply grounded in both society and culture [16, 17]. In the last decades, the Games Studies discipline grew in consistency, and today, the game is becoming a useful communication system to convey stories, experiences and meanings. The game is an emerging approach with a great potential because it allows players to freely and safely acts within a protected space [18]. The contemporary research shows indeed how the game by nature defines a place that is in some way other, in which players distance themselves from the ordinary [20, 22]. Spaces

where, according to the Hungarian psychology scholar Csikszentmihalyi [19], players can freely make mistakes and, above all, build experiences from the mistakes they did. As researchers, we identify the game as a way to lead players to live experiences that we can observe and study, especially in terms of experiences gathered by players and the emotional states elicited by playing. Indeed it allows the designer to design perspectives that are alternative or complementary to the reality. We consider serious games as the most appropriate typology to foster accurate and complex experiences, because of their ability to involve users into realistic, interactive and engaging situations [20].

Similarly, simulators allow obtainment of dynamic representation of the behavior of a particular system. Being particularly realistic and reliable, simulated models make real scale reproductions: they propose a structure and an evolution over time that is generally similar to those of the phenomena or processes reproduced and simulated. As realistic models, simulations are a representation of phenomena and/or processes that take place in reality.

Serious games are interactive simulations in which players can directly face unusual and unpredicted situations, approaching the experience with a high and meaningful level of involvement [20, 21]. We decided to propose a serious game that is nonvirtual, but that is, on the contrary, contextualized in a real environment. It depends on the fact that an experience that requires physical immersion in an environment proves to be more involving and concrete than a virtual and digital one. It actually benefits on one hand of both the abstraction and the conceptual structure that is typical of a classical serious game, the digital one. On the other, it takes advantage of the immersion that derives from the act of playing in a physical space, with the entire body.

## B. Needs and mission: their connection

As described above, to observe and better understand the emotional impact that a remarkable shift in technological paradigm could have on users' perceptions, we intend to use a ludic approach. Indeed, if the fictional world is well structured, coherent and believable enough, the game can lead players to a state of openness to possibilities, and users are allowed to immerse themselves in a situation and a context that are set apart from their usual one [22]. This allows researchers to observe, understand and map the set of

emotions that users/players feel during the experience. Our goal is to understand the emotional states elicited in each user to finally observe and analyze how players behave and react using this NFC, with a specific focus on how it affects their patterns of actions. We intend to therefore detect and understand the correct pattern to eventually improve the desirability of NFC, considering that by satisfying psychological needs we can generate positive experiences.

## C. Description of the game structure

The game we propose is a serious game in which players are asked to solve simple missions. Each mission is a module designed to make players interact with NFC technology within a secure and controlled environment where they can freely experiment. The game environment is quite realistic and futuristic at the same time. It is composed of areas and each of them represents a specific scenario. These scenarios will be designed following the set of human needs proposed by Hassenzahl, corresponding to technology and media experiences [23]. Following Hassenzahl's, we are able to imagine how NFC could be employed in order to fulfill human needs. To succeed in their tasks, player have to move in the game environment, recognizing some important products and interfaces, in order to interact and "dialogue" with them. A limited set of interactive and responsive objects is part of each scenario and acts as a game element (Fig. 3).

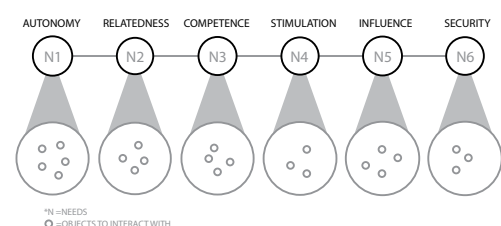


Fig. 3. The gameplay can be represented as a string of pearls, composed of scenarios (from N1, to N6) with different objects inside to interact with. These objects simulate an interaction that uses NFC technology

The six areas composing the game environment are strictly connected to a specific need (Fig. 4), referring to the previously mentioned list of human needs for technology and media experiences [20]. In his study, Hassenzahl explored the sources and consequences of fulfilling six fundamental human needs, namely:



(1) Autonomy, (2) Relatedness, (3) Competence, (4) Stimulation, (5) Influence, and (6) Security, through using interactive products and media. As said, we intend to build each scenario imagining how the NFC technology could satisfy a certain need. For example, in order to design a scenario in which NFC is supposed to fulfill a need of Relatedness (2), we will work on proximity and on social interaction facilitated through technology, with the possibility to have the presence of a friend in a place close to the actual position communicated to the player by the NFC technology. In this case, technology is clearly satisfying the need to be close to a friend, taking advantage of their physical proximity to meet him/her.

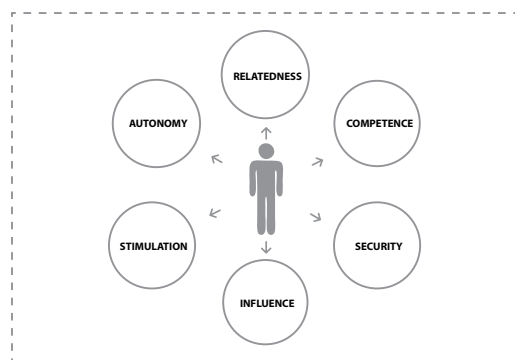


Fig. 4. The game environment is composed of six areas. Each area presents a specific scenario corresponding to one of the Hassenzahl's set of human needs

To have a meaningful and reliable game session, it is crucial to define both clear goals and to give the player clear feedbacks on the game activities and actions that he/she is accomplishing [22, 24]. For example, we will use proximity sensors to simulate the game system reaction to the player actions: hence, the objects will answer to the user approaching, displaying information. Moreover, it is fundamental to structure short missions, no longer than 10 minutes each, in order to avoid extended/prolonged negative feelings such as boredom and frustration.

Each mission will be structured as a single player experience in order to facilitate the possibility to focus on the experience he/she is living. Indeed, to complete the mission and progress in the game, the player must complete a self-evaluation of the emotions perceived during the mission. It is fundamental that each player gives his/her own personal and unique restitution of the emotions perceived: following this principle, other players' evaluations will not be visible.

The evaluation system is simple and direct, in order to avoid misunderstanding, to be consistent and coherent, it will be designed with a ludic interactive approach. The player will stand in front of a structure of seven containers – called Self-Evaluation Cylinders (Fig. 5) – representing the basic emotion classes outpointed by Panksepp [10]: (1) Fear, (2) Seeking, (3) Rage, (4) Panic/Grief, (5) Play, (6) Lust, (7) Care.

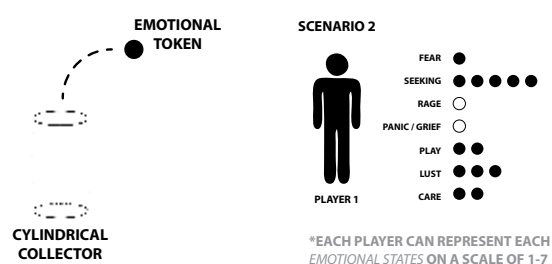


Fig. 5. Self-Evaluation Cylinders for Mapping Emotions. The figure shows an example of evaluation that the Player 1 is presenting, referring to the emotions perceived in the 2nd Scenario, Relatedness

The player will be asked to evaluate each of the emotions classes from 0 to 7, having at his/her disposal seven tokens for each set of emotions, for a total amount of 49 sphere-shaped tokens. Whether the player experienced a feeling of Fear, he/she will put tokens (from 1 to 7) in the "Fear" Cylinder; otherwise, we won't put any (counting as 0 = no activation for the corresponding feeling). During the mission, the player could probably perceive a combination of different emotions, so he/she will proceed in evaluating all the others emotions (i.e. putting other tokens in the "Seeking" Cylinder and so on). The *self-evaluation* is a crucial step because it is the moment when each player makes a personal analysis of the emotions elicited, also evaluating how much they felt activated. The simple fact of putting one or more tokens into a Cylinder means that the player perceived the emotional state corresponding to that specific Cylinder, with regard to the current scenario and the respective need.

#### D. Expected results

Whereas we intend to analyze the experience the users/players live during the game, it is crucial both to collect data and to observe behaviors. In particular we intend to achieve:

- A survey that inquires socio-demographic, cultural and behavioral information allowing us to generate a representation of the target and what is perceived;
  - An observation of players during their experience through facial and body tracking for emotion recognition.
- These observations are necessary to map which emotional states have been perceived by users during the game. In particular, the result of the facial and body tracking complete and validate the self evaluation that each player produced at the end of each scenario, conveying an external and scientific point of view: the one of the researcher that is observing, in spite of the one of the player who is deeply involved in first person. The data gathered could potentially be useful for research, especially in the industries field: they can contribute to build future scenarios concerning the potentiality of NFC technologies in a variety of applications areas.

## 6. Conclusions

This framework can be considered an original contribution to knowledge because it connects the Hassenzahl [6] list of needs to the set of basic emotions outlined by Panksepp [10]. The *Reverse Engineering of Emotions* framework addresses Emotional Design from a different perspective: it proposes to consider emotions as the starting points, and correlate them to user experience, interaction and needs.

Providing a map of the emotional states elicited from the users during the serious game experience, this framework allows observing and deeply understanding the user experience patterns. Referring to the example of Relatedness previously described in paragraph 5 and Fig. 5, we can claim that once the player discovers the proximity of a person nearby, the feeling of Seeking is highly present according to the player's interest in meeting him/her. In this sense, the researcher can firstly observe how the overall interaction with the objects occur and secondly, take advantage of this knowledge to better design a potential and different interaction. In particular, we point out how the map obtained can become a facilitator to understand possible uses. The framework can be applied to a variety of products that requires an observation of the experience and emotions elicited by the interaction with the interactive objects that populate each scenario.

Defining the framework we identified two possible points of weakness: on the one hand it requires spaces

equipped to host both the users/players experience and the activity of observation that researchers will conduct. On the other hand, we identified the proximity sensor as the best way to simulate NFC, but in the near future there could be better technological solutions available on the market to simulate the NFC technology. To conclude, we consider this approach of particular interest because it arises from the encounter of three different competences: (1) Emotional Design, (2) the Serious Game approach and (3) Service System Design. The presence of heterogeneous perspectives allows the research to benefit from a variety of points of view. Nevertheless the research group could take advantage of the presence of additional competences, for example, in the fields of cognitive science, psychology in particular. From a different point of view, also the cognitive science disciplines could indeed take advantage and be interested in the way in which interactive objects are perceived, communicated and display information. A psychologist, to be more specific, could benefit from studying the way in which behavioral and mental processes are activated through the use of NFC objects in the created scenarios and how they are used in the interactions between users.

## References

1. Hassenzahl, M., Tractinsky, N.; User-experience research agenda. In: Behavior & Information Technology, 25(2), pp. 91-97. Taylor & Francis, London (2006)
2. McLuhan, M.: Understanding Media, p. 19. McGraw-Hill, New York (1964)
3. Ugur, S.: Wearing Embodied Emotions. Springer, Milan (2013)
4. Shepard, M.: Sentient City: Ubiquitous Computing, Architecture, and the Future of Urban Space. The MIT press, Cambridge/London (2011)
5. Norman, D. A.: Emotional Design: Why We Love and Hate Everyday Object. Basic Books, New York (2006)
6. Hassenzahl, M.: Emotions Can Be Quite Ephemeral; We Cannot Design Them. In: Interactions, 11(5), pp. 46-48. ACM, New York (2004)
7. Colombo, S.: Sensory Experiences. Informing, Engaging and Persuading Through Dynamic Products. Unpublished PhD Thesis, Milan (2014)
8. Kleinginna, P. R., Kleinginna, A. M.: A Categorized List of Emotion Definitions, with Suggestions for a Consensual Definition. In: Motivation and Emotion, 5(4), pp. 345-379. Springer, Berlin (1981)

9. Dael, N., Mortillaro, M., Scherer, K. R.: Emotion Expression in Body Action and Posture. In: *Emotion*, 12(5), pp. 1085-1101. American Psychological Association (2012)
10. Panksepp, J.: *Affective Neuroscience: The Foundations of Human and Animal Emotions*. Oxford University Press, Oxford (1998)
11. Shedroff, N.: *Experience Design*. New Riders, Indianapolis (2001)
12. Crilly, N., Moultrie, J., Clarkson, P. J.: Seeing Things: Consumer Response to the Visual Domain in Product Design. In: *Design Studies*, 25 (6), pp. 547–577. Elsevier (2004)
13. Ortony, A.: *The Cognitive Structure of Emotions*. Cambridge University Press, Cambridge (1988)
14. McCarthy, J., Wright, P.: *Technology as Experience*. The MIT Press, Cambridge (2004)
15. Castells, M.: *The Rise of the Network Society. The Information Age: Economy, Society and Culture*. John Wiley & Sons, New York (2000)
16. Huizinga, J.: *Homo Ludens*. Taylor & Francis, London (1949)
17. Fink, E.: *L'oasi del gioco*. Raffaello Cortina, Milano (2008)
18. Crawford, C.: *The Art of Computer Game Design*. Osborne/McGraw-Hill, New York (1984)
19. Csikszentmihalyi, M.: *Flow: The Psychology of Optimal Experience*, p. 59. HarperCollins, New York (1992)
20. Anolli, L., Mantovani, F.: Come Funziona la Nostra Mente. *Apprendimento, Simulazione e Serious Games*, pp. 155-156. Il Mulino, Milano (2011)
21. Abt, C.C.: *Serious games*. University Press of America, Boston/London (1987)
22. Salen, K., Zimmerman, E.: *Rules of Play: Game Design Fundamentals*. Cambridge, The MIT Press (2004)
23. Wiklund-Engblom, A., Hassenzahl, M., Bengs, A.: What Needs Tell Us about User Experience. In: *Human-Computer Interaction—INTERACT 2009*, pp. 666–669. Springer, Berlin (2009)
24. Suits, B. H.: *The Grasshopper: Games, Life and Utopia*. University of Toronto Press, Toronto (1978)

**Jacklynn Pham**

Carnegie Mellon University, Pittsburgh, United States  
jacklynn@cmu.edu

# Expanding the Palette of Digital Interaction

## Abstract

The range of digital interactions we see in our devices today falls short of its potential to create more nuanced and dynamic interactions. By unlocking our notions of how interaction design elements (described as the building blocks of interaction design) can be used, designers could create richer multisensory experiences that more thoroughly explore what digital experiences can be. For example, how a designer could create a thoughtful auditory or haptic experience that supports—or is independent of—the visual interface. This paper attempts to reimagine designer's approach to translating digital interactions across experiences with an experiment in prompting reflection-in-action. Practitioners are asked to collectively reflect-on and reflect-in through an online design exercise. This method of causing and capturing focused reflectivity has designers describe different ways interaction design elements contribute to intention in experiences. Responses are captured on a website, becoming a survey of interaction elements as contributors help build a 'thesaurus' of what design elements can do. This paper also describes the sociolinguistic and rhetorical theory that informed the design experiment. The goal of this work is to extend designers' ability to translate design elements into different sensory experiences through engaging with communication theory perspectives.

## Keywords

Interaction design, reflection, theory, rhetoric, sociolinguistics

## Introduction: a disparity in experience

In practice, many interaction designers still rely heavily on visual cues in the bulk of their work. Design is rapidly outgrowing its visual-focused tradition as we are called upon to create thoughtful experiences that account for all the senses [14]. Today, there are few technological barriers for creating multisensory experiences as well crafted as the visual ones on our devices. It is now becoming feasible that designers will regularly work on projects with no screens at all, with small screens (like wearables), or with immersive technology (like designing for the Oculus or "4D theaters"). But the path to creating artful non-visual interaction design experiences is not well-trodden.

This gap was brought to my attention recently when I was learning how to design for accessibility. Part of the training included a day-in-the-life video of a vision-impaired woman. Meant to help viewers understand the day-to-day context that blind people live in, it included activities like finding a misplaced set of keys to using public transport to running an errand. When the woman demonstrated how she uses her smart phone, I was struck by the clumsiness of the interaction. It had been a perfect opportunity for interaction design to serve, but the actual experience was noticeably

undeveloped. The device's interaction with her was crude at best and, when compared to the careful visual details of the interface that she couldn't see, it was barely functional (it could not even recognize her name when she said it). The time that went into marrying the typography, the speed of screen transitions, and colors of a screen to develop the brand's identity was lost to her as an electronic voice haltingly dictated the page's content. What if accessibility went beyond transferring mere functionality and focused on translating the complete beauty of an experience?

Enhancing these currently marginalized moments—like creating an auditory experience *independent of* or *interwoven with* the other modalities—benefits visually-impaired and sighted users alike. For instance, designers could reposition how haptic feedback is typically used from a subordinate experience (turning on vibrate 'just in case' we can not hear our phone ring) to a primary role in order to translate an experience to a screenless wearable. Digital designs that are made to be more nuanced, multisensory, and sincerely adaptable could make experiences truly inclusive.

Researchers like Erik Stolterman point towards a more dynamic device landscape with new interaction design challenges, but mainstream digital interaction today feels constrained by our tradition of designing static, two-dimensional pieces [27]. When companies like Google and IBM release extensive design style guides prescribing design patterns, those patterns waterfall into conventions and can constrain perceptions of what is possible. Designer and engineer Bret Victor vented his frustration that interaction designers are following the same approach to interface and device interaction over and over again. He challenges us to design with the future in mind: instead of continually designing interactions between fingertips and glass, he points to the rich market of already existing assets, like research in haptic technology and tangible interfaces [28]. But how do professional designers continue evolving the way they use interactions in order to design for the future? Presumably they are attending interaction design conferences, reading books like Dan Saffer's *Microinteractions* or Jon Kolko's *Exposing the Magic of Design*, or even using creativity tools like Synectics or John Lockton's "Design with Intent Toolkit." This project offers another professional development opportunity through an interactive challenge aiming to deepen designer's impressions of interactions.

This exercise is informed by research on the benefits of reflection-in-action and from rhetorical and sociolinguistic perspectives of communication patterns. This online activity functions becomes both a method for inciting and capturing the more tacit knowledge of designers. Participants will have the opportunity to engage with their profession on a more personal level as they co-create definitions of use, catalogued on the website's wiki-like database.

The scope of this project was to examine screen-based interaction techniques (as opposed to rather than industrial design, for example), though examples of physical interactions (those between device and person) are given to aid understanding. In digital interactions reimagining what is possible is an interesting problem: devoid of form, it is completely up to the designer to create experience. Like words for a writer, the designer creates experience in the minds of its user through the skillful blending of interaction elements.

### Reflection in the design practice

This investigation acknowledges the work of scholars like Jonas Löwengren and Erik Stolterman for building a relationship between reflection and interaction design [21]. Influenced by Donald Schön, these researchers elevate the conscious articulation of designers' knowledge as a compliment to learning-by-making activities. Schön's work on action-oriented knowledge introduced a formal study on reflection for professionals. The two primary ways for accessing knowledge are reflection-on-action (revisiting the decision-making process of past activities) and reflection-in-action (the spontaneous reflection that occurs in the midst of interaction) [21], [25], [30]. A more critical questioning—or *practical reflectivity*—of designers' work helps shake up "taken-for-granted assumptions" and re-open broader possibilities [10], [30]. The exercise attempts to tap into the value of reflection-in-action. This is not a new activity, but an experiment with creating it. Going through a reflective exercise and articulating one's thoughts on more abstract qualities of interaction design may help shape new designers' critical eyes, like how explaining the elements of typography helps students be more discerning of typography they encounter in the future. Articulation of these ideas (talking or writing about them) commits attention to these ideas, solidifying previously unconscious knowledge. Already practicing

designers have the opportunity to empower their design process by being more conscious of the improvisation they already do. Articulated reflection changes from a descriptive activity into a chance for designers to continue advancing their understanding of design. This learning is an intrinsic outcome of being a reflective designer: “To reflect means that you use your critical mind to examine your role as a designer; it requires you to examine the purpose, outcomes, and benefits of doing design in different ways, and using different methods, tools, guidelines, or theories” (Löwgren & Stolterman) [21].

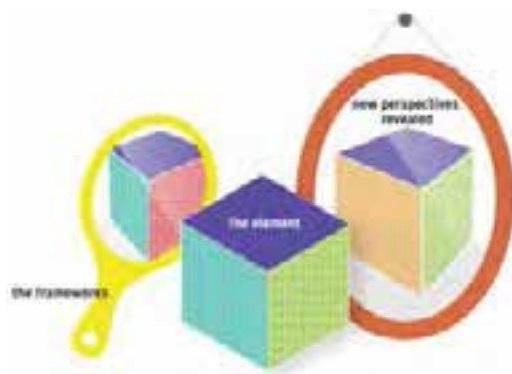


Fig. 1. Illustration of concept: the reflection caused by the framework-based prompts help reveal already available possibilities of an element that might otherwise remain hidden.

These ideas are supported by Albert Linderman’s work on drawing out tacit or less apparent expert knowledge through articulating past activities (“sense-making”) in order to surface new insights on one’s work [20] (Figure 1). He worked with top business executives to capture some of their tacit knowledge before they left

a company. He found that expression of actions (i.e. verbalizing) caused participants to relive the activity and reveal surprising reflection-in moments. These reflection-in moments are arguably more accurate accounts of tacit knowledge [30]. Having improvisational opportunities to study one’s profession may help designers create innovative experiences independent of science and technology [26].

### An interaction design experiment as intervention

This project centers around describing interaction design elements on an in-progress online website: [ixtranslation.com](http://ixtranslation.com) (Figure 2). For the purposes of this paper, *interaction design elements* are defined broadly as the atomic qualities of interaction that can be manipulated and combined to create interactions (Table 1). This is similar to how words and sentences are arranged to create a story. For instance, in graphic design: typography, scale, color, and position might be used to create document hierarchy. In digital interaction: animation, transitions, timing, sounds, vibration, and sequence might be manipulated to create a new experience.

An initial prototype has been built using WordPress that provides users with collaborative wiki-like functions like font-end entry submission, editing, and commenting. Entries for elements include 1) the name of the element, 2) a general definition, 3) common examples of it in use, and 4) responses to how it is or can be used in interaction design based on different frameworks (to be explained in more detail later).

Table 1. Examples of interaction elements. Interaction design element examples with a focused on screen-based interaction resources

Interaction design element examples with a focused on screen-based interaction resources				
Visual	Auditory	Haptic	Movement	Contextual
Typography	Volume	Vibration	Animations	Location (of user/device)
Color/Saturation	Speed	Orientation	Transitions	Ambient sound
Scale	Pitch	Physical movement of device	- scrolling	Environment data (temperature, time)
Weight	Direction		- direction	Speed of device (GPS)
Transparency	Distance	Texture	- in/out	Data on previous activities
Graphics	Timbre	Proximity	- expand/collapse	Information on other users (location, previous interactions)
Media/Video	Timing	Weight	- reveal/hide	Social account information
White space	“earcons” (short, associated sound)	Where on the body it interacts with	- application of physics	User’s planned calendar
Expectations				



Fig. 2. Screenshots of the ixtranslation.com homepage and design challenge web page

Participants are encouraged to respond to the element using six different frameworks: *informational*, *orientational*, *feedback*, *metaphorical*, *indexical*, and *performative* (Table 2). It is preferred that visitors will interact with the framework implicitly by submitting an entry through a design exercise (called a ‘design challenge’ on the website), however they may also learn about the frameworks by reading about them on the website. This exercise questions participants on the subject of each of the frameworks. Table 2 shows how the prompts are communicated to discover the perspective of the frameworks, but that the participant needs no prior knowledge of them to respond. These responses are then published on the website (after some moderation) as an entry so that, ultimately, participating in the design experiment helps build new entries in a growing library of interaction elements.

The six sections of entries are intended to help reveal new possibilities of elements that a designer hasn’t considered before. The act of articulating these possibilities through writing encourages participants to express, in concrete terms, how elements can be used to create experiences. In other words, participants are forced to solidify their thoughts rather than letting half-ideas float away undefined, and are therefore more likely to remember them. The exercise is most rewarding when participants go through each prompt to think about an element from different perspectives.

To explain the activity more concretely, imagine the element—normally something like ‘color’ or ‘tempo’—is instead a paper cup in your hand. You are asked what it is for. Your first answer is that the cup is a tool for containing liquid you intend to drink. But with each additional question your mind finds other possibilities: you recall that it could help you build a sandcastle, you could wedge it under a table leg to sturdy a wobbly table, you could write a message to a friend on the surface, or you could cut it up and make something new. The framework-based prompts also help prod your pre-conceptions of an element to reveal new facets of use. The design challenge instructions communicate to participants (and it is true) that there are no ‘right’ or ‘wrong’ responses, just the goal of stretching their assumptions of design elements. Table 3 provides a condensed version of a participant’s (a design professional) response to the design activity. It is clear that he is thinking intentionally about the element and it’s use.

The website began as a way to systematically define elements, but this thought experiment became a key benefit of the system. Participating transforms *narrative* experiences (which “force us shift to thinking about and formalizing in language what we are doing and experiencing” [10]) into cognitive ones as our assumptions or attitudes are questioned. While it is true that designers do not typically work without the context of their projects, this does not invalidate the kind of creative thinking that comes from discussing an element in isolation. Designer and researcher William

Hidden from user		Visible to user	
Category	Definition	Example prompts	Example element: Temperature
Informational	Literal; What is shown is what is meant	How could/is the element informative? At the most basic level, when is this element used to provide purely functional information?	A thermometer measures temperature; the unit of measurement it outputs is purely informational.
Orientalational	Provides wayfinding information for user through a process or a screen	How is/could this element be used to direct the user within the screen, system, or activity? Is the element used for wayfinding or tell you where you are in a system?	Thermal vision creates literal maps based on temperature
Feedback	Response to action by user or device	How could/does this element provide feedback on user interaction? What would it happen to this element is used to respond to user input?	We might put a hand over an old toaster after turning it on to feel if it's warming up or not
Metaphorical	Representing one thing in terms of another; often used to enhance understanding	How does this element represent or borrow from real life in order to enhance understanding by users? What metaphors does this element use?	Something 'hot' can be a metaphor for something popular Digital temperature might be displayed like a mercury thermometer
Indexical	Making use of identity and expectations between sender-receiver	How can/does the element help reveal knowledge about a system, brand, or actor? How might using this element tell you something about the identity of the device (its brand, etc)?	If a weather app portrays a happy sun versus a sad storm cloud, a person learns that the brand believes that sunshine is more desirable than rain
Performative	Eliciting of action based on shared understanding of a situation	How does experiencing your element in a situation change users behaviors (actions) or influence their thoughts (mood, understanding, etc)? How could it (implicitly) encourage or discourage users? What actions does it lead to?	A warm bus seat might deter someone from sitting on it because they might associate it with being recently used

Table 2. Overview of evaluative framework applied to each element of interaction on the wiki and how they were presented to users.

Gaver talks about how a certain ambiguity of context can elicit a more open outlook of what is possible [11]. It might cause designers to question their assumptions and think of new functions. For example, there was a participant who was discussing the element of 'scale' in the design exercise. She recognized how it is used in graphic design to show quantity or importance. She had even considered how scale is used to create grandeur in architecture, like in old cathedrals. She drew a blank, however, when thinking of ways that scale could be

used to provide feedback (feedback is when a system responds to a user input, like a button changing color when you hover over it [24]). Still pondering 'scale' later than night, and, having done some handiwork over the weekend, she remembered searching for just the right size screwdriver in order fix a shelf. She realized that screwdrivers use scale (size) in order to allow or prevent users from committing certain actions. Here, she had continued strengthening her understanding of scale even after completing the exercise and discovered



Entry created from participant of the interaction design challenge (condensed)	
<p>Motion:</p> <p>Motion is any movement or change in position or time (wikipedia)</p>	<ul style="list-style-type: none"> <li>• Informational: "Motion is naturally highly informative, if used with thought &amp; intent. Very few successful motions exists on their own. This element is used to connect sequence through structure; highlight elements and dim others through zooms; relay a mood or feeling through embodiment. It is a design element that is 4D in that it uses time as a variable."</li> <li>• Orientational: "Because motion is an "in-between" design element, it is difficult to pinpoint "A" example. One approach is to see motion's role; it acts as a bridge. It is a mechanism for feed-back that needs to connect a user action with a task the user is trying to accomplish. Because the user is often trying to accomplish a multitude of tasks with limited input options...motion, is very important in making the experience feel connected and seamless."</li> <li>• Feedback: "Motion can be invariably used for many, if not almost every digital interaction. However an element unique to screen based interactions might be in ability to give contextual feedback to user actions and commands."</li> <li>• Metaphorical: "Motion uses a lot of natural physics; action and reaction. Some examples are elements that are overlaid upon one another have shadows (3D), elements that are in the distance fade (proximity)."</li> <li>• Indexical: "The beauty and great challenge of motion is that it is inherently intuitive. But let me clarify. Motion is intuitive to judge whether or not it is working, but it is not as intuitive to create interactions. This is often because 1. interactions need work across demographics. 2. but every demographic and culture is different. 3. because we experience a large part of motion intuitively, it is difficult to clearly identify and articulate the entirety of what constitutes the motion and effect you are trying to design/achieve."</li> <li>• Performative: "An unintuitive, unnecessary, repetitive, redundant motion or transition can be very distracting, annoying, and even downright painful to use an app or interaction. This often appears in PowerPoint presentations or even a PowerPoint alternative called Prezi."</li> </ul>

Table 3. An example of a participant's response to the interaction design challenge (does not include the picture examples they provided).

previously buried ways the element could be used in future digital interactions to provide feedback. While this website collects descriptions of design elements, the project does not seek to be a conclusive document on interaction design. It serves as an intervention between designers and the stale design patterns they might fall victim to in regular practice. This could be especially helpful for design students who may not be as practiced at (or comfortable with) challenging design patterns. The website also showcases of the collective knowledge of the design profession as it evolves: its members discussing a growing number of elements (or resources) that they can manipulate. The resulting repository of elements and definitions can also help inspire designers when they are feeling stuck. For instance, one participant was working within design constraint and she used the website as a reference of

tools she could manipulate. She wanted to alter a shape to communicate different things, but had exhausted several transformations already. When she browsed the collection, she found an element she had not thought of applying yet (transparency) and employed it in her final project. Professions peripheral to design, like engineering or project management, could also be served with this system. These other professionals do not intend to immerse themselves in design (and therefore never acquiring knowledge-by-doing), but will still have the opportunity to learn about the complexity of refining elements into thoughtful interactions by reading entries on the website. Overall, this online collection has the potential to create distributed knowledge among design practitioners, students, academics, and, interdisciplinary team members [2].

Despite impressive work testing the boundaries of rich interaction design in industrial design [6], [18] and full-body interactions of both sound & visuals within the HCI department at Carnegie Mellon University [13], there still exists an innovation gap between recognizing the potential for new interaction techniques and actually using the elements available in new ways, especially for new or student designers. Professionals who contribute to the collection can re-evaluate the tools of their craft and discover different ways for creating more thoughtful interactions. The result is collaborative thesaurus of different ways design elements can be manipulated across modalities.

### **Influential theory: Communication patterns and interaction design**

At the heart of this design experiment is developing sensitivity to the intent of an experience in order to richly translate it. Humans are most practiced at judging intention through our social interactions. Like researchers have discovered before, this paper accepts that there are comparable patterns of communication between human-computer interactions as the conventions we see in human-to-human interactions. When we understand human-computer interaction as socially constructed, it can benefit from the same conventions gleaned from communication among humans. For example, Wendy Ju's work, *The Design of Implicit Interactions* (2015), uses linguistics, sociological, and ethnographic perspectives as a way of designing more nuanced interaction [15]. A better understanding of these theories will bring more maturity to the practice of design, especially when applying non-visual elements, which have a younger tradition in digital interaction. The design challenge helps participants engage with this theory, learning by experiencing the ideas inspired by it.

Scholars like Richard Buchanan and Klaus Krippendorff have described the relationship between design and rhetoric [5], [16]. Buchanan's work establishing a connection between rhetoric and design provides a significant foundation for evaluating the non-verbal communicative aspects of design. By accepting that designed objects (industrial, two-dimensional, virtual, etc.) exhibit a persuasive force—influencing actions, creating values, and shaping individuals and communities—we open them up to a rhetorical understanding [5]. Krippendorff proposes looking at

design through a linguistic lens in order to bring about “new ways of conceptualizing the world and new practices.” [16]. This “linguaging” of interaction design elements provides a model for how elements can be used to create an experience.

It's important to distinguish that this project does not focus on the grammar or syntax side of linguistics when applying this perspective to design. Work has been done describing the semantics aspects of design, like Krippendorff applying a semantic foundation to design [16], Kress & van Leeuwen describing rhetorical force of visuals [17], and, less directly, in Steffen's work with describing the history of design semantics and its role in product innovation [26]. Designers may use a semantic, or literal, understanding of elements at our disposal to broaden their view and a more pragmatic view (how things are actually used) to deepen their perspective. Evaluating interaction design on how it is actually used and what affect it has on people is more appropriate when translating experiences. It accounts for things like behavior, culture, and preference in interaction design. The linguistic study itself has progressed from focusing on the literal definitions of words to one more interested in language-in-use, context, and social relationships. By examining how people use elements within design's language, we address more ways they can transform independently from the designer's original intentions [23]. A simple example is that the element of vibration, used as a notification on phones. It's designed to be another way of receiving alerts even though the phone is on silent mode. But, as any user knows: it is not silent. Students can too-often be found using the low noise from the vibration as a socially acceptable way to let their phones quietly ring in class. There is a curious unspoken agreement where most people courteously ignore the noise because they believe that the owner intended for the vibration not to be heard, only felt.

These rhetorical and sociolinguistic theories touch participants the most in the last three of the frameworks: *metaphorical*, *indexical*, and *performative*. Again, participants were prompted to describe in the elements using these and three other frameworks.

**Metaphorical interactions.** At its most basic level, metaphor is a way of representing one thing in terms of another. These metaphors transfer a complex or unfamiliar image to a more straightforward one to

ease interpretation. Much of interaction design deals with metaphor, a well-studied area in rhetoric. As Lakoff & Johnson explore, metaphors can either be *representational* or *structural* [7], [19]. In *representational* metaphors, what is presented is based on a real-world experience. For example, some digital calendars are designed to look like physical calendars, from creating shadows to animating page turns. There are also culturally created symbolic relationships like slowing down or speeding up being represented by a picture of a tortoise and a hare, respectively. These symbols are more meaningful for people who know of the story of the “Tortoise and the Hare.” A *structural* metaphor refers more deeply to how we understand a concept and therefore perform it [19]. For instance, there is an underlying structural understanding that ‘good’ is represented as ‘up’ and ‘bad’ is represented by ‘down.’ Evidence we think this way is rooted in speech: “I was feeling *down* yesterday, but my spirits are up today.” These kinds of culturally embedded metaphors are present in the way we design interactions. Positive interactions are rewarded with a high tone while negative ones (like loosing in a video game) result in a tone lower in pitch. Apple’s Time Machine application (a hard drive back up and restoration service) includes another structural metaphor where time is physical and directional: we typically move forward for the future and backwards for the past. Giving time a dimension, the application, it creates a time-ordered stream of one’s window/document in a physical space (Figure 3).



Fig. 3. Apple Time Machine user interface (UI)  
(via support.apple.com)

Although the UI actually moves forward to access past versions of documents, users can mirror their mental models of the movement through time and understand what is happening. More closely aligning our digital

interactions to the structural metaphors we live by could help us create interactions that are easier for new users to adopt.

**Indexical interactions.** Knowledge about identity is expressed in interactions through our indexing, or the construction of values or positions through social interactions [3-4], [12]. When applications like Facebook reorganize its layout, giving priority to a newsfeed as “Home” rather than our profile page, we may interpret this as Facebook valuing staying up-to-date with our network’s activity more than contributing content ourselves.

This framework explicitly considers design to be for and part of social interactions where actions are interpreted as meaningful. It touches on interpreting interactions between: between user and device, user and user, and user and the world. The work by J.L. Austin connected language and action by exploring our ability to understand the deeper intention (*illocutionary force*) behind a speaker’s literal (*locutionary*) actions, whether verbally or non-verbally communicated. Austin explains that exchanges and actions are influenced by predetermined agreements among groups on what an appropriate response is within a rhetorical (recognizable) situation [1], [29]. In other words, a successful linguistic exchange happens someone responds in an expected way to another person [1]. These expectations can be directed by designers like creating an identity for the device or brand. For instance, MailChimp (an email marketing service provider) has been celebrated for its style guide that explains the voice & tone of their brand’s messaging. This guide explicitly asks their designers to consider the user’s feelings per action in order to craft an appropriate content [22]. It also provides tips and examples of a MailChimp-approved response. When these stylistic choices are thoughtfully used across a service, like MailChimp, they have the ability to create a personality for the brand that is recognizable and influential for a user.

**Performative interaction.** Performative interactions are socially-constructed forces, which exhibit a power over the user’s actions, emotions, or behavior [1], [8], [29]. They are understood gestures (*illocutionary forces*) that lead the receiver towards expected actions or performances (*perlocutionary actions*) [1].

In sociolinguistics, it is not only words themselves, but also the recognized situations that determine the exchange between a speaker and receiver [1], [3], [8]. This takes into account the identity of the speaker, their relationship to the receiver, where they are, the props they might use, and the quality of performance they give. Performative interactions are related to *triggers* in Fogg's Behavior Models on persuasive interaction (the trigger of a behavior); however, it is more implicit, like a nudge that considers more of the context and the performer's role in the persuasion [9]. These implicitly persuasive interactions encourage a user's behavior based on conventions or cultural norms. In language, when someone asks, "Is there any salt?" it is understood in context that the speaker is requesting salt, not voicing his curiosity to know if salt exists in the world. In interaction design, when a user is typing in a text field and it expands, the system has invited him to write more. If it remained a small text box that does not expand, the user is apt to write less because the structure makes it seem inappropriate.

Adding these three perspectives to the design process can help professionals approach their 'interaction vocabulary' differently and understand the nature of creating more human interactions.

## Conclusion

The design exercise presented in this paper is a creativity tool based in theory made to help deepen our sense of design elements and, as a result, expand our palette of what is possible. It uses articulated reflectivity to engage with one's practice and one's curiosity. The exercise is a less didactic way to continue learning different facets of experience creation and, since the entries are published, captures that insight for others. As a public project, it could come to represent the joint definitions of interaction design elements from scholars, students, and seasoned practitioners alike. Löwengren & Stolterman see the potential of reflecting-in and reflecting-on practice as source of creating the product of knowledge for the entire practice: "Design theory can be seen as knowledge that can liberate the designer from preconceived notions and conceptions of how the design process can and should be performed," [21]. With dynamic, multi-sensory, and wise devices among us, there should be a commitment to creating thoughtful interactions across senses. As our devices and the way

we use them changes, it is urgent that designers rethink how digital interactions are constructed in order to convey implicit intentions as well as function. The range of interactions in typical devices does not adequately represent what is possible.

Communication perspectives from rhetoric and sociolinguistics studies can help us reimagine 'how' and 'for what' interaction elements are used. These disciplines offer insight on how intention is transferred from a speaker to a receiver indirectly. Experimenting within these theories allows designers to critically examine how elements create an experience and speculate on how other elements could enhance or adopt the same communicative qualities. For example, if a visual element helps convey a sense of security, how could an auditory or haptic element perform the same function. Working with these theories through the design exercise may allow designers to more readily see innovation opportunities and finally give substance to marginalized digital experiences.

## Acknowledgements

Thank you to my advisor Cameron Tonkinwise for his support and guidance on this project. Thanks also for David Kaupfer, Justin Mando, Marc Rettig, Joep Frens, Jodi Forlizzi, and Suguru Ishizaki for their comments during my research process.

Part of this research project was funded by the generous support of kynamatrix Research Network's "Innovation through Collaboration" 2015 Grant Award.

## References

1. Austin, J. L.: *How to Do Things with Words*, 2nd ed. Cambridge, MA: Harvard University Press. (1975)
2. Borchers, J. O.: A pattern approach to interaction design. *AI & Society*, 15(4), 359-376. (2001)
3. Bourdieu, P.: *Language & Symbolic Power*. Cambridge, MA: Harvard University Press. (1991)
4. Bucholtz, M. and Hall, K.: Identity and interaction: A sociocultural linguistic approach. *Discourse Studies* 7(4-5): 585-614. (2005)
5. Buchanan, R.: Declaration by Design: Rhetoric, Argument, and Demonstration in Design Practice. *Design Issues*, Vol. 17, No. 3 (1985)
6. Djajadiningrat, T., Wensveen, S., Frens, J., & Overbeeke, K.: Tangible products: redressing the balance between appearance and action. *Personal and Ubiquitous Computing*, 8(5), 294-309. (2004)

7. Engelhardt, J.: *The Language of Graphics* (Doctoral dissertation, PhD thesis, 2002, Institute for Logic, Language & Computation, University of Amsterdam. ISBN 90-5776-089-4). (2002)
8. Fairclough, N.: *Discourse and Social Change*. Cambridge: Polity Press. (1992)
9. Fogg, B.: *A Behavior Model for Persuasive Design*. Persuasive '09. Claremont, California. (2009)
10. Forlizzi, J., & Ford, S.: The building blocks of experience: an early framework for interaction designers. In *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques* (pp. 419-423). ACM. (2000)
11. Gaver, W.: Ambiguity as a Resource for Design. *CHI 2003*, 233-240. (2003)
12. Goffman, E.: *The Presentation of Self in Everyday Life*. Garden City, NY: Doubleday Anchor Books. (1959)
13. Harrison, C.: Research Brief. [chrisharrison.net/HarrisonResearchBrief.pdf](http://chrisharrison.net/HarrisonResearchBrief.pdf) (Accessed January 2015)
14. Haverkamp, M.: *Synesthetic Design: Handbook for a Multisensory Approach*. Basel: Birkhauser (2012).
15. Ju, W.: *The Design of Implicit Interactions*. Morgan and Claypool Publishers. (2015).
16. Krippendorff, K.: *The semantic turn: A new foundation for design*. Boca Raton: CRC/Taylor & Francis. (2006).
17. Kress, G., & Leeuwen, T.: *Reading images: The grammar of visual design* (2nd ed.). London: Routledge. (2006)
18. Kyffin, S., Feijs, L., & Djajadiningrat, T.: Exploring expression of form, action and interaction. In *Home-oriented Informatics and Telematics* (pp. 171-192). Springer US. (2005)
19. Lakoff, G., & Johnson, M.: *Metaphors we live by*. Chicago: University of Chicago Press. (1980)
20. Linderman, A., Baker, J., & Bosacker, S. C.: Surfacing and transferring expert knowledge: the sense-making interview. *Human Resource Development International*, 14(3), 353-362. (2011)
21. Löwgren, J., & Stolterman, E.: *Thoughtful interaction design: A design perspective on information technology*. Cambridge, Mass.: MIT Press. (2004)
22. MailChimp. Voice & Tone style guide. <http://voiceandtone.com/> (accessed January 2015).
23. Redström, J.: RE: Definitions of use. *Design Studies*, 29(4), 410-423. (2008)
24. Saffer, D.: *Microinteractions*. Sebastopol, CA: O'Reilly. (2013)
25. Schön, D.: *The reflective practitioner: How professionals think in action*. New York: Basic Books. (1983)
26. Steffen, D.: *Design semantics of innovation. Product language as a reflection on technical innovation and socio-cultural change*, Department of Art and Design History, Bergische Universität Wuppertal, Germany. (2010).
27. Stolterman, E., Jung, H., Wil, R., & Martin, A. S.: Device Landscapes—A New Challenge to Interaction Design and HCI Research. *Archives of Design Research*, 26 (2), 7-33. (2013)
28. Victor, Bret. A brief rant on the future of interaction Design. Accessed January 2015. [worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/](http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/) (2011)
29. Winograd, T., & Flores, F.: Chapter 5: Language, listening, and commitment. In *Understanding computers and cognition: A new foundation for design*. Norwood, N.J.: Ablex Pub. (1986)
30. Yanow, D., & Tsoukas, H.: What is reflection in action? A phenomenological account. *Journal of Management Studies*, 46(8), 1339-1364. (2009).

# In Search of the Right Design Abstraction for Designing Persuasive Affordance towards a Flourished Society

## **Abstract**

In this paper, we propose a design abstraction referred to as gameful digital rhetoric to design meaning in the real world. Gameful digital rhetoric uses two models, the GamiRhetoric model and the GamiValue model, to enhance meaning in the real world based on the concepts typically used in digital games and thereby assist in the design of digital rhetoric. We present how the models are used to analyze an existing popular commercial game. We also conduct preliminary experimental studies concerning how the rhetoric in the GamiRhetoric model influences human behavior in the real world when the associated value in the GamiValue model is changed. Our aim is to design the influence on human behavior in the real world to achieve a flourished society.

## **Keywords**

Digital rhetoric; Happiness; Gamification; Persuasive affordance;

## **1 Introduction**

Advanced information technologies have dramatically changed our daily lives. Specifically, pervasive and ubiquitous computing technologies offer a variety of new opportunities to improve our lifestyles. For example, mobile phones and ubiquitous public displays enable us to receive more timely information, while ubiquitous sensing technologies allow us to develop a

variety of new services that can adapt their meanings and functions to the current situation. Moreover, social media such as Facebook and Twitter make it possible to create a new social culture among people. For example, crowdsourcing may change our work style significantly, and crowdfunding may expand our business opportunities. We have developed various digitally enhanced physical artifacts and social media that demonstrate future possibilities for using the aforementioned technologies in our projects [15, 16]. However, our experiences with development show that it is difficult to improve our daily lives solely through technology because the quality of our lives heavily depends on our attitude and behavior. For example, various smart city technologies make our lives more efficient and convenient; however, to realize human well-being in our cities, we must still alter our attitude and behavior.

Our aim is to enhance the real world surrounding people to enable them to realize human well-being. Seligman defines the well-being theory [19] as a theme of positive psychology. He defines five factors needed for humans to flourish: positive emotion, engagement, meaning, relationships and achievement. The factor of human well-being steers people toward desirable behavior. For example, positive emotions reduce the risk of catching a cold or an infectious disease. Additionally, a husband and wife who have positive images of one another can create a fruitful married

life. Seligman notes that people without positivity tend to think there is no way to improve their lives by themselves, whereas people with high positivity can act to have productive lives [19]. Therefore, it is important to focus on achieving human well-being to guide human behavior.

Recently, digital marketing and social media practitioners have adopted this approach under the term *gamification* [4]. The idea is to use game mechanics, such as those of online games, to make a task entertaining, thus encouraging people to conscientiously complete tasks. However, traditional gamification does not address human well-being in terms of Seligman's definitions of human well-being, as demonstrated in the next section. The gameful digital rhetoric complements the traditional notion of gamification to overcome this issue.

The main contribution of this paper is an approach that enhances traditional gamification to achieve a flourished society by enhancing the meaning of the real world. Our goal is similar to that of the movement named “*Game for Changes*”<sup>1</sup>, which aims to overcome current social problems by using game concepts. Our approach also offers design abstraction to blur spatial, temporal and social boundaries between the real world and the fictional world. The discussion in this paper offers several useful insights to realize a better digital-physical hybrid world and help us to design a flourished society.

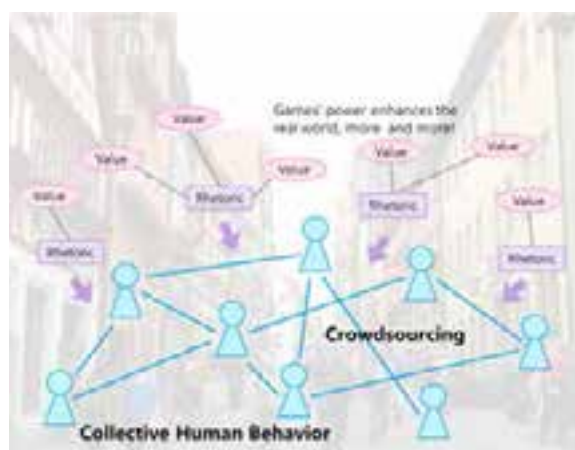


Fig. 1: An Enhanced World with Rhetoric and Value

In this paper, we consider games' power in terms of both “rhetoric” and “value” as design abstractions for achieving a flourished society. Gameful digital rhetoric that offers digitally implemented persuasive affordance and consists of the two abovementioned abstractions enables us to enhance the meaning of the real world,

as shown in Fig. 1. We define gameful digital rhetoric as expressions that inform, persuade and inspire human behavior through digitally mediated virtual objects incorporated into the real world using digital technologies. The concept of dividing games' power into the two models is useful in designing and analyzing digital games or gamified services.

## 2 Gameful Digital Rhetoric

*Digital rhetoric* in video games, which we call gameful digital rhetoric, often plays a role in manipulating a player's actions to advance a game. It also becomes a sign that encourages a particular type of human behavior when it is embedded in the real world through ubiquitous computing technology. Gameful digital rhetoric consists two abstractions: “*rhetoric*” and “*value*”. “Rhetoric” is defined in the GamiRhetoric model and “value” is defined in the GamiValue model presented in Section 3. For example, a crowdsourcing infrastructure is embedded in the real world for navigating collective human behavior. In [16], we present how fictional virtual humans can enhance social influence in a social media infrastructure. Additionally, in [12], we demonstrate that virtual currency can be used to make us aware of important social issues by enhancing human activities through gameful digital rhetoric. Thus, virtual objects can be useful tools for influencing human behavior, thinking, and feeling in the real world. Incorporating gameful digital rhetoric into the real world contributes to enhancing the meaning of the real world if the gameful digital rhetoric is meaningful to people. As shown in [5, 10], meaningfulness is an important design factor for emotionally engaging people. The enhanced meaning gained through gameful digital rhetoric makes explicit the desirable goals achieved through activities and encourages people by offering many attractive imaginary and artificial benefits.

A digital game, which is produced by the assembly of information technology, has the power to provide all of the factors presented by Seligman that are required to realize human well-being [19]. Castranova identified positive emotions as the single most important motivation for game playing [3]. McGonigal also states that positive emotions are the ultimate reward for participation [8]. Seligman argues that engagement is a concept related to flow [19]. During flow, people typically experience deep enjoyment, creativity, and



Fig. 2: Human Well-Being and Gameful Digital Rhetoric

complete involvement with life, where engagement that causes people to experience a flow state is an essential component in game design [7]. Csikszentmihalyi notes that the flow experience has all the building blocks of personal fulfillment such as clear goals each step of the way, immediate feedback on one's actions, and balance between challenges and skills [2]. Almost all digital games include immediate feedback under players' control, and well-designed digital games provide clear goals and appropriate challenges based on each player's skill. Regarding meaning, games have various rhetorical aspects, many of which have been discussed in previous studies; currently, rhetorical power is being reinvestigated to understand the powerful effects of games [1]. Additionally, games can create positive relationships. Digital games explicitly provide meaningful and valuable benefits for taking part in collective behavior. In fictional game worlds, players frequently tend to collaborate to achieve a common goal because they reap individual benefits by doing so. In MMORPGs, such as *World of Warcraft*<sup>2</sup>, multiple players must cooperate to perform a complex mission. McGonigal also argues that gamers form bonds with other gamers quickly. In her study, McGonigal illustrates the relationship created through collective activities in games' social fabric [8]. Moreover, achievement is often used in games as a useful incentive to motivate people [7]. Games clarify the process of achievement by using points, badges, leaderboards and other similar features [4].

The foregoing discussion clearly shows that games' power can enhance the five factors defined by Seligman, enabling them to become the permanent building blocks for a life of profound fulfillment toward a flourished society. Gamification is a promising approach to increasing human motivation and has been adopted in various information services recently. However, traditional gamification mainly focuses on only two factors: engagement and the achievement of Seligman's five factors. Therefore, it is difficult to achieve human well-being in terms of Seligman's definition, as shown in Fig. 2. The two factors, engagement and achievement, are designed based on goal setting [4], but other factors must take into account meaning in our daily lives. Gameful digital rhetoric addresses the semiotic aspects of digital games, and the abstraction offered by gameful digital rhetoric complements design frameworks developed in traditional gamification studies.

A digital game offers a virtual world that contains various virtual objects and missions that influence a player's behavior in the fictional world. Typical virtual objects include virtual currency, virtual humans, virtual goods and virtual clothes. Well-designed video games offer players many attractive imaginary and artificial benefits through meaningful and valuable experiences. When designing an attractive and successful digital game, a game developer defines meaning based on how a player perceives virtual objects and events in the virtual world. If a player feels that the world is meaningful, he or she will enjoy the game. We believe that the same reasoning applies to the real world. Making the world meaningful is essential to influencing human behavior to achieve a flourished society. If we perceive that objects and events in our real lives are meaningful and valuable, we can enjoy our lives. For example, stories are added to brand-name products to make them more meaningful. Gameful digital rhetoric offers a similar effect because it can enhance the meaning of the real world through virtuality. Additionally, inexisiting fictional effects are promising for enhancing the real world [13]. In [15, 17], we show that virtuality and fictionality can strongly influence human behavior to make certain lifestyles highly desirable.

### 3 Frameworks for Analyzing Games' Power and Enhancing the Meaning of the Real World

Our goal is to seek the abstractions that enable the design of information services that enhance meaning



in our real world. To this end, in this section, we describe two new models for enhancing meaning in the real world. The first model is the GamiRhetoric model, which defines six frames for determining how to enhance meaning in the real world. The second is the GamiValue model, which defines eight frames for attaching value to virtual objects.

### 3.1 GamiRhetoric Model

The semiotic aspect of the real world is essential to discussing how the world is meaningful [6]. The GamiRhetoric model is a semiotic model for designing digital rhetoric to make the digital world meaningful that consists of six types of rhetoric: curious rhetoric, narrative rhetoric, collective rhetoric, procedural rhetoric, social rhetoric and economic rhetoric. These six types of rhetoric have been extracted from experience with building several crowdsourcing services, as detailed in [16]. The paper provides further evidence of how each rhetoric is extracted from our experiences. In crowdsourcing infrastructures, designing social influence requires that cognitive effects be exerted on humans. In this context, changing meaning in infrastructures alters cognitive effects on humans. The six types of rhetoric mentioned above are used to design the meaning of these infrastructures. Curious rhetoric influences people through the five senses, which offers us emotional engagement, such as interest, happiness or comfort, and increases our curiosity, thereby motivating our activities. Narrative rhetoric refers to the casting of an argument as a narrative. A typical narrative teaches people what they should do in their ideal daily lives and has two salient aspects. The first aspect is describing ideological messages in the narrative, and the second aspect concerns goal setting in the narrative. Collective rhetoric refers to participants' cumulative efforts, and is one of the essential components that motivates participants to continue their efforts. Procedural rhetoric was first presented by Bogost, who stated that it involves the practice of using processes persuasively [1]. This type of rhetoric is peculiar to digital games, which operates based on interaction with a player. Finally, economic and social rhetoric offers norms, rules and mechanisms for fostering interactions among people that are typically used to coordinate collective action in the real world. This rhetoric includes various social mechanisms, such as market economy, gift economy,

altruistic society, battle and role-playing mechanisms, which are also typical underlying mechanisms used in popular video games.

Regarding the utilization of the frame of the GamiRhetoric model, enhancing the meaningfulness added to each frame is important. The agency and immersion properties of this model are useful concepts that are implemented in video games [7] to make objects more meaningful. The agency property relates to whether participants can control the effects on their activities, and the immersion property refers to whether these effects reflect players' real activities without violating reality.

### 3.2 GamiValue Model

There is research that focuses on the concept of value to design attractive products. Using values has recently been recognized as an important design approach to developing desirable information services [15, 18]. In analyzing digital games, it is useful to summarize systematically what values players feel toward digital games. These values have been extracted from user experiences with various digitally enhanced products through the *Delphi card sorting method*<sup>3</sup>. The values in the model are extracted from a semiotic point of view, and the model defines eight frames for attaching the following values to virtual objects: *informative, aesthetic, empathetic, stimulative, serene, common, rare* and *ideological values*. In [15], we also show how values can be extracted from experiences with developing digitally enhanced dairy artifacts.

Informative value is the utility offered by personalized information in helping users make better decisions.

Aesthetic value is an important concept in making artifacts more attractive. Aesthetics is a branch of philosophy addressing the nature of art, beauty, and taste and the creation and appreciation of beauty.

Empathetic value is effective in evoking a user's emotions. Empathy engages the user, making him/her feel close to the empathetic form, regardless of whether it is a living being. Stimulative value arouses people's senses through feelings such as excitement, surprise, thrill, and enthusiasm. Serene value is also related to players' feelings; however, the value is associated with calmness, warmth, comfort and relaxation. Common value and rare value are generated in social communities. Objects with common value are considered valuable by and available to many. Objects

that exhibit popularity, such as fashionable and famous brands, have common value. In contrast, objects with rare value are unique and difficult to obtain. Some objects with high rarity enable their owners to feel high self-esteem by demonstrating their status. What is herein referred to as ideological value is the notion of influencing users' thinking and behavior by influencing their attitudes and values—in other words, educating users on a deeper level.

#### **4 Analyzing an Existing Popular Game with the Proposed Models<sup>4</sup>**

In this section, we analyze the Nintendo game *Pokémon*<sup>5</sup> using the GamiRhetoric and GamiValue models. The analyses focus on the games' transmedia storytelling, exploring how the original game is expanded into other media, such as novels, anime, social media, and festival events. We can observe the types of rhetoric and values that exist in Pokémon-related media. The basic objectives of Pokémon are to battle and obtain Pokémon throughout the game story. Pokémon offers multiple media channels through which the details of the game's fictional world are defined using a transmedia storytelling concept, including Pokémon-related comics, animated cartoons, movies, card games, festivals, amusement parks, and character goods. Transmedia storytelling is a highly promising technique for enhancing the meaning of the real world because it allows us to add additional media channels to popular existing media channels [11, 17]. Pokémon is one of the most popular contents that use multiple media channels to enhance the Pokémon world.<sup>6</sup> We believe that the analysis of Pokémon via gameful digital rhetoric provides an opportunity for developing guidelines for the use of gameful digital rhetoric to enhance the meaning of the real world. The analysis has been conducted by an expert who has played various digital games for more than ten years. In particular, the expert knows all media channels used in Pokémon very well.

##### **4.1 Rhetoric in the Pokémon Game**

The Pokémon game contains all six types of rhetoric of the GamiRhetoric model presented in Section 3.1. The visuals of various Pokémon, the visuals and sounds of each city that the player visits and the battle scenes represent parts of the curious rhetoric. Because there are over seven hundred Pokémon in the game, the probability that there are Pokémon that fit a player's

preferences is high. These characteristics significantly enhance the game's agency and immersion. Additionally, for a player, obtaining his/her favorite Pokémon and exploring his/her favorite city strengthen the bond between the player's interest and the game world. The feature also contributes to enhancing the realness of the game.

Collective rhetoric is added by elements such as badges, experience points and an illustrated Pokémon guide.

The guide heightens the agency property because the recorded Pokémon are only those that players have obtained or met. Additionally, the entire game relies on the mechanisms of incremental achievement based on the player's level. The strong relationship between the game and players' activities also contributes to increasing the realness of the game world.

The narrative rhetoric of the Pokémon world contains ideological messages, such as friendship between or at least coexistence of players, who are called Pokémon trainers, and Pokémon. A player is made aware of the ideological message by navigating the Pokémon story under his/her control.

The Pokémon game consists of basic objectives such as obtaining, battling and exchanging Pokémon. These objectives represent the typical features of procedural rhetoric. Procedural rhetoric enhances the game's realness by providing immediate feedback through the interactions between the player and the digital world. Players obtain Pokémon by throwing a Poké Ball toward Pokémon; a successful capture indicates that the player and Pokémon become friends; this feature is one of the main rhetorical interactions in the Pokémon world. The procedural feature is available only in the digital world, not in other media channels.

A player typically undertakes the basic actions of battling and exchanging Pokémon as a Pokémon trainer with non-player characters in the digital world; however, players can perform these actions with real persons in the real world. This mechanism is considered indicative of social rhetoric. Economic rhetoric, such as virtual economy and the rarity of Pokémon, also exists in the game's world. The social rhetoric and the economic rhetoric generate a strong relationship between the game world and the real world, which increases the realness of the game world.

##### **4.2 Emotional Value in the Pokémon Game**

In this section, we discuss the value of each type of rhetoric described in the previous section. Through

curious rhetoric, players can derive aesthetic value from the graphics of cities and landscapes in the game and empathetic value from the Pokémon trainers, which appear similar to the players who control them. Empathetic value is also generated by the Pokémon that the player obtains and raises. This effect is related to collective rhetoric and narrative rhetoric. The sources through which a player gains a sense of value vary depending on each player's situation. If the source that generates empathy concerns only Pokémon's visual appearance, then only curious rhetoric influences players. However, players can also empathize with Pokémon because they spend substantial time together and engage in dramatic interactions with the Pokémon. In this case, a player's Pokémon cannot be replaced by other Pokémon, although they share an identical visual appearance. The key factors are collective rhetoric and narrative rhetoric. A description of brave and thoughtful characters or a story involving the symbiosis of people and Pokémon incorporates ideological factors and conveys ideological value through narrative rhetoric. Procedural rhetoric can provide various values to players. The variety of Pokémon and their moves during a battle enable players to explore infinite strategies. This variety is related to informative value by enhancing the possibility that players will make decisions based on their individual preferences. During a blistering battle, players can gain a sense of stimulative value. Interaction with Pokémon is related to procedural rhetoric and provides significant serene value for Pokémon fans. Economic rhetoric enhances value among social communities. Obtaining particularly popular Pokémon is connected to common value; in contrast, acquiring rare Pokémon generates rare value.

### 4.3 Enhancing Original Meaning through Other Media

There are other types of media that are used to enhance the Pokémon world. Animation is strongly related to narrative rhetoric. Although the actor who performs the actions of obtaining Pokémon, fighting, and exploring is the player himself/herself in the digital game, the performer of these actions is an animated character. Therefore, a player also feels that he/she resides in the Pokémon world in the animation story. This relationship encourages audiences to think deeply about characteristics of ideological value in animation, such as the importance of bravery, friendship and

challenge. Curious rhetoric, on the other hand, is incorporated into Pokémon-related events. Curious rhetoric conveyed through stimulating visuals displayed while participating in real-world events enhances the realness of the game world [13], which causes the participants to develop great interest in the game and empathy for the characters. Additionally, Pokémon events often contain collective rhetoric and economic rhetoric elements because there are rare Pokémon that can only be obtained at these events. The experience of participating in the events is made visible in the form of collecting rare Pokémon in the digital world. A new Pokémon movie is screened every year, and players can obtain rare Pokémon featured in the movie. The hero Pokémon in the movie often has a backstory in which the narrative rhetoric defines the characteristics of the Pokémon. Indeed, the story enhances the empathetic value of the Pokémon. In the real world, the collection of Pokémon goods alternates with the collection of digital Pokémon. The activity is also related to collective rhetoric, which can generate rare, empathetic and serene value.

## 5 Incorporating Gameful Digital Rhetoric into the Real World

In this section, we discuss embedding gameful digital rhetoric into the real world to make the real world meaningful and valuable. The discussion presented in this section offers several examples demonstrating how the meaning of the real world can be enhanced via gameful digital rhetoric. Incorporating economic and social rhetoric into the real world tends to be successful because these factors are inherent to the real world. Collective rhetoric is also easy to use. For example, the collection of cards, seals or other goods prevails among many people. If the purpose of collection is consistent in the game world, then many fans consider the collection meaningful and valuable. In particular, the collection of tangible things in the real world increases the realness of the game world. Regarding curious rhetoric, we must consider the boundary between the digital fictional world and the real world. Embodying the virtual characters in the real world using ubiquitous computing technology is a relatively easy method by which to enhance the real world; however, the degree of this influence depends on the target individual. People who believe that there is a strong boundary between the digital fictional world and

the real world consider embodied objects meaningless. Therefore, curious rhetoric loses its power. However, whether the fusion of gameful digital rhetoric and the real world succeeds is influenced by the game's theme. In cases in which the main theme in the digital world is also common in the real world, such as the theme of "love" or "music", we can blur the boundary between the two because we can perceive the reality of the theme. Incorporating a fictional narrative into the real world provides the possibility of enhancing the agency property through narrative rhetoric [13]. Role-playing by adopting a fictional role in the real world without losing one's grasp of reality is effective in incorporating fictional gameful digital rhetoric into the real world. For example, live-action role-playing [9] is a popular approach to incorporating fictionality in pervasive games. However, when the audience of a narrative loses its sense of reality, members of the audience cannot play a fictional role because they are aware that the narrative remains within the fictional world, which has no direct relationship to the real world. Thus, the audience members believe that the rhetoric can exist only in the fictional world, and thus, the rhetoric merely influences the audience's behavior and thinking while remaining in the magic circle of the fictional world. However, a narrative that is too realistic may decrease a player's pleasure because the narrative is not different from that experienced in his/her daily life. Therefore, there is a tradeoff between the degree of reality and the degree of fictionality used when implementing narrative rhetoric. To evaluate the influence of rhetoric described in the previous section in the real world, we conducted two studies. These studies represent a first step in considering how to incorporate gameful digital rhetoric into the real world. In discussing the studies, we focus on the following two aspects, which are often found in games: storytelling, and gift economy.

Six people (five male and one female) participated in the studies, and their ages ranged from 21 to 28. We created situations based on certain scenes, and the participants completed questionnaires under a comparative scheme. This discussion is useful for influencing human behavior by incorporating games' power as a form of digital rhetoric into the real world. However, the current studies illustrate only small aspects of our approach; thus, we must conduct more complete studies to validate our approach.

### 5.1 Study 1: Storytelling for Collective Action

The study investigated the style of a narrative. To motivate people, they must be made consciously aware of the necessity of their participation in achieving their goals in their respective activities [12]. In traditional media such as movies and literature, a narrative is typically used to teach people why achieving their goals is essential. When a narrative is related to solving serious social problems, such as environment sustainability or human well-being, the narrative affects human behavior because it may demonstrate why the behavioral changes of humans are essential and it may increase their competence in making these behavioral changes.

In this study, each participant was presented with two types of narratives that were used in two configurations. Both narratives represented the necessity of participating in collective action to achieve a sustainable society; however, the manners in which the narratives were presented differed. The first narrative was written from the third-person perspective and thus contained many sentences presented from a neutral perspective (e.g., "*Recently, the environmental problem has become serious*" or "*To solve the environmental problem, it is important for many people to co-operate.*"). On the other hand, the second narrative contains sentences presented from the first-person perspective, as if the reader is a person who is directly concerned about the problem and performed concrete activities to protect our environment, in a style typically used in video games. Additionally, the second narrative expresses the influences of collective activities based on concrete roles that the participant plays or the quantitative numbers that he/she must contribute (e.g., "*You are the chosen person with the special power to save the world*" or "*If you set the temperature of your airconditioner even one degree higher, you can reduce your use of CO<sub>2</sub> by 33 kg and save 1,800 yen in a year.*"). The difference between the two types of narratives is how informative value is added to narrative rhetoric; the second style offers more subjective information that is related to the participant.

In the study, we asked the participants' opinions about the two configurations. The participants responded to the following questions on a 5-point Likert scale (5 = strongly agree, 4 = agree, 3 = don't know, 2 = disagree, 1 = strongly disagree) after reading the two aforementioned narratives.

*Q1 I can understand the importance of taking some action to contribute to solving environmental problems.*

*Q2 I intend to take some actions to contribute to solving environmental problems.*

With respect to Q1, the acceptability of the first narrative was 4.00, and that of the second narrative was 4.17. With respect to Q2, the acceptability of the first narrative was 2.83, and that of the second narrative was 4.00. The score of the second narrative clearly exceeded that of the first narrative for both Q1 and Q2. All of the participants responded that the second narrative motivated them more than the first narrative did. In the first narrative, participants claimed, *"I can understand that environmental problems are important issues, but I cannot understand how the problem is related to me" and "I cannot imagine what I can do to help solving the problems or what the effect of my current behavior is on our society."* On the other hand, with respect to the second narrative, one participant stated, *"It is easy to understand the importance because there were some examples of concrete activities and concrete numbers" and "I feel a sense of closeness with the narrative"*. Based on the results of the study, we argue that the second narrative provides more of the agency property than the first narrative does, which suggests that the narrative rhetoric was more powerful in the second narrative. The style of narratives significantly affects human behavior, and some ideas borrowed from video games are useful in creating better narratives. Specifically, a video game typically uses narratives from the first-person perspective, and both curious and collective rhetoric can augment the narrative to present concrete information such as stimulating visuals or collective items to complement the information presented in the narratives. Incorporating strong narrative rhetoric through games contributes to increasing informative value, allowing for better decision making. Narratives communicated from the first-person perspective can also enhance ideological value, leading people to think on a deeper level.

## 5.2 Study 2: Gift Economy

In this study, we compared the effects of an empathetic virtual human and a human stranger, and each participant was exposed to two configurations with an empathetic virtual human and a human stranger. In the study, we also investigated how a participant perceives the rarity of a gift from one of the empathetic

virtual humans. The approach makes it possible to enhance factors of social influence such as reciprocity, social proof, and commitment and consistency. As demonstrated in [12], such social influence becomes weak if people are strangers to each other. The study shows that incorporating empathetic value and rare value may improve the situation. Some promising strategies that work well among people who are quite familiar with each other can be used even in cases in which they are strangers to each other by replacing the strangers with empathetic virtual humans.

In the experiment involving an empathetic virtual human or stranger, we asked the following questions to each participant, to which the participants responded on a 5-point Likert scale.

*Q3 Under the condition that "you are given a gift by your empathetic virtual human", please evaluate the following statements I – III.*

*Q4 Under the condition that "you are given a gift by a stranger", please evaluate the following statements I – III.*

*I: I feel happiness when a gift is given.*

*II: I feel rarity about the given gift.*

*III: I feel reciprocity when I am asked for a favor.*

With respect to Q3-I and Q3-III, all of the participants' answers were 5.00, and with respect to Q3-II, the average response was also high, 4.50. In contrast, the results related to the situation in which a gift was received from a stranger were low. The average degrees of happiness (Q4-I), rarity (Q4-II), and reciprocity (Q4-III) were 2.33, 2.50, and 2.33, respectively. For all of the questions, all of the participants responded that the experiment involving an empathetic virtual human gave them more delight than an interaction with a stranger. With respect to the former, one participant claimed, *"I want to cherish and reciprocate a gift if I was given a gift by my favorite"*, and another participant said *"I think I cherish the gift more than had I bought it by myself"*. On the other hand, a participant who received a gift from a stranger said, *"It [the degree of happiness] depends on whether the gift is pleasant or useful for me"*. There were also some negative opinions, such as *"I have doubts when a stranger gives me a gift"* and *"The gift from a stranger is terrible."* These results show that the curious rhetoric did not work well in the stranger scenario. Gifts from strangers are not sufficiently meaningful to generate emotional benefits; in particular, they lose empathetic value and economic value. Although being 'given a gift' is the same in both configurations, the attitudes of the participants

were largely different between the configurations. The most important factor in motivating people appears not to be a mechanism, such as 'giving a gift', but rather the meaning attached to the mechanism. Focusing on only the mechanism may risk making a service meaningless. Additionally, we suggest that building relationships among friendly community members results in better social effects on participants' attitudes and behavior because the empathetic human - whether virtual or fictional - evokes positive feelings in participants' daily experiences.

## 6 Conclusion

Our aim was to enhance meaning in the real world to enable people to realize human well-being. Traditional gamification, which mainly focuses on engagement and achievement, does not address human well-being. We demonstrated that leveraging the full power of video games can help overcome this issue. As a first step toward achieving this aim, we provided abstractions defined by the GamiRhetoric and GamiValue models. We believe that the gameful digital rhetoric provided by information technology is a bridge between multiple disciplines, such as behavioral science and cultural studies. Our research contributes to enhancing the real world to enable the realization of human well-being.

Fig. 3 shows the two approaches employed in this study: "rhetoric"- and "value"-based design. The first approach discusses "rhetoric" first and assigns "value" to the chosen "rhetoric". The second approach discusses

"value" first. Based on our experiences with building digitally enhanced artifacts [15] and crowdsourcing services [16] with gameful digital rhetoric, we consider the first approach more appropriate for designing products and services and the second approach better for analyzing products and services. However, further study in this regard is warranted.

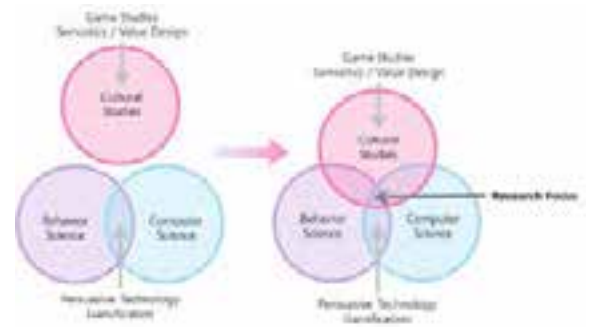


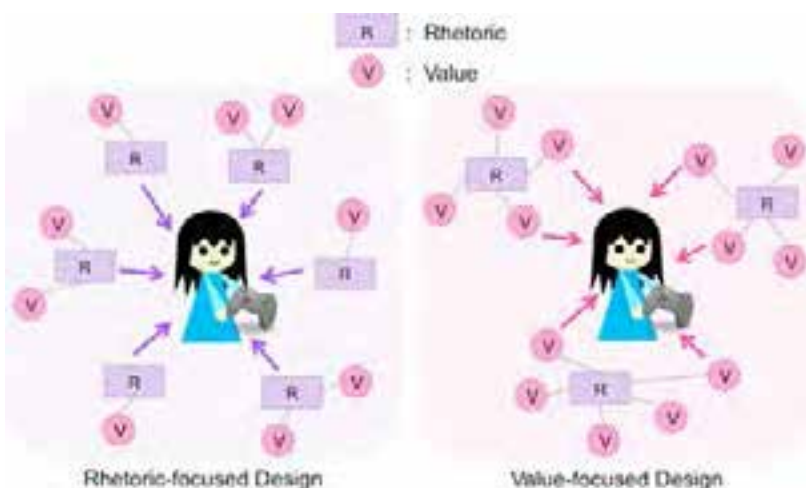
Fig. 4: A Future Research Program

As shown in Fig. 4, current human-computer interaction studies mainly focus on the intersection between behavioral science and computer science. For example, persuasive technologies have been widely adopted in many studies to develop products and services to influence human behavior. However, in this approach, because the semiotic aspect is not discussed, it is difficult to use games' full potential. As a next step, we must also discuss the intersection between behavioral science, computer science and cultural studies and develop a new interdisciplinary research program that incorporates these areas of study.

## References

1. Bogost, I. "The Rhetoric of Video Games", *The Ecology of Games, and Learning*, MA: The MIT Press, pp.117-140, (2008)
2. Csikszentmihalyi, M. "Flow and the Psychology of Discovery and Invention." Harper-Perennial, New York, (1997).
3. Castranova, E. "Exodus to the Virtual World: How Online Fun is Changing Reality". New York: Palgrave Macmillan, (2007)
4. Deterding S., Dixon D., Khaled R. and Nacke N. "From game design elements to game-fulness: defining "ramification"", In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, pp.9-15, (2011)
5. Hart, I., "Meaningful Play: Performativity, Interactivity and Semiotics in Video Game Music", *Musicology Austria*, Vol. 36, No. 2, (2014)

Fig. 3: Rhetoric-Focused and Value-Focused Design



6. Krippendorff K., "The Semantic Turn: A New Foundation for Design", CRC Press. (2005)
  7. Juul, J., "Half-Real: Video Games between Real Rules and Fictional Worlds", MIT Press, (2005)
  8. McGonigal J. "Reality Is Broken: Why Games Make Us Better and How They Can Change the World", Penguin Press, (2011)
  9. Montola, M., Stenros, J., Waern, A., "Pervasive Games: Theory and Design", Taylor & Francis, (2009)
  10. Nicholson, S., "A RECIPE for Meaningful Gamification", Chapter 1 in Gamification in Education (Wood, L. and Reiners, T. ed.), Springer, (2015)
  11. Sakamoto, M. and Nakajima T., "Augmenting Yu-Gi-Oh! Trading Card Game as Persuasive Transmedia Storytelling", In Proceedings of the 2nd International Conference on Design, User Experience and Usability (2013)
  12. Sakamoto M. and Nakajima T. "Micro-Crowdfunding: Achieving a Sustainable Society through Economic and Social Incentives in Micro-Level Crowdfunding". In: Proceedings of International Conference on Mobile and Ubiquitous Multimedia (2013)
  13. Sakamoto M. and Nakajima, T. "Gamifying Intelligent Daily Environments through Introducing Fictionality". International Journal of Hybrid Information Technology, Vol.7, No.4 (2014)
  14. Sakamoto M. and Nakajima T. "The GamiMedia Model: Gamifying Content Culture". In: The 6th International Conference on Cross-Cultural Design, LNCS 8528 (2014)
  15. Sakamoto, M, Nakajima T., Alexandrova T., "Enhancing Values through Virtuality for Intelligent Artifacts that Influence Human Attitude and Behavior", Multimedia Tools and Applications, (2014)
  16. Sakamoto M., Nakajima, T. Akioka, S., "Gamifying Human Behavior with Gameful Digital Rhetoric", Waseda University Technical Report (2015)
  17. Sakamoto, M. and Nakajima T., "Incorporating Fictionality into the Real World with Transmedia Storytelling", In Proceedings of the 4th International Conference on Design, User Experience and Usability (2015)
  18. Sakamoto, M, Alexandrova, T., Nakajima, T., "Analyzing the Influence of Virtuality on Playful Social Interaction", Multimedia Tools and Applications (2015)
  19. Seligman, M. E. P. , "Flourish: A Visionary New Understanding of Happiness and Well-being", Free Press, (2011)
- <sup>1</sup> <http://www.gamesforchange.org/>
  - <sup>2</sup> <http://us.battle.net/wow/en/>
  - <sup>3</sup> [http://iasummit.org/proceedings/2007/files/Delphi\\_Card\\_Sorting.pdf](http://iasummit.org/proceedings/2007/files/Delphi_Card_Sorting.pdf)
  - <sup>4</sup> In [14], we analyzed several other popular games using the GamiMedia model which is a successor to the GamiRhetoric model.
  - <sup>5</sup> <http://en.wikipedia.org/wiki/Pok%C3%A9mon>
  - <sup>6</sup> In [11, 17], we also analyzed other content such as Yu-Gi-Oh! TCG and Megumi and Taiyo Tweet Love Story.

# Object's Personality, a Tool to Chase an Aesthetic Approach in the Design of Smart Objects

## Abstract

Nowadays we experience a growing presence of smart products in the everyday life. This happens thanks to the presence of technologies such as Internet of Things and Artificial Intelligence, which are able to augment products, in particular related to the level of ability of those products to take decision on our behalf [1]. This phenomenon establish new questions related to the design of the interaction with those products, it transforms the way we interact from a traditional static interaction to a dialogue, which evolves in time, between the product and the user. As supported by many researches in the latest years [2][3][4][5], I believe that a possible answer to this need can be given through a greater use of aesthetics values in the design of the interaction, balancing the “efficiency” value, recognised as the main driver in the human computer interaction until now.

As designer I experienced a lack of design tools able to help me in pursuing this goal. Indeed many researches in this field discuss the definition of aesthetics of interaction [6][7][8], but few of them focus on the creation of design tools to use aesthetics of interaction paradigms in the interaction design realm [9][10][11][12]. After discussing the actual literature, in this paper I will present the state of the art of my research in the definition of Personality, a design tool to chase an aesthetics approach in the design of smart products.

## Keywords

Interaction Design, Aesthetics of Interaction, Personality, Design Tool.

## 1 Introduction

In the latest years an aesthetics culture is emerging in the Human-Computer interaction realm, many academic researches show the importance of balancing the “efficiency” element of the designed product together with the aesthetics aspect, in order to create the desired experience in the use of the product [2][3][4][5][6][7][8]. An increasing part of the researches in this field are related to the identification of the aesthetics attributes that contribute to shape the experience. In this case the work of Lenz et Al [11] is particularly meaningful because, taking inspiration from the work of Hassenzahl, distinguish between different approach to aesthetics of interaction dealing with the How-level and the Way-level [13]. It defines the How-level as “*the concrete way interactions with the material are arranged to put functionality into action*”, such as “*turning a knob, pressing a lever, using a voice command*”, and the Why-level as “*what makes use meaningful to people*”, such as “*feeling close to someone or being stimulated during a long wait*”. Together with the distinction in different levels, they explore which are the aesthetics elements that contribute to design the interaction on the how-level, by creating the so called Interaction Vocabulary, and they explore the



relationship of these attributes with the why-level, by understanding how the experience is shaped by the use of certain attributes instead of others. As the authors stated the Interaction Vocabulary can be defined as a design tool to help designer to shape the experience they imagine. In the same direction goes the work of Lundgreen [12], it looks to the same problem from the teaching perspective, trying to define a tool through which students can discuss and identify the interactive attributes related to the how-level, in order to later use them to coherently shape the experience planned. The tool identified by Lundgreen is called Physical Poets, according to this tool students design different personalities and imagine an interaction between or with them, in order to attain and later to justify the aesthetics choices applied in a successive interaction design process. In other words the design of a personality helps to identify and to justify which are the interactive attributes of the product to use in order to obtain the planned experience. The teaching experience described by Lundgreen stops at the first step, claiming that this method helped the discussion and the understanding of aesthetics logic in the interaction design process, she doesn't show the impact on the actual design output, but it looks clear the effectiveness of the method used. Together with other reasons, Lundgreen introduces the use of personalities claiming that when we deal with interaction design we deal with complex systems with an high number of variables, and linking all those variables to a inner logic (aesthetics) can became very complicate, therefore the use of personality can became a "guiding star" in the design process.

This last point is what I believe to be very relevant in the interaction design process nowadays with the development of smart objects [14]. The vision of Weiser [15], about smart environments, is becoming real nowadays thanks to the diffusion of Internet of Things (IoT) and Artificial Intelligence (AI). Objects are evolving and transforming their nature, they are not anymore steady. They are able to evolve their behaviour in time, according to the information they get from the user but also from other external sources (sensors, web, other objects). For this reason, the interaction with these objects cannot be designed assuming them as static, but should instead afforded as a dialogue evolving in time [14]. The smartness of the objects introduce a new level of complexity in the interaction design

realm which cannot be tackled only with traditional design methods based on the "efficiency" paradigm, it requires a greater use of aesthetics value, as said before. To respond to the high level of complexity we need to create a tool to contain this complexity by connecting it to a inner logic driven by aesthetics values, I believe that to design the interaction for a smart object it is useful to use personalities in order to create the inner logic to drive aesthetics choices. For this reason I will present in this paper Personality, a tool I developed to drive aesthetics values in the design process. As first I will explain the reason why I chose personalities and in the later paragraph I will go through the empirical process used to design this tool. In the last part of the paper I will present some design experience in which I used the tool.

## 2 Why Personality

In this first paragraph I would like to go through four fundamental points, which are at the base of my choice to work on personalities as a design tool.

In the design of tangible products, aesthetics is expressed in terms of form, materials, colours, surfaces. On the other hand, in the design of smart applications and systems, the aesthetic quality perceived in the fruition is significantly related to intangible formal attributes such as the mechanisms of the interactive processes, the styles of dialogue between users and objects, the cause and effects dynamics. If we take into consideration the design of traditional tangible products like a chair, during the design process often the aesthetics logic is driven by a metaphor or a set of metaphors represented as "moodboard" [16][17] or other visualisation tools. An example of metaphor can be "*this chair should be comfortable as a cloud*", this metaphor will probably drive decisions related to colours, shape, softness of the material etc. (how-level), that together will define the aesthetics of the chair itself and the consequent experience of using it (why-level). Being a chair a static object the metaphor that envision the aesthetics values is as well static (i.e. the cloud). If we consider smart objects, as we said before, we deal with reactive and proactive objects with an evolving behaviour. For this reason I argue it is fundamental to use what I call "evolving metaphors", that I identified in "personalities". If we metaphorically assign to objects a personality, we are able to envision the intangible and evolving formal attribute (how-level) of the interactive experience and we are able to design them coherently

with the experience planned (why-level).

Continuing the parallelism with the moodboard tool, I believe that a tool, designed to chase aesthetics value in the design process for smart objects, should be able to describe the constraints of the design action, but at the same time should be blurry enough to allow lateral thinking [18]. I argue that through the use of a metaphor such as personalities, we are able to synthesise design constraints and, at the same time, give space to the designer for interpretation. As Lundgreen suggests, personalities have inside their description many aspects and variables between which a designer can choose the relevant ones to drive the project [12].

The first reaction to the assignment of a personality to an object, to drive the design process, is usually seen as a mistake or at best as a big risk. I believe this is due to the negative collective image we share of objects assuming forms or behaviour strictly connected to human aspect and behaviour. This is related to the study presented by Mori [19] about what he defines as uncanny valley, in which is reported how a product, which looks like a person is perceived in a negative way by the user. I would like to underline that I intend to use personality as a design tool in the design process and not to transfer human behaviours or appearance to objects. I am aware that there can be a deviation toward a wrong interpretation of the design tool, as well as for any other design tool, and I believe to be a risk worth to take.

As last point I would like to underline that the *Personality* tool I'm going to present is completely different by the "personas" tool introduced by Cooper [20]. Personas are a tool to model a possible user in order to shape the design according to the personas identified, *Personality* instead is only related to products and it doesn't have any relationship with the user.

### 3 Personalities as a Design Tool

The process to the definition of the personalities tool went through two main steps that I will explain in the following paragraphs.

#### 3.1 The Lamp Experiment

In order to establish a platform where to experiment different kind of behaviours of a single object, I created a thought experiment (gedankenexperiment Einstein) reproducing a smart object responding to the smart characteristics defined above. The smart object created

is a smart lighting system for desk. The system is enriched with sensors related to pressure, sound and video, as described in the image below.

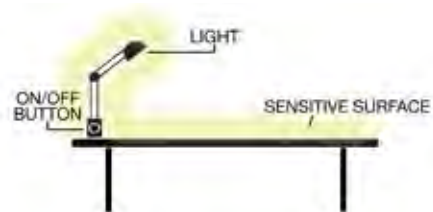


Fig. 1. Smart lighting system for desk

As first step I decided to create a lamp behaviour based on traditional paradigms of interaction, therefore I designed the behaviour according to the Aesthetics of Convenience as defined by Hassenzahl [21]. He claims that most of the products are designed with an interaction responding to usability principles. Products help users to smoothly achieve a goal, in the most convenient way, with a seamless interaction. To do so I created a prototype in which the smart lighting system is able to detect a user's behaviour and to associate it to the action of switching on or off the light. Learning from the repetition of those behaviours, the system is able to create patterns through which it controls the light when one of the behaviour happens, anticipating the user desire. This kind of paradigm is the base of many smart systems that are entering our life, such as the Nest thermostat, which learn from the repetition of our behaviours in order to control and to adjust the temperature in the environment. To explain the concept I created a video-scenario (link); a group of designers, engineers and possible users saw the video and commented it. A high level of participant claimed that the interaction with the lamp feels flat.

To explore a different user experience I decided to act on the Why-level, by planning to build a lamp able to be supportive and sympathetic in respect to the user. To work on the How-level of the interaction in order to obtain the planned user experience, I decided to apply a stereotype of personality to build an evolving metaphor. I chose what I called the "caring mother" personality, to describe the personality and the possible relationship with the user I created the semantic network [22] as showed in the image below.



Fig. 2. Semantic network relationship caring mother - child

Then I substituted the subjects of the semantic network with the lamp and the user obtaining the metaphor as described below.



Fig. 3. Caring mother personality's metaphor

Thanks to this metaphor I shaped the behaviour of the lamp on the How-level by working on the formal attribute of the interactive language, or, better, on the aesthetics of the interactive experience. The main characteristic of the new lamp is its ability to detect people's behaviour and to behave proactively in order to build an active and constructive dialogue that can evolve in time. This lamp is not functional in the traditional sense, and its behaviour is not simply guided by the aim to pander a forecasted user's need. The lamp uses the action of switching on or off the light and different levels of light intensity to communicate with the user. In some cases, as described in figure 4, the lamp does not respond to a user action, but it behaves in a self determined manner, in order to enforce the meaningfulness of the communication process. The lamp reacts to the user's behaviours in a constructive way, which we believe to be the base for a dialogue with smart object. To explain the entire user experience in the interaction with the lamp I used a video-scenario (link). I would like to underline that the use of video-scenario, in this case, was fundamental to explain the experience of interaction with the object and to underline and to give visual identity to the formals aspects of the interactive experience, which are often implicit and difficult to represent [14].



a)



b)



c)

Fig. 4. Lamp video-scenario – if a) the user is taking a rest from the work, b) the lamp switches on to communicate it is time to go back to work, but in c) the user is “kicking” the lamp to switch it off again, almost trying to translate in interactive paradigms, the sentence “come on, let me rest another 5 minutes”.

The use of the “caring mother” personality helped me a lot during the design process, it facilitated the design of the aesthetics of interaction coherently with the inner logic derived by the personality. This element is underlined by many aspects represented in the video-scenario. An example is the use of different light intensities to communicate different level of importance of the message that the lamp wants to communicate, or the different kind of reaction of the user to the lamp behaviour in order to interact with the lamp. An important gesture that came out naturally is the moment, represented in figure 4, in which the user kicks the lamp while it is asking him to go back to work, in that moment, with that kick the user seems to say: “Come on Mum! Leave me alone!”. On the other hand I think that came out clearly the need to improve the personality tool regarding two aspects. The first aspect is related to the need to chose and to design the right personality to achieve the right

experience. I believe that it complicates the process when the designer has to come out with the right stereotype of personality to use, without having a series of reference point to help out in this task. As seen in the teaching experience described by Lundgreen [12], this task requires a strong effort, which is relevant when the goal is to teach the aesthetics principles and the potentialities of the personality tool, but it can become chaotic and misleading when the goal is to apply a metaphor to obtain an inner logic. The second aspect is related to the visualization I used to represent the stereotype of personality and its relationship with the user, the semantic network. In my experience the information represented in the semantic network are too vague, this is a positive aspect because allowed me to reason and to activate lateral thinking, but at the same time I experienced problems in translating them into formal attribute of the interaction. Those two elements became the starting point to develop further the personality tool, as I will explain in the following paragraphs.

### 3.2 The identification of personalities' stereotypes

In order to respond to the first problem I decided to identify a set of stereotypes of personalities. The idea is that a designer can chose between this set the right personality to use in order to design the planned experience. To do so I took into consideration first the study by Norman [23] and then by Goldberg [24] which claim that a human personality can be described by five traits, that they call the Big Five traits of personality. The big five traits of personality are: openness to experience, conscientiousness, extraversion, agreeableness and neuroticism. Each of the five traits is represented by two opposite polar: openness to experience by the tendency to be *imaginative, independent, and interested in variety* versus *practical, conforming, and interested in routine*; conscientiousness by the tendency to be *organized, careful, and disciplined* versus *disorganized, careless, and impulsive*; extraversion by the tendency to be *sociable, fun-loving, and affectionate* versus *retiring, somber, and reserved*; agree-ableness by the tendency to be *softhearted, trusting, and helpful* versus *ruthless, suspicious, and uncooperative*; neuroticism by the tendency to be *calm, secure, and self-satisfied* versus *anxious, insecure, and self-pitying*. According to the five traits I decided to create a set of ten stereotypes

of personalities, for each personality every trait is described by one polar, and personalities are all different one from the other. After obtaining the 10 different combinations, I analyzed the personalities and according to the characteristics I gave a name to each of them, as I report in the list below.

#### **The lovable romantic – The sensitive idealist:**

Imaginative, independent, and interested in variety; organized, careful, and disciplined; sociable, fun-loving, and affectionate; softhearted, trusting, and helpful; calm, secure, and self-satisfied.

#### **The detached philosopher – The sophisticated mathematician:**

practical, conforming, and interested in routine; disorganized, careless, and impulsive; ruthless, suspicious, and uncooperative; retiring, somber, and reserved; calm, secure, and self-satisfied.

#### **The attention craver – The enthusiastic**

**partygoer:** imaginative, independent, and interested in variety; disorganized, careless, and impulsive; ruthless, suspicious, and uncooperative; sociable, fun-loving, and affectionate; anxious, insecure, and self-pitying.

#### **The beauty seeker – The impulsive hero:**

imaginative, independent, and interested in variety; disorganized, careless, and impulsive; softhearted, trusting, and helpful; retiring, somber, and reserved; anxious, insecure, and self-pitying.

**The risk taker:** imaginative, independent, and interested in variety; organized, careful, and disciplined; ruthless, suspicious, and uncooperative; retiring, somber, and reserved; calm, secure, and self-satisfied.

**The wise sage:** imaginative, independent, and interested in variety; organized, careful, and disciplined; softhearted, trusting, and helpful; retiring, somber, and reserved; calm, secure, and self-satisfied.

**The loving parent:** practical, conforming, and interested in routine; organized, careful, and disciplined; sociable, fun-loving, and affectionate; softhearted, trusting, and helpful; calm, secure, and self-satisfied.

**The charismatic leader:** practical, conforming, and interested in routine; organized, careful, and disciplined; softhearted, trusting, and helpful; retiring, somber, and reserved; calm, secure, and self-satisfied.

**The big boss – The strict regulator:** practical, conforming, and interested in routine; organized, careful, and disciplined; ruthless, suspicious, and uncooperative; retiring, somber, and reserved; calm, secure, and self-satisfied.



Fig. 5. Example of card

**The model student – The disciplined soldier:**  
 practical, conforming, and interested in routine;  
 organized, careful, and disciplined; sociable, fun-loving,  
 and affectionate; retiring, somber, and reserved;  
 anxious, insecure, and self-pitying.

In order to describe and to visualize the personalities, I created a set of cards. One personality is represented by one card, it is made of: the name of the personality; a short description of the characteristics of the personality, in which I tried to give a possible glimpse of the impact on the smart object personality; a decagon, in which is graphically represented the personality's polarization.

### 3.3 The application

In order to verify the value of the tool in the design process, I decided to ask a group of students from the Design School of Politecnico di Milano 3rd year bachelor degree in communication design, to use it during a week workshop sponsored by Telecom Italia S.p.A. The request of our sponsor was to design an app with a smart recommendation system, the goal of the app was to drive the exploration of Milan during the next Expo2015. The company proposed a database of point of interest in the city divided in five categories: food and drink, culture, shopping, accommodation and

entertainment. We agreed to design one app for each category, and that every app would have the same main feature described as follows: according to the position of the user the app should provide a number of options (1 to  $\infty$ ) regarding an X user's need (food, culture, shopping, accommodation and entertainment). The number of students participating to the workshop was 24, and we divided them in 10 groups. We assigned to each group a stereotype of personality in order to design the interaction with the app according to the given stereotype. We then assigned to each group a category of point of interest, in this way for every category we obtained two different apps according to two different personalities.

FOOD & DRINK	THE RIG BOSS	THE WISE SAGE
CULTURE	DETACHED PHILOSOPHER	SENSITIVE IDEALIST
SHOPPING	MODEL STUDENT	RISK TAKER
ACCOMMODATION	LOVING PARTNER	ENTHUSIASTIC PARTYGOER
ENTERTAINMENT	CHARISMATIC LEADER	BEAUTY SEEKER

Fig. 6. Matching between Groups of Point of Interest and Personalities

According to the given personality we asked students to act: on the how-level to shape the interaction, by taking into consideration the values proposed by the Interaction Vocabulary; on the quality, quantity and ranking of the content represented by the point of interest suggested to every user's request; on possible secondary functionalities of the app to add to the main one, such as creation of an agenda or sharing of information.

For each app students had to present as final output a description of the app, a mock-up of the interface and a video scenario to envision the interaction and the experience.

## 4 Result and Discussion

The evaluation of the experiment was based on two main factors: the quality of the student work, evaluated by a pool of professors taking part to the workshop and a pool of experts employees of Telecom Italia S.p.A.; and a questionnaire we gave to the student to evaluate the tool used.

### 4.1 Analysis of students' projects

For a matter of space I'll describe in the followings lines two projects belonging to the same category of point of interest, which were selected by professors and experts as two of the most representatives.

The project selected are *click2food* and *shakeat* both of them belonging to the food and drink category. The group with the *click2food* project was asked to design their app based on the "the big boss" personality. According to this personality, students designed an app able to respond to the user's need to find a place

where to eat, by proposing a series of steps in which the user can chose only from two options; every time that the user select one of the two options proposed, the system reduces the number of possibility to propose and at a certain point it decides to propose a restaurant where the user should go. At this point the user doesn't have an alternative, therefore s/he should decide if to agree with the app and follow the indication to reach the place or s/he can start the research again.

We agreed that the system designed responded to the characteristics of the personality used. From the visual point of view the app is simple and "skinny", the behaviour is proactive and decision maker, the interaction is direct and fast, all characteristics that can respond to the inner logic deriving by the use of "the big boss" archetype of personality.

The *shakeat* project instead is based on "the wise sage" personality. According to this personality, student designed an app to select which kind of food to eat starting from the combination of different ingredients. The app proposes a selection of vegetables and meat to chose and to combine by shaking the phone. As a result the app proposes a dish which contains the ingredients selected and it indicates also the country from which that dish belongs, plus a selection of other national cousin where it is possible to experience that kind of flavour. The app proposes to the user also a culinary itinerary through the expo pavilions to try different kind of food based on the ingredients selected.

Fig. 7. Click2food interface mock-up



Fig. 8. Shakeat interface mock-up

Also in this case the system is clearly designed following the inner logic belonging to the personality assigned to the group. The app behaviour allows the user to select among a large variety instead of giving a restricted set of options, and it motivates and explains the choice made; the interaction is more complex and dynamic, the

shaking gesture subsumes a selection between a wider set of options in respect to the single and direct “tap” used in the click2food app.

The same dynamics and design choices were observed in the other projects and groups, therefore the teaching group agreed to say that the personalities tool allowed students to envision and design compelling experience, based on an aesthetics research of the interactive aspects; students were able to go beyond traditional paradigms of interaction by reasoning on every single design choice under the “guiding star” of the personality assigned.

#### 4.2 Analysis of the questionnaire

In order to evaluate the impact of the personalities tool from the point of view of the designer, I prepared a questionnaire for the student to express their opinion; the complete list of questions, answers and percentage related to each answer can be find in the appendix 1. The questionnaire was divided in three sections. The first cluster of question had the goal to understand if the students were familiar with interaction design field in general, if they had the occasion to work with a similar tool before, if they would like to use again the tool and if the way I represented the tool was clear and understandable. It came out that most of the students were quite newbie in the field of interaction design, but the final output of the workshop demonstrated that this didn't have a big impact on the quality of the projects. Just one student declared that s/he sometimes used something similar to the personality tool in the design process. An interesting aspect is represented by the fact that more then half of the student claimed that, the way the personality is described in the card was very clear and for another 30% it was enough clear, but half of them also said that they needed to associate to the given personality a real or fictional character, in order to better visualize the personality. This element demonstrated that they needed to create an intermediate step between the personality and the product designed. I think it is an important point to work on to refine the tool, may be by improving the representation of the personality on the card through the use of evocative images or a more complex and evocative description. A positive fact that came out is that more then 80% of the students expressed the wish to use again the tool.

The second cluster focused on understanding if the tool helped the students by empowering some aspects

of the design process. Students agreed that the use of personalities helped them a lot in envisioning innovative features to add to the main feature. Almost all of them claimed that thanks to the new tool their attention to the quality of use of the app increased a lot, as well as their attention to the quality of the interaction on the how-level. More then half students said that the tool highly increased their creativity and their level of abstraction. From this answer it is possible to say that the Personality Tool had a big positive impact in the design process, and it is a valuable reason to push forward the study of the tool.

The goal of the third cluster of questions was to understand which was the main students' concern during the week project, this allowed me to understand if they were focusing their attention toward the use of the tool and if they really felt the tool as a valuable instrument. Among other concerns such as the technological feasibility, the sponsor's expectations and the coherence of their app in respect to other app with a similar goal, it came out clearly that students were mainly driven by the goal of designing a pleasurable interaction and by the coherence with the personality assigned.

#### 5 Conclusions

In this paper I underlined the phenomenon of an aesthetics research in the realm of interaction design, this new paradigm, defined as aesthetics of interaction, is emerging with the goal to balance the “efficiency” paradigm which is recognized to be the main driver in interaction design. This element is even more important nowadays with the emerging of smart products given the nature of this kind of products. While the definition and description of aesthetics of interaction is well discussed in literature, I experienced a lack of design tools to explore the new paradigm during the design process. After analysing two of the main tools found in literature, I decided to propose Personality a design tool empirically developed to chase an aesthetics approach for the design of smart products. In my research I identified personality as an evolving metaphor to apply to smart objects, the metaphor allows to picture an inner logic (aesthetics) that will drive the design choices. In this sense I made a comparison between the Object's Personality and the moodboard or other form of visualization, which are used in product or fashion design to describe aesthetics references. After a first step in which I used a first draft of *Personality*,



I developed further the tool and I decided to test it during a week workshop with design students. In this occasion the tool proved to be very helpful during the design process, it allowed student to reason about the interactive attributes of the products and to design a coherent experience. The tool presented in this paper is still a work in progress, which needs to be refined according to the outputs explained in the result and discussion paragraph and tested in different situations. Regarding this, I would like to underline that during the workshop the students weren't allowed to chose the personality to use in their project, because the goal was in general to test the validity of the tool in shaping and driving the design choices. As a further step I would like to test the tool in a more realistic situation, in which the designer as first step specifies the experience s/he wants to design and later s/he chooses the right personality from the set proposed in the *Personality* tool, in order to be guided in the design of the planned experience.

## 6 Acknowledgements

This work was partially supported by the Joint Open Lab "S-Cube" - Telecom Italia S.p.A. – Innovation division, Italy. I would like to thank the student of the School of Design – Communication Design division at Politecnico di Milano, which took part to the “Beyond Simplicity” workshop sponsored by telecom Italia S.p.A. My gratitude goes also to professor Marco Maria Maiocchi, professor Margherita Pillan and Anna-maria Andrea Vitali who were part of the teaching team in the same workshop and that gave me significant advices on the research.

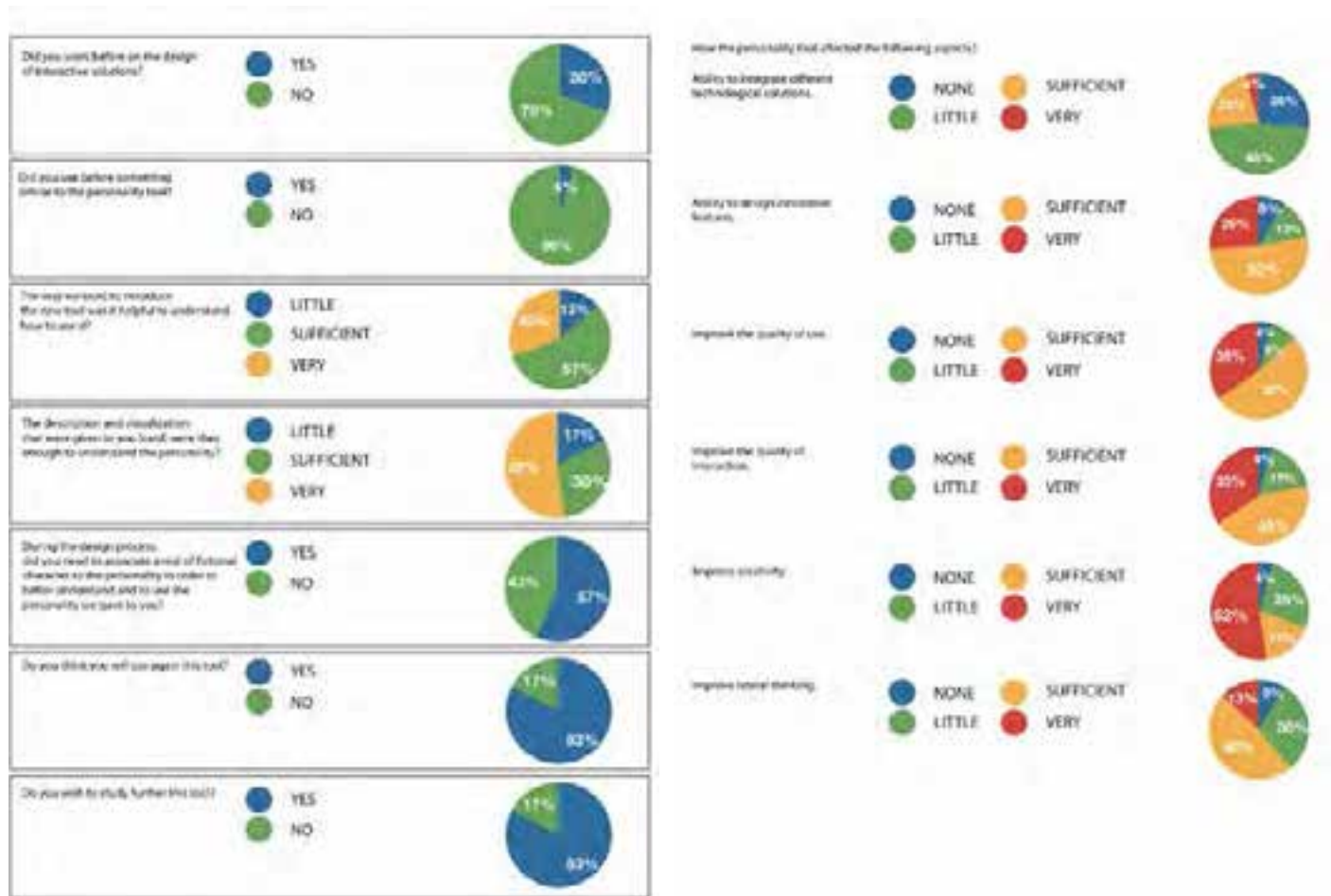
## References

1. Norman DA (2007) The Design of Future Things. Hum Factors Ergon Manuf 18:232. doi: 10.1002/hfm.20127
2. Fiore SG, Wright P, Edwards A (2005) A Pragmatist Aesthetics approach to the design of a technological artefact. Proc 4th Decenn Conf Crit Comput between sense Sensib - CC '05 129–132. doi: 10.1145/1094562.1094581
3. Folkmann MN (2010) Evaluating Aesthetics in Design: A Phenomenological Approach. Des Issues 26:40–53. doi: 10.1162/desi.2010.26.1.40
4. Bardzell J (2009) Interaction criticism and aesthetics. Proc. 27th SIGCHI Conf. Hum. Factors Comput. Syst. pp 2357–2366
5. Locher P, Overbeeke K, Wensveen S (2010) Aesthetic Interaction: A Framework. Des Issues 26:70–79. doi: 10.1162/DESI\_a\_00017
6. Hummels, Caroline, Philip Ross CJO (2003) In search of resonant human computer interaction: Building and testing aesthetic installations. Hum. Comput. Interact. '03
7. Lim Y, Stolterman E, Jung H, Donaldson J (2007) Interaction Gestalt and the Design of Aesthetic Interactions. Art Des 22–25. doi: 10.1145/1314161.1314183
8. Lowgren J (2009) Toward an articulation of interaction esthetics. New Rev Hypermedia Multimed 15:129–146. doi: 10.1080/13614560903117822
9. Lim Y, Lee S, Lee K (2009) Interactivity Attributes : A New Way of Thinking and Describing Interactivity. CHI'09 Proc. SIGCHI Conf. Hum. Factors Comput. Syst. pp 105–108
10. Djajadiningrat T, Matthews B, Stienstra M (2007) Easy doesn't do it: Skill and expression in tangible aesthetics. Pers. Ubiquitous Comput. pp 657–676
11. Lenz E, Diefenbach S, Hassenzahl M (2013) Exploring Relationships Between Interaction Attributes and Experience. Proc. DPPI 2013. pp 126–135
12. Lundgren S (2008) Treating and Teaching Aesthetics as Personality. Nord. 2008. pp 511–514
13. Hassenzahl M (2010) Experience Design: Technology for All the Right Reasons. Synth Lect Human-Centered Informatics 3:1–95. doi: 10.2200/S00261ED1V01Y201003HCI008
14. Spadafora M., Vitali A.A., Pillan M. (2015) Objects are not slaves. Envisioning an Aesthetic Approach to the Design of Smart Objects. In proceeding of the Cumulus conference "The Virtuous Cycle"
15. Weiser M, Gold R, Brown JS (1999) The origins of ubiquitous computing research at PARC in the late 1980s. IBM Syst J 38:693–696. doi: 10.1147/sj.384.0693
16. Garner S, McDonagh-Philp D (2001) Problem Interpretation and Resolution via Visual Stimuli: The Use of “Mood Boards” in Design Education. Int J Art Des Educ 20:57–64. doi: 10.1111/1468-5949.00250
17. Lucero A, Martens JB (2006) Supporting the creation of mood boards: Industrial design in mixed reality. Proc. First IEEE Int. Work. Horiz. Interact. Human-Computer Syst. TABLETOP'06. pp 127–128
18. De Bono E (1970) Lateral Thinking: A Textbook of Creativity. Penguin Books 3:6 – 30.
19. Mori M (1970) The Uncanny Valley. Energy 7:33–35. doi: 10.1162/pres.16.4.337
20. Cooper A, Reimann R, Cronin D (2007) About Face 3: The essentials of interaction design. Inf Vis 3:610. doi: 10.1057/palgrave.ivs.9500066
21. Laschke, M. Hassenzahl, M. Diefenbach S (2011) Things with attitude: Transformational Products. Creat. Conf. pp 1–2



22. Maiocchi M (2015) The Neuroscientific Basis of Successful Design. Springer
23. NORMAN WT (1963) Toward an adequate taxonomy of personality attributes: replicated factors structure in peer nomination personality ratings. J Abnorm Soc Psychol 66:574–583. doi: 10.1037/h0040291
24. Goldberg LR (1990) An alternative “description of personality”: the big-five factor structure. J Pers Soc Psychol 59:1216–1229. doi: 10.1037/0022-3514.59.6.1216

## Appendix 1 – Questionnaire questions and answers



# Play design and sense-making: players and games as digital interactive contexts for effects of sense

## Abstract

Exploring how meaningful experiences are addressed through digital interactive artefacts, this research investigates how design choices and techniques impact on emerging interactive experiences supporting *effect of sense*. *Effect of sense* is a semiotic phenomenon emerging between the perception of a designed product and the final receivers [1]. While it has been deeply explored for material product and tangible features [2], this paper investigates how the intangible dimension of digital interactive experiences mediates *effect of sense*. The focus is on digital interactive artifacts that enable meaningful play experiences [3], beyond traditional forms of entertainment and engagement that consider game void boxes without value and ideologies within. The paper advances this approach questioning in how many ways it is possible to enable *effects of sense* designing interactive processes, sensorial and perceptive features of games. This objective is driven by the emerging trend that shifts the attention towards digital representations and interactive contexts potentially carrying senses - and meanings - overcoming the conventional interpretation of meaningful play as prepackaged experiences decided by the designer *a priori*. The paper presents a selection of games as case study to enlighten the design dimensions and the techniques employed, in order to validate our hypothesis and set the basis for a design framework that moves from the wide concept of meaningful play to the design of interactive experiences based on sense-making processes.

## Keywords

Play design, meaningful play, effect of sense, interaction design.

## 1 Introduction

The paper introduces a new perspective to the design of digital interactive artifacts that enable meaningful play experiences. Starting from Salen and Zimmerman [3] definition of meaningful play as the experience emerging from the relationship between players input and feedback received, prior researches [4][5][6][7] investigated the rhetorical value of play experience beyond the traditional pattern of engagement as defined by the entertainment industry. Indeed, an increasing number of games and experiments have been designed to investigate the expressive potential of digital representation in transferring ideas and visions. The resulting digital games provide players novel interactive experiences that experiment at different degree with all the design dimension of a game. The games presented through the paper guided our exploration to identify the interactive techniques and the languages that contribute to the emergence of meaningful play. Although it is very common to use the words “meaningful play”, very few researches have tried to formalize the different techniques designers use as a “grammar” to design what they defined as meaningful. The objective of this research is to set the basis for the definition of a design framework that describes the relationship between

interactive, perceptive and sensorial effects and the emerging sense making processes enabled through the play experiences. Through the paper, this approach requires to focus the attention from the concept of meaningful (play) to *effects of sense* (and sense making processes). To better frame the perspective of this paper, I refer to Krippendorff's definitions of senses and meanings [8]. According to Krippendorff [8] "sense is the feeling of being in contact with the world without reflection, interpretation, or explanation. It involves all senses: seeing, hearing, touching, tasting, smelling, and even the kinesthetic sense." Thus senses and sense making processes are the background of meaning that indeed "restores perceived differences between what is sensed and what seems to be happening." Following this definition meanings - and meaningful experiences - emerge from the relationship between sense(-making processes) and the context of interaction, in my case. Thus, this paper investigates how through the language of interaction, interactive dynamics and behaviors, formal attributes of digital games the designer can elicit interpretative processes in players, before to focus on specific meanings and messages. Before to start the analysis of the games, the next paragraph reframes the definition of play experience in order to understand better the relationship between games, play, interactive experience and *effect of sense*.

## 2 Theoretical Foundation

### 2.1 Play: a perspective about digital representation, interactivity and effect of sense

For the purposes of the paper play is defined as an interactive process between the players and the elements of the game – rules, setting and representation [9]. Considering interactivity as the intrinsic characteristic of play underlines the perceptive and cognitive aspects of play and the dimension of signification [10] made by players on the base of the information and signs perceived. As stated by Ware in [11] indeed perception, interaction and cognition are three dimensions of a same complex process that drive our interpretative processes: "Seeing is all about attention, and when we interact with an information display, such as a map, diagram, chart, graph, or a poster on the wall, we are usually trying to solve some cognitive problem" [11]. This approach allows exploring the potentialities of digital interactive representations in games from the perspective of generation of sense

by players through the interactive system of signs and perceptive dimensions that characterized the games. According to some cognitive theories indeed every time we interact and perceive world representation (such as digital games) we are immerse in a process of coding/decoding of information received, trying to establish a connection with our previous knowledge or giving sense to the new information received [11][12]. For this reasons we agree with Manovich's [13] definition of interactivity as not only physical but also psychological: despite the type of artifact we are interacting with, we are always trying to recall previous information, reordering knowledge or filling in the missing one. Giving the above assumption, play design is a design action on senses emerging through the interactive experience of play. In semiotic effect of sense is a phenomenon enabled by the designer through a *product of sense* (the interactive artifact in our case) [1], and tied for definition to the knowledge build on the perceptual level [14]. Sense making, for example, is that cognitive process that allows us to recognize the form of an animal in a cloud. How are effects of sense elicited through the design of play experiences? The paper will reframe the concept of meaningful play investigating the different ways an interactive process could support the process of making-sense acting on cognitive and perceptual levels through formal attributes of interactions. In more detail the perspective we are adopting is that one of interpreting the players as a reader and the designer as a writer. As the *second level reader* defined by Eco [15], the main idea beside our interpretation of meaningful play, is that the designer is like a writer providing the "interactive" text through which the reader can establish, connection and interpretation. However since the designer can't actually foresee how every player will interpret the game, by defining the interactive system and the dimension of the game, she/he is providing the context for the experience to emerge.

In next paragraphs I will analyze a selection of video games explaining how meaningful play has been afforded by game designers.

## 3 From play to meaningful play

When games and play started to be considered for their expressive potentialities granted by interactivity and the idea that "doing means also understanding" [4], a number of researches from digital humanities and

game studies have started to focus their attention to meaningful play and the use of games beyond traditional forms of entertainment. Describing games as digital and interactive representation means to not only focus on games as a conventional system of rules for engaging players, but more as an interactive context containing instructions and that requires players to establish a connection between the information received beyond pure engagement and entertainment purposes, thus play becomes meaningful play. In our collection of case study we focused on some specific type of games, mostly experimental and/or designed by independent game designers. This choice is guided by the fact that it is in this type of games that experimental play has been mostly explored instead of responding to the traditional objectives of the entertainment industry. The preliminary framework outlined at the end of the paper tries to formalize and derive some best practices from an ongoing process of experimentation, to understand in a broad sense how we can design interactive artifacts that elicit effects of sense and are meaningful, while defining formal and aesthetics attributes of interactive experience.

To develop this preliminary framework I analyzed five different games – *The Marriage*, *Passage*, *Proteus*, *Portal*, *Luxuria Superbia* – that provide meaningful play experiences acting on different formal dimensions of the game.

### 3.1 The Marriage

The Marriage by Rod Humble (<http://www.rodvik.com/rodgames/marriage.html>) is an experimental prototype in which game designer's feel about the marriage is translated into an interactive system: every interaction with and among the game elements is designed to digitally "retrace" the interplay between two partner, their reciprocal needs and behaviors in respect to each other and the external world. The two "characters" of the game are two colored square (pink and blue) representing the two sides of the marriage and moving slowly within a fixed area (Fig.1). External "forces" to the relationship are represented by grey and black circle. The objective of the player is to interact with the graphic avoiding or allowing certain interaction to happen between the two squares and the circles, in order to preserve the life of the two squares, in fact, the existence of the marriage. Following the instruction given by the game designer, here it is how the game uses the interactive process to retrace how the marriage

works for the designer: "You have two controls. 1) When you mouse over the blue or pink square the blue square reduces in size and both squares move towards each other. 2) When you mouse over a circle it disappears and the pink square gets smaller. When the edge of the blue square collides (or "kisses") with the edge of the pink square (but not when they overlap): the blue square shrinks slightly and becomes more transparent. The pink square grows slightly and becomes less transparent. When the blue square touches any coloured circle but black then the blue square becomes less transparent and grows in size to a significant degree. When the pink square touches any coloured circle but black then the pink square grows in size slightly. When the pink or blue square touch a black circle they shrink significantly. As time passes the pink square becomes more transparent. When squares collide with things then a white bar at the bottom of the screen increases in size. When either the pink square or blue square shrink to nothing or become totally transparent then the game is over. The general game flow will be balancing the need to have the pink & blue squares "kiss" to insure the pink square does not fade from the marriage versus the blue square needing to touch the circles to insure it does not fade."

Despite the player can share or not the view proposed by the designer, this is an example of how designing a system in which the effects of the decisions of player are evident should support interpretative processes. Indeed, the author affirmed that: "The game was created to be played, to be enjoyed by each person exploring the rules and how it related to their own life" (<http://www.rodvik.com/rodgames/marriage.html>).

Fig. 1. The Marriage, interface: the two squares represent metaphorically the two side of the relationship, while the grey and the black circles the external forces



From designer's perspective the statement is clear: he designed the interactive system planning exactly how the player should play and which are the consequences – and the implicit meanings - of every player's decisions. It is a prepackaged play experience that we can define meaningful as it is aimed at delivering a specific message to players.

The game is valuable for the purposes of this paper because it explores different design dimensions of the game: 1) expressiveness of the interactive process (later explain in this paper as *procedural rhetoric* [6]); 2) metaphors; 3) absence of sounds and music. With the expressive power of interactive process, we are referring to the use of game mechanics to reproduce and explain a situation, a context or a system during the play experience. The designer expresses his point of view or a vision about a situation and a system by digitally translating it. Through the play experience players experience situations, controversies and life issues. As a matter of the fact, procedural rhetoric has his foundation in mechanics and rules considered as a peculiar dimension of games. Their consumption process differs from other type of media and this makes them more effective in persuade or deliver a message. Procedural rhetoric was defined by Bogost [6] as the possibility to explain how a system works and deliver information through game mechanics and modeling the system of rule assembled together in order to evocate a real system: "[...] an argument made by means of a computer model. A procedural rhetoric makes a claim about how something works by modeling its processes in the process-native environment of the computer rather than using description (writing) or depiction (images)."[16]

Thus according to proceduralist, meaningful play emerges through the correspondence between the interactions made possible in the game, the interactive process which is build over time, and the adherence to directly or metaphorically evoke the real life or the context the designer want to suggest or criticize. The marriage is a fully exploration of this approach indeed the decision to use the metaphors of two squares is justified by the conviction that rules and mechanics are strong enough in tracing a system. The use of a graphical metaphor actually could be ambiguous: even if it could be intriguing and it elicits the sense-making process of players, on the other side it

could be that the players don't get designer's statement. In the end a final consideration has to be done for the absence of sound and music. As we will see in other examples, the presence of sounds could be useful in the construction of the play experience, here their absence is aimed at driving the attention to mechanics and their implicit meaning as defined by the designer.

### 3.2 Passage

*Passage* is an experimental video game by Jason Rohrer (<http://hcsoftware.sourceforge.net/passage/>). In this video game the player experiences a male character lifetime as a linear process: the player can only move the character from left to right, or up down to explore the space constrained in a small rectangular portion of the screen (Fig. 2). While the character is moving in the space, he can collect treasures until he finally meets a female character. If you decide to touch her, the two characters start their journey moving together within the game space, even if the relationship makes the collection of treasures tougher. Meanwhile, time passes and both the characters get older, until at the end of the game they both die.



Fig. 2. *Passage*, interface: the linear frame and the two characters moving together

*Passage* expresses and investigates metaphorically the human condition. Effect of sense here is tied to the following dimensions: 1) interaction possibilities; 2) storytelling and metaphors; 3) time dimension;. Interaction possibilities refers to the actions made possible to the players within the game world. In *Passage* they are limited (in respect for example to The marriage) but enough to describe metaphorically the lifetime condition. Together with the metaphor of the linear journey where you can encounter treasures and people, the limited interaction is designed to evoke what actually is our "passage" in our life: a moment framed between a start and an end, through which different things may happen, but we can experience only a small part of them. Indeed, it is possible to play

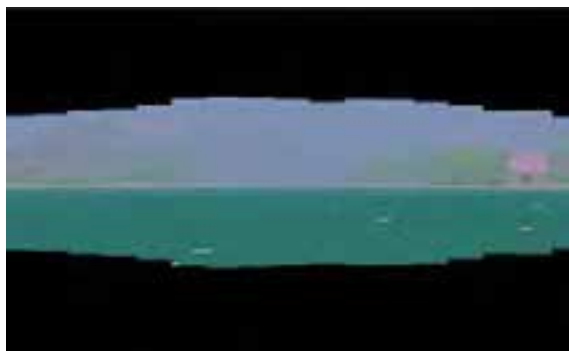
the game different times deciding if play alone or with the female character making experience of two totally different life. Another dimension that contributes to storytelling is time: while you move the character in its limited pixel world time passes, you get older and you can't escape from your destiny, death.

### 3.3 Proteus

Proteus (<http://www.visitproteus.com/>) by Ed Key and David Kanaga is a “game of audio-visual exploration and discovery” in an open world in which the interactivity consist only in exploring and adventuring from a first person perspective a unique world, a dream-like island drawn in pixel art that change every time it is played (the game world is procedurally generated). The game starts with you opening eyes (Fig.3a) finding yourself in the middle of the sea. On the horizon you see an island from which some sounds and music seem to come. When you decide to approach the island, you discover a colored world to explore (Fig. 3b), without any specific instruction. There is no interactivity with game elements, as for example animals you can casually encounter run away. The sounds change according to player's position, it is silent at the top of an hill, or richer of effects within the hill. There are no instruction on how to move or proceed, unless when during the night, as time has passed, some flashing lights detach player's attention. Moving within the lights the player passes to the next “season”. Each island differs from the previous one, changing slightly as it happens in real world from spring to summer, from summer to autumn, from autumn to winter. The changes regard sounds, as well also graphical mood. The end of the game is different every time, and in the end you finally close your eyes.

Like in *Passage*, effect of sense here is tied to few interaction possibilities (the primary means of interaction is simply your presence in the world) even if this time there is no any constraints in terms of objective or time: the player can only walk and move in the landscape, or sit down, like taking a rest, and look around without any specific goal, in a meaningless way, because there aren't game elements to interact with. In this example every player is free to interpret the play experience. We can compare the minimal interactive techniques to the art of “hesitation” of some literary works, defined by Eco [15] as the decision to stop the narration and introduce description paragraph o leave something incomplete in order to elicit readers' curiosity or open the possibility of imagination and interpretation of future actions. The perception is that you are playing a game that is saying: “So what to do?” I think this is what happens in *Proteus*: instead that having a clear message or a statement reflected in a strict system or rules, the designer is providing an interactive context, an experience of exploration that has it sense in its apparently nonsense and un-interactivity. Exploring this dimension of no-interactivity, the effect of sense is left to the player. For its definition as audio-visual exploration game graphical and sound style play a key role in providing an intriguing aesthetic experience. The surrounding landscape and its inhabitants creates the sounds and the music that change accordingly to the season you are exploring, becoming even slower and silent in autumn and winter. A second dimension affecting the play experience is the variable of time. While exploring the island time passes from day to night, and from a season to another one, contributing to the perception of a story to be discovered and interpreted.

Fig. 3. Proteus: a) opening scene; b) landscape of one islands



The examples analyzed until now are at two opposite sides: from one side there is the exploitation of well defined mechanics and procedures and clear designer's statement, on the other one, the reduction of interactivity at its minimum without a clear meaning. In the next paragraphs, we will see two other types of games that explore effect of sense focusing more on perceptive experience.

### 3.4 Portal

*Portal* (<http://www.valvesoftware.com/games/portal.html>) by Valve software, is an hybrid between a first person shooter and a brain teasers: players must solve physical puzzle, opening portals, moving objects through the portal in ways that are usually impossible and that subvert common gravity rules (Fig.4).

In this case the interestingness of the game is granted by the experimental gameplay based on solving perceptual puzzle requiring the player a cognitive effort to make "sense out of noise". The controversial and surreal way the objects and the player move towards the portals supports that natural activity of our brain to find sense where everything seems senseless and controversial in respect to our previous mental models [17] [18]. In *Portal* there is no a message or a statement expression by the designer, however it enlightens a gameplay technique that is interesting for the player for itself and for the pleasure of solving a puzzle picture like it happens for optical illusions. Our brain is constantly

pushed between two or more possible but incoherent visual solutions, and this is considered more alluring for our brain, that a one-way explicit solutions [17]. *Portal* explores the dimension of visual perception introducing unexpected cause-effect reactions that contrast with previous players' knowledge. Exploring this dimension grants effect of sense tied to the constant tendency to find coherence in an interactive representation while applying our previous experience of the world.

### 3.5 Luxuria Superbia

*Luxuria Superbia* (<http://luxuria-superbia.com/>) by Tale of Tales is defined by its authors as a "simple game of touch, pleasure and joy made for fingers on touchscreens and joysticks on computers. *Luxuria Superbia* is a musical journey from the sensuous to the spiritual. Exciting designs explode from your gestures as you glide through tunnels, beautiful as flowers. It's all about the experience and the interaction." *Luxuria Superbia* is an artistic and emotional game: it is based on the metaphor of a garden, where you play with 12 different flowers-like tunnels. The game clearly evokes its sensual nature. The player has to color every flowers by "caressing" the "petals" while in same time satisfy the request of the flower, paying attention to the feedback received by the flower itself: colour intensity changes, increasing soundtracks, descant hums and sigh, or the text occasionally appearing on the screen ("touch me", "keep going") (Fig.5).

Fig. 4. Portal, an example of controversial situation through the opening of the portal

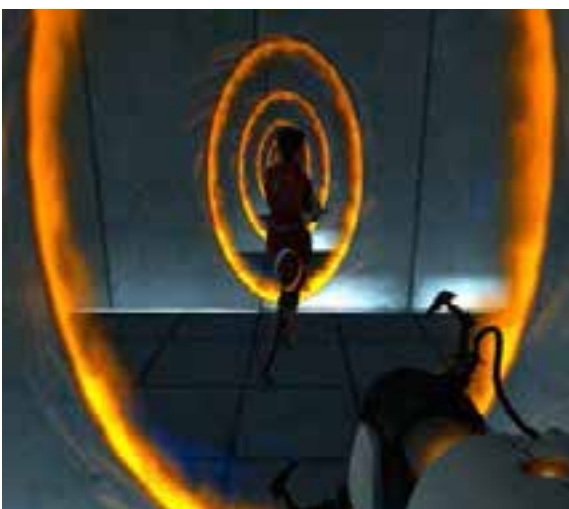


Fig. 5. Luxuria Superbia, one of the flower to color and the feedback text





The effect of sense here derives from the way you interact with the screen. The modality of interaction – the metaphorical act of caressing the flowers – contributes clearly to the effect of sense because there is continually a dialogue between player's way to caress the flower (fast, slow etc) and the feedback received. More the player is able to interpret the feedback received and to adjust his actions, more the result will be higher and the flowers will be satisfied.

The effect of sense would probably not be the same in other ways, and this is the reason why it works very well on touchscreen devices. In this case the design of interactions modality, plus coherent sounds and visual effects was effective in creating a play context that becomes meaningful as it glues to previous players experience and knowledge. Here the sense effect is supported by the capability to recall through interaction something already known by players, while creating the digital interactive context to play with this knowledge.

*Portal* and *Luxuria Superbia* are designed to produce effect of sense exploring different design dimensions and also two different ways to produce effect of sense. While in *Portal* the interactive system is designed to be controversial in respect to previous mental model, introducing and requiring the acceptance of new knowledge, in *Luxuria Superbia* the effect of sense is driven by the capability to recall previous information and make player experience it through the digital representation.

## 4 Results and Discussion

### 4.1 Describing meaningful play

This analysis allows deriving some design guidelines and reflections to better frame the relationship between formal dimensions of the play experiences and the “effects of sense” produced. Considering the limited number of case study presented, this is a preliminary contribution to be further expanded in future researches.

The preliminary results enlighten a novel conception to the design of meaningful play making a step back and framing the problem around the sense making process activated in players and on the effects of sense carried by the way we interact with the game and its formal dimensions. Indeed, different interactive languages are employed reflecting different approaches towards the formal dimensions of games and their meaningful use, while also reflecting different ways game designers

interpret their roles towards players' experience. Interpreting the design action as the process to create products that are not only material and formal dimensions but also senses and meanings [14] [21], designing games means to design interactive spaces, contexts, and play experiences that carry information used and interpreted by final players.

Through the paper five main design aspects of games were outlined:

*Procedural rhetoric*: the use of rules and mechanics to retrace and explain a system and deliver a message, a perspective, a point of view on specific topic and real issues. The interactive process is designed to evoke a specific context and interactive dynamic, and creating new knowledge connection in players.

*Metaphors*: graphical language or interactive processes retrace abstract and intangible concepts for “understanding and experiencing one kind of thing in terms of another.” [19] For our purposes metaphors are useful as the translation of concepts between two different fields contribute at eliciting effect of sense every time players try to establish a meaningful connection between their preexisting knowledge and the metaphorical contents experienced through the game.

*Interaction possibilities and Interaction modalities*: the interactions made possible through the game affect the number of ways players can interact with the game world and thus receiving more or less information by interacting with it. In some games, especially in the case of procedural rhetoric interaction possibilities are more complex and aimed at the construction of sense by the players through the system of interaction. In other game, like *Proteus* indeed, interaction possibilities are reduced at their minimum, and the effect of sense arise from the absence of a clear sense behind the minimum possible actions, as well as other dimensions of the game (like sensorial effects, time and storytelling). Together with interaction possibilities, interaction modalities define the formal aspect of interactions, the “how” [20] you interact with game elements. In *Luxuria Superbia* for example, the way you interact with the flowers contributes to the effect of sense in significant way, as it directly evokes a specific context and situation. The type of action itself carries the meaning.



*Sensorial and perceptive effects:* exploiting the multisensory features of digital games, play with sensorial and/or perceptive effects can act as reinforcement to the interactive experience. In *Proteus* or *Luxuria Superbia* we have seen how sounds and music aren't only "cosmetic features" but reinforce the sense of some actions made by player, as they change accordingly to players input and movement within the game. In *Portal* conventional perceptive experience is subverted requiring players to interpret and adapt to the novel reference system.

*Perception of Time and Storytelling:* the final dimension is time. In some games, like *Passage* or *Proteus*, the dimension of time is fundamental as it contributes to the perception of a narration within the game and thus the possibility for the player to look for a sense in the interactive process in respect to the time that passes.

Finally, the different uses of these strategies allows also to map the games in a matrix according two main axis:

- A. Meanings/Senses: how much the play experience is constrained to specific meanings (rhetoric) or sense-making (dialectic): if from one side there are games designed to deliver a specific experiences (through for example procedural rhetoric – *The marriage*, *Passage*), from the other one there are games that activate a dialectic relationship with the player, leaving a higher degree of freedom in the process of interpretation (*Proteus*).
- B. Recalling knowledge/Subverting knowledge: the paper identified how different interactive techniques in a game could glue to previous players' knowledge in different ways. From a cognitive perspective, the effect of sense plays with our previous experience: recalling previous information, subverting previous knowledge and introducing new knowledge connections.

## 5 Conclusion and future research

In conclusion the contribution of the paper is to approach meaningful play not only as the possibility to convey clear messages to players, but more as the design of interactive experiences for "effect of sense". This change of paradigms has two main consequences. First of all the process of interpretation of players is the focus of the play experience. This means that if from one side the designers can not foresee exactly how the

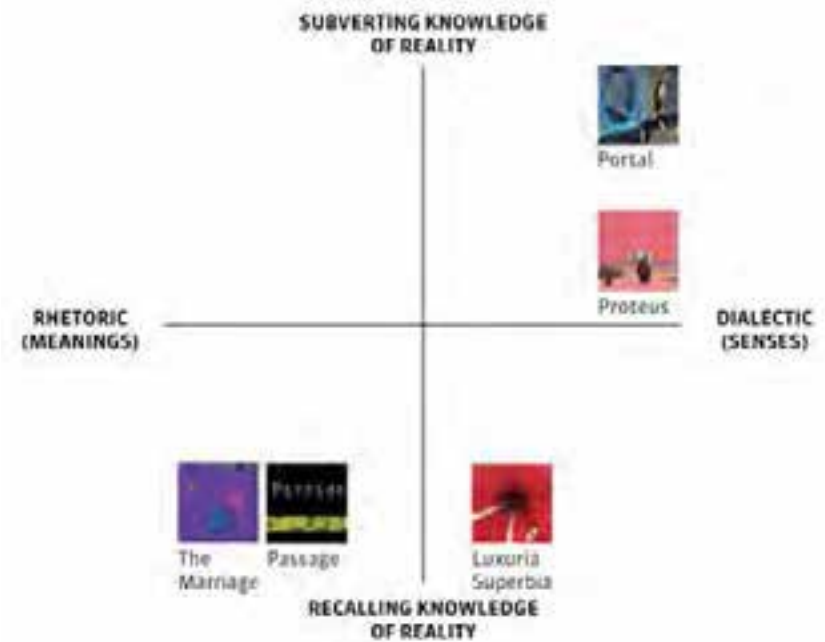


Fig. 6. Map of the games analyzed

experience will be perceived, from the other side it is their responsibility to investigate and become aware of the potential meanings and sense making processes activated by the interactive languages of digital product through the intangible dimensions of play. In second instance the contribution of meaningful play as activator of effect of sense is useful to open a discussion around an emerging field of interaction design in which interactive experiences mediated by digital technology based artefacts have started to be considered as something more than a void box for entertaining or solving needs.

Future researches will expand this initial framework by analyzing other type of games and refining the definition of the different interactive techniques found until now.

## Acknowledgements

This work was partially supported by the Joint Open Lab "S-Cube" – Telecom Italia S.p.A. – Innovation Division.

## References

1. Zingale, S.: *Gioco, dialogo, design. Una ricerca semiotica*, Milano, ATi Editore, pp. 9-10 (2009)
2. Gatti, E., Bordegoni, M., Spence, C.: *Investigating the influence of colour, weight, and fragrance intensity on the*

- perception of liquid bath soap: An experimental study. *Food Quality and Preference*, Vol. 31, pp. 56-64, Elsevier (2014)
3. Salen, K., Zimmerman, E.: *Rules of Play: Game Design Fundamentals*. Cambridge MA, The MIT Press (2004)
  4. Frasca G.: *Play The Message, Play, Game and Videogame Rhetoric*. PhD Dissertation, IT University of Copenhagen, Denmark (2007)
  5. Rusch D.: *Mechanisms of the Soul: Tackling the Human Condition in Videogames*. In *Proceedings from DiGRA* (2009)
  6. Bogost I.: *The Rhetoric of Video Games*. In K. Salen, edited by, *The Ecology of Games: Connecting Youth, Games, and Learning*. The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press, pp. 117-140. doi: 10.1162/dmal.9780262693646.117 (2008)
  7. Gualeni S.: *Augmented Ontologies or How to Philosophize with a Digital Hammer*, *Philosophy and Technology*, Vol. 26 (2) Springer Science+Business Media Dordrecht, DOI 10.1007/s13347-013-0123-x (2013)
  8. Kipperndorff, K.: *The Semantic turn: a new foundation for design*, CRC Press Taylor and Francis Group (2006)
  9. Pichlmair, M.: *Designing for Emotions – arguments for an emphasis on affect in design*. PhD dissertation, Technischen Universität Wien (2004)
  10. Laurel B.: *Computers as theatre*. Reading, MA.: Addison Wesley (1991)
  11. Ware C.: *Visual Thinking for Design*. Morgan Kaufmann (2008)
  12. Dewey J.: *Logic: The Theory of Inquiry*. H. Holt & Company, New York (1938)
  13. Manovich L.: *The Language of New Media*. Cambridge, MA: The MIT Press (2001)
  14. Bianchi, C., Montanari, F., Zingale, S. (edited by): *La Semiotica e il Progetto 2. Spazi, oggetti, interface*. Franco Angeli, Milano (2010)
  15. Eco, U.: *Sei passeggiate nei boschi narrativi*. Harvard University, Norton Lectures 1992-1993. Tascabili Bompiani, Milano (2003)
  16. Bogost, I.: *Persuasive games: The proceduralist style*. Retrieved online on 8th February 2015 [http://www.gamasutra.com/view/feature/132302/persuasive\\_games\\_the\\_.php](http://www.gamasutra.com/view/feature/132302/persuasive_games_the_.php) (2009)
  17. Zeki, S.: *La vision dall'interno, Arte e cervello*. Bollati Boringhieri, Torino (2003)
  18. Ramachandran, V. S., Hirstein, W.: *The science of art: A neurological theory of aesthetic experience*. *Journal of Consciousness Studies*, 6.6-7: 6-7 (1999)
  19. Lakoff, G., Johnson, M.: *Metaphors we live by*. University of Chicago press (2008)
  20. Lenz, E., Diefenbach, S., & Hassenzahl, M.: *Exploring relationships between interaction attributes and experience*. In *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces* (pp. 126-135), ACM (2013)
  21. Kazmierczak, Elzbieta T.: *Design as meaning making: from making things to the design of thinking*. *Design Issues* 19(2) (2003): 45-59.

### Game References

- The Marriage, Rod Humble (<http://www.rodvik.com/rodgames/marriage.html>)
- Passage, Jason Rohrer (<http://hcsoftware.sourceforge.net/passage/>)
- Proteus, Ed Key and David Kanaga ([www.visitproteus.com](http://www.visitproteus.com))
- Portal, Valve Software (<http://www.valvesoftware.com/games/portal.html>)
- Luxuria Superbia, Tale of Tales ([www.luxuria-superbia.com](http://www.luxuria-superbia.com))

# Examining Sensorial Interfaces as the Stimuli for Remote Affective Communication

## Abstract

Current communication technologies have a significant role in providing and maintaining social connections and networking, but have not yet been developed to entirely support interpersonal communication, especially in creating and maintaining intimacy and a sense of connection in an intimate relationship, specifically between young adult children and their older parents. Under the emerging trend of ubiquitous computing, this study examines the possibility of creating new means of augmenting intimacy in remote affective communication between young adult children and older parents. From a small target group, this exploratory study rooted in family communication activities and family life is exploring the possible themes, cues and artefacts that support family closeness but may be missing in conventional communication (audio and video). By generating a group of concepts and new tools for remote family interaction, the findings of this study offer insights into new means of communication tools for supporting family connectedness.

## Keywords

Affective communication, remote intimacy, wearable technology, interaction design research, sensory enhancement.

## 1 Introduction

The demands of modern life require, more often than

not, that adult children move away from their parents and extended family for various reasons, such as continued education, work or to establish a new family creating a new social phenomenon marked by physical separation and modifying the traditional dynamics between young adult children from their parents [5]. The first consequence of this voluntary separation is the reduced contact with and time spent by family members together, creating a larger disconnect between children and parents, a loss of awareness of each other and the loss of a sense of natural intimacy [1, 18]. Due to the development of communication technologies in this information age, a variety of digital devices, instant messaging and social networking services have emerged that support family communication and interaction on a daily basis. Nowadays digital information transfer is the dominant form of communication (e.g. digital text, audio and video etc.) [4]. People use phones, texts and emails to communicate more frequently and with ease, compared to writing old-fashioned letters. Willis [15] notes that mobile devices are “best suited to support the sharing of personal information such as emotional states”. In addition, wearable computational artefacts [7] such as clothing, jewellery and other accessories have been shown effective for supporting intimate interactions. Jewellery can provide a meaningful interface to meet people’s social, emotional, and aesthetic needs [8]. Compared to other devices and objects, jewellery has

more intimate and portable properties, being nestled closely to people's bodies.

However, current technologies might not be fully developed to support affective communication across distances [12, 15, 16]. Verbal and visual communication methods are not, however, substitutes for physical togetherness [3]. In the use of digital communication media forms, some of the emotional content and meaning of the message is often lost, compared to face-to-face interchanges or physical mail. "Emotion is communicated to others using a variety of different cues, such as facial expression, vocal intonation and body language" [10]. Communication that occurs without these cues risks a loss of meaning [15].

Therefore, integrating these cues into communication is important in supporting intimacy.

Researchers have investigated how technology can enhance the quality of family communication based on improving existing communication tools, such as sharing photos via a picture blog [1], and augmenting video-conferencing with a camera-projector system [17]. According to Mark Weiser [14], also known as the Father of ubiquitous computing, "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". This description predicts that current forms of computing technologies will expand in scope and reach to a point where they will be no longer just communication means but will find their way into people's lives until they identify with them [7]. This predictive perspective applies to the topic of discussion and offers a window of opportunity for studying how to integrate digital interaction with everyday objects that might provide new ways to communicate remotely. Associated with the problem of remote communication among family members, this is an opportunity to study various forms of remote communication that can leverage other communicative sensory enhancements to better support intimacy.

In the context of emerging ubiquitous computing technologies, this study explores the sensory interactions in existing communication methods and other day-to-day intimate activities between young adult children and older parents living apart. By conducting mixed methods research, including diary studies and co-design workshops, the investigation hopes to enhance, support or build new forms of affective communication derived from current communication practices,

identify possible future design applications and make design recommendations for enhancing the affective experience of remote intimacy.

This study hypothesizes that, by understanding how people attribute affective meanings to things in their lives, it may be possible to transfer those meanings to new technologies. These potential technologies might be able to facilitate new forms of interaction that leverage other sensory ways of communicating to stay in touch and enhance remote intimacy between older parents and young adult children.

## **2 Methods**

### **2.1 Participants**

In the preliminary diary study, through a combination of purposive and convenience sampling, 2 groups of participants were recruited by email and through referrals from colleagues and friends. The first group included 7 parents (average 52 years old, 2 men, 5 women) who communicate regularly with their children who no longer live at home. The second group contained 8 students (average 25 years old, 3 men, 5 women), who had moved far away from home, and also communicated with their parents remotely. In the co-design workshops, using the same sampling methods, 4 older parents and 6 young adult children were invited to participate in 3 identical, but separate workshops, with 3 participants who had already done the Diary study (1 parent). The 10 participants were divided into 5 pairs to complete the workshop tasks, and balanced for gender, and for participant roles (parent/child).

### **2.2 Objective**

The preliminary Diary study was designed to further the understanding of existing communication patterns and to collect inspirational elements from the participating family members. This research method targeted the use of tools to enable remote communication (i.e., phone and laptop), associated artefacts, themes related to family conversation or emotional experiences. Participants recorded two instances of their communication activities with their parents/children within a specific time frame. They noted the following: who they spoke with, the tools, locations, duration of the communication, and a description of the technical aspects of the communication process. Then, the data from the Diaries was used to generate

materials for further investigation in the workshops. For example, 8 participants (4 parents and 4 adult children) recorded that family photos reminded them of the time to be together. Family photos in various forms then became an object for consideration in the subsequent workshops.

The objective of the workshops was to explore whether, by applying new technologies to some of the memorable objects in the participants' daily lives, different kinds of interactive communication tools would emerge. In addition it was important to understand the way people imagined that they would respond to these non-traditional tools. Each of the 3 workshops consisted of two exercises. The first exercise used card sorting to explore the meanings and nature of different communication messages, and aimed at finding answers to the following questions:

1. What is the nature of these messages and how would respondents categorize them?
2. Which or what types of messages are important to them?
3. Which or what types of messages would they prefer to use in communication?

Based on the first exercise, the second exercise required the participants to create prototypes and scenarios focused on examining the possibilities for creating new interactive tools that they would be willing to use.

1. What type(s) of communication tools would the respondents develop if they could?
2. What would be the imagined inputs and outputs used to represent the conveyed messages?
3. Compared to traditional tools, what type(s) of messages could the respondents convey via these envisioned communication tools?

## 2.3 Materials

MESSAGE CARDS	How are you doing today? I miss you Is everything ok? Share my emotion Kiss Smile	Express my concern Recall memory Togetherness/Connected Health Blessing/Praying Birthday celebration
	Necklace Bracelet/Watch Glove	Lamp Teacup Family photo Other

Table 1. Content of Message & Object cards

The materials prepared for this study included: cards for sorting, kits of props, recording and video recording devices, and instruction sheets. First, 2 types of cards were generated following the input data analysis obtained from the initial Diary study. The first set consisted of "message" cards, which included 13 types of messages used for exercise 1. The other one was a set of "object" cards that the preliminary diary participants found meaningful for demonstrating intimacy; they were used for exercise 2. The content of cards is exemplified in Table 1.

The kits of props were also prepared to support the participants' attempt to develop ideas and models inspired by the "object" cards, and included: paperboard, teacups, gloves, mini-flashing lights, sticky notes, markers, scissors and glues etc. They were meant to help participants implement creative ideas in physical forms and share them with others. Additionally, instruction sheets were prepared to help participants understand the tasks more clearly. To record comprehensive data, workshop organizers setup recorders during each workshop.

## 2.4 Procedures

### (1) Exercise 1:

The first exercise was a card sorting game for both adult children and the parents. Each card contained a message idea derived from the Diary study about what participants might want to communicate, such as "I miss you" or "How was your day?". They were asked to identify what type of messages were most important to them when communicating with their children or parents. The exercise contained 3 steps, followed by a presentation as described below:

- a) Each group sorted each message into categories and gave those categories names;
- b) They ranked most likely messages that they would use within each category;
- c) They prioritized these categories and discussed which categories would be the most important ones to share with their family member who was far away;
- d) Finally, each group shared their selection/choices with the rest of the participants in the workshop.

### (2) Technology tutorial:

- a) After completing the first part, the organizers gave a simple and short tutorial about how technology can

enhance any object, including wearable technology, to provide the potential for intimate communication. The idea was to introduce the concept that technologies can be integrated into the types of objects that the Diary participants had associated with their family communications. In addition, this would provide participants with the basic knowledge they might need to participate in the second exercise.

b) In the tutorial, organizers discussed how current technologies have been greatly improved, enabling people to explore new ways to approach everyday activities and to communicate. Heart rate monitors and pedometers were used to demonstrate examples of wearable technology. The idea was that participants might already be familiar with items like these, which use computer chips or sensors to add smart functions or new features to wearable devices.

c) To ensure participants had the same understanding of technology principles the organizer explained two important elements in designing smart and interactive objects: input and output. The simple example of a flashlight was used to demonstrate the inputs and outputs, and to help them understand how to effectively use them to create the envisioned features and functions for communication. After learning this basic concept, the workshop proceeded to exercise 2.

### (3) Exercise 2:

In the second exercise, the teams were asked to pretend that they have a magic object that can connect with their family member who is far away. Each team could choose one or more object cards representing an object that they could imagine having in their environment. It would be an object they would like to be able to use to connect with their family member.

a) Participants were asked to pretend that the objects they chose could have input and output at both ends that somehow would enable them to send messages to one another in a way that does not use words. They were asked to identify 2 or 3 kinds of “magic” properties that would enable them to share the important messages they identified in the previous exercise. They had 10 minutes to discuss and decide what special functions the object might have and what the inputs and outputs for this way of communicating

would be, in terms of what would people do with the object and how they would see it and feel about it.

b) After participants decided what they wanted the object to actually do, they used the supplies provided in the kit to make a rough physical model of the object or objects in 10 minutes, making sure that the objects included the input and output features.

c) Based on the ideas and models they developed, each team spent 10 more minutes to create a user scenario. They sketched step-by-step pictures to illustrate the ways that they imagined their object would work.

d) Finally each team had 5 minutes to act their scenarios out and explain how their object works.

## 3 Findings

### 3.1 Messages

	Category No.1	Category No.2	Category No.3	Category No.4	Category No.5
Group 1	How are they	Share our emotion	Happy times	Say something at the end of a communication	
Group 2	Wellbeing	Temporary feeling	Emotion caused	Event/Festivals	Missing
Group 3	Expressing concern	Recall memory	Regretted moment		
Group 4	Concern	Special greeting	Daily greeting	Physical expression	
Group 5	Personal wellbeing	Communication	Events		

Table 2. The categories generated from the card sorting exercise and corresponding three main categories

In the first workshop exercise, participants categorized information based on their understanding of the properties of 13 messages; and the methods they used to prioritize categories referred to their personal preference and the sequence of communication in a colloquial sense, like which message would be used at the beginning or the end of a conversation. The results in Table 2 outlined the categories created in each group. According to the titles of the categories and their interpretations, these messages were refined to three main categories, which interconnect and illustrate a regular pattern of family remote communication scenario. They were: “Expressing concern & wellbeing”, “Emotion” and “Memory & togetherness” respectively.

#### (1) Expressing concern & Wellbeing:

The first type of message, graded by frequency of preference, was “expressing concern and wellbeing”

above any other type of message. It tied in with the inquiries about “health” and “wellbeing” (example: “everything is ok?”). From the 5 groups’ discussions, they all stated that “expressing concern”, “asking about health” and “wellbeing” (is everything ok) were part of the routine of daily greeting at the beginning of a conversation. This type of messages was the most preferred expression that could extend to any other sort of messages or topics.

## (2) Emotion:

The second type of message was tied to expressing emotion, and they included messages like “I miss you”, “smile”, “kiss” and other emotions. People were unable to share some emotions due to the limitations of current communication methods, or they preferred not to exchange some emotional information so that family members would not worry about them. However, they elaborated in their communication with intimate family members that they wanted to know more information about their relatives. An adult child stated: “with my parents, I rarely share my emotions with them. Especially when I’m not feeling well, so I do not want them to know that, but I would like to find out if my mom is healthy and only then maybe share what is going on with me.”

## (3) Togetherness & Recalling memory:

Another type of information refers to what can be grouped into the theme of “Memories and Togetherness” content that is more in-depth and personal. Togetherness was best expressed in the time parents and children used to spend together, like a home visit, family activities and other special events. Participants did not place this category at the top of the list because current means of communication do not emphasize memories. However, the preliminary Diary data indicated that togetherness and memories bring people closer together, because by recalling such memories and by sharing similar sensory experiences, family members feel more connected.

## 3.2 Objects

In the second exercise, each group selected one or two object card(s) to develop the ideas of communicating through new tools (Figure 1). Their choices focused on wearable objects (i.e. watch, bracelet and necklace etc.), teacups, and family photo frames.

### (1) Wearable:

The participants chose the objects in the brainstorming section of the workshops and also identified the portability and accessibility as important factors to consider. The group discussions indicated that watches and other wearables (bracelet and necklace etc.) were chosen most frequently because their portability and accessibility would allow participants to communicate without the limitations of time or location. Group 1 stated they would prefer something that would always be with their children, to make it easier and possible to reach the children anytime they want. Group 2 thought the watch could be a clue for an incoming message.



Figure 1. Object models developed by the five groups

### (2) Teacup:

Two other groups generated the idea of making magical teacups as possible means to convey the message of “togetherness” and “recalling memory”. They conceived teacups not just for drinking, but also because they triggered rich meanings by association, such as togetherness and warmth. From the observation of these groups’ discussions, mealtime or teatime past experiences were found to contribute to the creation of memories associated with togetherness. Using tableware like teacups could possibly evoke similar sensory (scent) experiences of those memories, which might create an invisible connection with or elicit an emotional response from a family member. According to the participants’ imagination, different teas/scents represented different meanings. If the teacup had a certain database to recognize these meanings, participants could share emotions, send meaningful

messages, or even allow them to drink the same type of tea “together” over the distance. Group 3’s concept was a rotating mechanism with a flavour palette and mesh at the bottom of teacups; each type of tea represented a different emotional message (e.g. mint tea is equal to stress and anxiety; strong green tea is equal to trying to stay with your work). Another group created a special dropper tool, which was used to drop different dyes into the teacup. Differently coloured dyes represented different messages participants wanted to convey and send.

### (3) Family Photo Frame:

One group also selected the photo frame as a form to communicate memories, and they stated that family photos represented one of the most direct and familiar means to express yearning for family members. They developed an interactive digital photo frame for the parent, and used the space on the photo frame to create an interactive screen for communication.

### 3.3 Inputs & Outputs

Inputs and outputs in general provide more information for analyzing the features of these conceptual models and the remote interaction process. These inputs and outputs could communicate through related sensory channels [9]. By analyzing the nature of inputs and outputs in the dimensions of sensory modalities (vision, touch, auditory and smell/taste) and their relevant roles (Table 3), two types of inputs were defined: active and passive, as well as separate types of outputs used for presenting signals and actual messages.

In Table 3, Touch plays a dominant role as an input. There are diverse actions that could enable people to initiate a connection to each other. Active inputs are the actions participants would do to trigger a contact, like touching a button, writing or pouring liquid. A single person usually completes them at the initial stage of a communication. In contrast, passive inputs do not need people’s active involvement, they are more like experiencing some physical properties of the objects themselves, sensed by devices, such as body temperature, heart rate and scents etc. These properties decide the expressions of emotion or mood. The comparison between the two types indicates that active inputs concentrate more on the tactile sense; but passive inputs have more variations distributed across multiple senses.

Also, the outputs could convert into 2 categories based on their roles and the order of communication. The initial outputs send the recipients signals that are necessary requirements to establish a connection. This type of output is noticeable by or visible to the receivers, like vibration, flashlight, and alert sound, which are common and already exist in traditional devices. Another variety of outputs represent the actual messages sent. These appear to be more varied by comparison to the signal outputs, using features such as: image, color, handwriting/drawing and scents. Vision and smell are the dominant senses associated with these messages. For instance, Group 2 proposed using handwriting/drawing to communicate on their wearable tools instead of digital text. The parent participant generated the following idea: “Think about if I wake up in the morning, my son just returning something that would show up on my fridge. That would make me happy. Like a drawing or something in his own words that I could see. Almost like texting but it is more intimate and actual, or you could even see them while they are writing, and then I would feel more connected by writing there”.

Vision is the most appropriate sense to receive some forms of information such as: colour, shape, image and light intensity/frequency. The participants were consistent in applying colours to implement their ideas, possibly because colours are selectable and distinguishable, thus allowing participants to easily code the message with meanings they wanted to convey. In other words, an ideal interface for a communication tool requires selectable properties in order to present

	INPUTS		OUTPUTS	
	Active	Passive	Signal	Message
Tactile	Touching/Knocking/Slide Writing/Tracing Pouring/Filling liquid	Temperature Heart rate	Vibration	
Visual	Rotating dial (Watch) Rotating flavor palette (Juicer) Camera	Color	Flasher/ Light	Colors Graphical image Projected graphics, shape Photo/Video Feedback drawing / text Light Intensity/Frequency
Smell /Scents		Dyes (Tea/Coffee) Sweet & sour Database of Favorite Food/drink	Smell	Tea Favorite scents
Auditory			Alert sound	Voice

Table 3. The Categories of Inputs (Active and Passive) & Outputs (Signal and Messages)



different messages in different scenarios. The diversity of visual outputs could meet such design criteria. For instance, Group 5 used different dyes for the magical teacup and lighting points on the watch representing different interpretations. “Yellow” meant peace/ “All is ok”, and “Blue” was “Ken’s favourite flower scent”. The models of the novel teacups revealed the potential association with the sense of smell. It could be a sign that in addition to the dominant sense of vision, it is also possible to explore other new types of sensory stimuli to enhance emotional experiences over long distance. Even though scents seem subtle and invisible, they have strong connections to personal memory identification. The magical features about scents that have been explored in this study could constitute an alternative means for sharing emotions and helping people feeling more connected.

Last, the auditory sense was less emphasized than the other senses. Only a few groups in this study mentioned the talking functions and alert sounds, which were similar to conventional means of communication, like the telephone and other instant communication tools primarily driven by verbal communication. This observation suggests that the participants were successfully removed from traditional verbal means of communication in the workshops, and were able to explore possible non-verbal interactions.

#### 4. Discussion & Conclusion

***(1) Conventional communication methods cannot convey all types of information; in the future they could be enhanced by different sensory means of communication.***

The study results indicate that conventional means of communication cannot transmit all types of messages that participants would like to send to family members. Conventional means of communication offer the opportunity to share more concrete meanings and physical content, including greetings, expressing concern, and discussing daily activities, but miss the more personal and emotional information, such as those found in the theme of “Togetherness and Memory”. This theme relates to the meaning of intimate experience in the sense of physical togetherness, which has been used to define intimacy in literature [3]. However, it has also been found through association with memorable artefacts rather than digital devices.

The investigation of emotional expressions also

identified some “concerned”, “inquiring” or “speechless” signals in communications, which revealed the non-verbal properties of family communication. Remote intimate sensory experiences are constructed with verbal communication as well as non-verbal communication. Still, non-verbal communications could help build the closeness in a parent–adult child relationship [1]. Current means of communication primarily function by exchanging verbal messages that allow people to express concern. Yet, existing literature and the current study suggest that regular video and audio methods cannot transmit some non-verbal cues of people’s affection [2], such as the sense of togetherness, memories and some less expressive emotions. This study explored a set of new tools, elements, and scenarios to support situations using non-verbal information as an alternative to the current verbal means.

In general, the study identified three main themes used for family interaction over long distance: Expressing Concern, Emotion and Togetherness/Memory. These dimensions, or themes could help to better understand the nature of remote intimate communication between young adult children and older parents. In the meantime, it suggests that current digital communications are limited in conveying intimate meaning, which might otherwise be possibly carried by particular everyday artifacts. These findings identify a possible gap in current interaction features. That could encourage designers to benefit from the use of memorable objects, and to explore potential new interaction tools that are able to convey richer types of information.

***(2) To augment the behaviour of parents and children through a sensorial interface for engaging in remote intimate experiences, designers need to shift focus from screen-based interfaces to a wider range of sensorial interfaces.***

The concepts for envisioned interactive tools explored in this study provide insights into developing sensorial interfaces that could augment remote intimate experiences between older parents and young adult children. The findings led to an understanding of some elements and features, which could be used in designing potential interactive objects. This study argues that context adaptability and non-screen based forms could be the new ground breaking features that future interfaces are required to have for remote intimate communication.

Context adaptability is particularly relevant to the form of wearable tools. Combining the general context of ubiquitous computing and intimate computing, this study suggested that wearable computing could be an effective form of intimate interaction that enhances intimacy between people and technology, as well as person-to-person relationships/interactions. Wearable objects are context-adaptable due to their portability and ability to connect remote people to each other without time or location constraints. Furthermore, wearable objects can be passive forms to enhance technological abilities [11], to detect affect, and to exchange emotional information by sensing body motion or heart rate.

Integrating both the findings of the present study and the discourse about future trends in technology, the present study proposes moving beyond screen-based interfaces to more diverse forms rooted in daily lives. The variations of these forms can support remote communication in two different ways. First, they could provide more types of sensory feedback and personal information that cannot be supplied by current digital communication, and potentially enhance the extent of intimate awareness [13]. For instance, the results identified that smell channels are strongly tied to the meaning of memories, family stories, and other personal attachments. Teacups were the initial models for communicating scents. Second, natural gestures rooted in daily activities could also be incorporated into new interfaces, not just touching a screen and buttons. These features fit into the general trend to create an integrated experience, a smooth hybrid of real world and digital interactions [6].

### **(3) The limitations of the study**

Due to the time and resource restrictions, the sample size was small. As a result, the inspirational materials of messages and objects used in the workshops were restricted in forms. These factors limited the diversity and creativity of the concepts when developing new interactive tools. To explore more possibilities and creative ideas for new interaction methods, future studies in relevant areas should aim to involve a broader sample of participants and more variations of materials. Another limitation was the adaptability and suitability for applying these new means of interaction. This research explored a few user scenarios that might not be suitable for all contexts. Intimate experiences are influenced by cultural/ local background and

individual family stories that may not be shared by a larger group. The metaphors and elements explored in this study might have different meanings in different cultural backgrounds. Therefore, to propose these new interactive methods for family communications, designers may need to develop highly customized forms of communication tools associated with personal attachment and preference. In that case, more user scenarios tied to different cultural backgrounds for intimate interaction would need to be investigated. Future interactive tools should also be more flexible to fit the context.

### **References**

1. Dalsgaard, T., Skov, M. B., Stougaard, M., & Thomassen, B. (2006). Mediated intimacy in families: understanding the relation between children and parents. In Proceedings of the 2006 conference on Interaction design and children, 145-152. ACM.
2. Frijda, N. H. & Mesquita, B., (1991). The various effects of emotion communication. Paper presented at the sixth meeting of the international Society for Research on emotion, 1991(July), Saarbrücken, Germany.
3. Grivas, K. (2006). Digital Selves: Devices for intimate communications between homes. *Personal and Ubiquitous Computing*, 10(2-3), 66-76.
4. Habib, R., & Khan, A. (2007). Easing the communication: the electronic letter. In Scandinavian Student Interaction Design Research Conference, 50.
5. Kobrin, F. E. (1976). The primary individual and the family: Changes in living arrangements in the United States since 1940. *Journal of Marriage and the Family*, 233-239.
6. Kuang, C. (2013, August 13). Like magic\_\_ Why a new golden age for UI Design is around the corner. *Wired*. Retrieved September 20, 2013, <http://www.wired.com/design/2013/08/design-and-the-digital-world/>
7. Mann, S. (1998). Definition of Wearable Computer. Retrieved Jun12, 2012, from <http://wearcomp.org/wearcompdef.html>
8. Miner, C. S., Chan, D. M., & Campbell, C. (2001). Digital jewelry: wearable technology for everyday life. In CHI'01 Extended Abstracts on Human Factors in Computing Systems, 45-46. ACM.
9. Planalp, S. (1999). *Communicating emotion: Social, moral, and cultural processes*. Cambridge University Press, Cambridge, UK.
10. Planalp, S., & Knie, K. (2002). Integrating verbal and nonverbal emotion (al) messages. *The verbal communication of emotions: interdisciplinary perspectives*, 55-79.
11. Picard, R. W., & Klein, J. (2002). Computers that recognize

- and respond to user emotion: theoretical and practical implications. *Interacting with Computers*, 14(2), 141-169.
12. Smith, J., & MacLean, K. (2007). Communicating emotion through a haptic link: Design space and methodology. *International Journal of Human-Computer Studies*, 65(4), 376–387. doi:10.1016/j.ijhcs.2006.11.006
  13. Tollmar, K., Junestrand, S., & Torgny, O. (2000). *Virtually Living Together\_ A Design Framework for New Communication Media*. DIS '00 Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques, 83–91.
  14. Weiser, M. (1999). The computer for the 21st century. *ACM SIGMOBILE mobile computing and communications review*, 3(3), 3-11.
  15. Willis, M. J., & Jones, C. M. (2012). Emotishare: supporting emotion communication through ubiquitous technologies. In *Proceedings of the 24th Australian Computer-Human Interaction Conference*, 657-660. ACM.
  16. Werner, J., & Hornecker, E. (2008). United-Pulse : Feeling Your Partner 's Pulse. *Mobile HCI, Amsterdam*, 535–538.
  17. Yarosh, S., Cuzzort, S., Müller, H., & Abowd, G. D. (2009). Developing a media space for remote synchronous parent-child interaction. In *Proceedings of the 8th International Conference on Interaction Design and Children*, 97-105, ACM.
  18. Zuckerman, O., & Maes, P. (2005). Awareness system for children in distributed families. In *interaction design for children*.

# Bringing Chinese Aesthetics into Designing the Experience of Personal Informatics for Wellbeing

## Abstract

We explore how Chinese Aesthetics might bring new concepts to Human-Computer Interaction (HCI), specifically health related personal Informatics (PI) through a design case YU(鱼). YU collects users' heart rate and presents an artistic display in a Chinese ink painting style. Different from goal-oriented designs, we study how the concepts of "naturalization of humans" and "harmony" direct the design practice through encouraging aesthetic appreciation of living. Instead of presenting a singular account of a "good," "bad," or "stressed" bodily status, we argue that mirroring the body in a living creature and using counter-intuitive mapping to display bio-data can help build connection to and appreciation of the body. We demonstrate this by comparing YU to an existing design Fish'N'Steps, given that they use a similar representation but with totally different motivations and methodologies. Design implications are drawn to inspire future interaction design.

## Keywords

Chinese Aesthetics, Health, Wellbeing, Body, Experience

## 1. Introduction

Humans have a long history of pursuing the idea of "Know Thyself," from the inscription of "Gnothi seauton" at ancient Greek temple, to the statement of "Knowing others is intelligence, knowing yourself is true

wisdom" in Tao Te Ching, to what William Shakespeare wrote in Hamlet "This above all, to thine own self be true." Natural and social scientists in various fields have been exploring how human body and mind function and how humans behave using theoretical and empirical methods. Emerging Personal Informatics Systems powered by pervasive sensor and mobile technologies make such knowledge more readily accessible to ordinary people.

Personal Informatics (PI) concerns about collecting personally relevant physical, psychological and behavioral information for the purpose of self-awareness, self-monitoring, and self-reflection [1,2,3]. Many existing PI systems<sup>1</sup> take a technology-centric, data-driven approach and are often goal-oriented. With the help of mobile and wearable devices, these systems allow users to keep track of their bio-medical status and daily activities in the form of numbers and graphs, in other words, to "quantify self" [4]. For example, motion sensors can record how many steps one has walked and how many hours one has slept (e.g. Fitbit<sup>2</sup>). Wearable heart rate and blood oxygen monitors (e.g. in Withings Pulse<sup>3</sup>) can measure one's vital signs. GPS, camera and microphone can provide further contextual information regarding one's habits and activities. By working with data, users can gain a more analytic understanding of their bodily performance, and can make more rational decisions to promote certain behavior or lifestyle [2].

Although quantifying self is an intuitive method for individuals to assess their performance and progress towards certain goals, many users of PI systems found the data sparse, noisy, sometimes hard to interpret, and difficult to form a big picture [2]. Therefore, there is a rising trend of shifting from personal analytics to knowing thy-self from an experiential view. Instead of setting a goal for their users, the experience-oriented PI systems try to engage people in the appreciation of living [5].

Chinese aesthetics has long been promoting such thinking. Chinese ink painter and art historian Zhang Yanyuan [6] proposed in his book “Famous Painting through History” that the process of art creation and appreciation, painting and calligraphy in particular, can “perfect the civilization, aid human relations, reveal infinite changes, fathom the subtle” and “uncover the secrets of nature.”

In this paper, through a method of research through design [28], we introduce, investigate and reflect on new design concepts drawn from Chinese aesthetics, and explore how these concepts may influence experienced-oriented personal health information design via a design case called YU. YU targets non-expert users who have no medical training or practices. It projects the users' pulse and heart rate biosensor data onto an animated Chinese painting of a fish, as a casual illustration of everyday wellbeing rather than a specialized therapy prescribed by healthcare professionals. To highlight YU's aim of encouraging users to explore and appreciate the rhythm and beauty of the life instead of judging and controlling the body, we compared it to an existing goal-oriented design Fish'N'Steps [7].

## 2. Related Work

With the rapid development of personal biosensor technology, a large number of systems and applications have been designed to promote physical and emotional wellbeing. Available commercial devices such as Samsung gear<sup>4</sup> and Withings<sup>5</sup> wearable tracker measure heart rate and monitor other daily activities for people to be aware of their overall health. These devices mostly communicate collected data to users by showing numbers or simple graphs in a direct, analytic way. Some other products provide further examination of the biosensor data and diagnosis of specific medical conditions from an expert perspective. For example,

the w/me wristband measures heart rate variability through an EKG sensor, which indicates reactions of the autonomic nervous system (ANS). Through a three-minute measurement of finger pulse, the system shows users a graph of their mental wellbeing in four different states: passive, excitable, pessimistic or anxious. This kind of personal informatics system adopts a diagnose-and-warn approach, actively collecting and interpreting the bio-data for users as an expert.

In HCI research, another type of designs has been proposed to shift the power of interpretation to the users [8,9,10]. Höök et al. point out that biosensors worn outside of the laboratory environment restricted the correctness and robustness of stress-related symptom analysis [10]. More importantly, they argue that the human body cannot only be seen as a physical body, but also an experiential and cultural body [10]. It is necessary to link one's subjective experiences to a specific social context. As an example, Affective Health designs evocative but open interfaces for empowering people to reflect on their everyday life [18]. Instead of diagnosing bodily status on the users' behalf, Affective Health mirrored the stress reactions back onto its users for their own interpretation. Through design explorations, Höök et al. proposed several experiential qualities for interactional design such as ambiguity, openness and fluency [9].

Researchers, designers, and artists have been exploring the design space of aesthetic experience-based presentation of personal informatics. Such presentations can take a variety of forms. For example, Khut et al. put up several installations of simple geometric visualization of real-time heart and breath rate data [11]. Inspired by the beauty of nature, Garde-Perik et al. created an adaptive environment with varying soundscape and animated lighting that enabled employees to deal with work-related stress [12]. Influenced by the philosophy of Somaesthetics [13], Schiphorst et al. designed the Exhale exhibition [14], which looked into the empathic nature of breath sharing in a network of people. Participants could feel one another's breath via vibrators sewed into the wristbands and speakers embedded in the fabric of sensually evocative skirts. Instead of having participants watch out for anomaly in their own vital signs, these projects guided them to enjoy the beauty and excitement of living.

### 3. Chinese Aesthetics

Many of the experience-based personal informatics design mentioned above have roots in aesthetic ideology. Eastern philosophies in particular exert a stronger and stronger influence in the recent trend of applying pragmatism to aesthetic interaction [15]. For example, Shusterman's somaesthetics [16,17], which particularly focuses on the attunement of the body-mind or soma, has evoked increasing attention to the study of bodily interaction. The theory of "somaesthetics" was actually inspired by classic Chinese aesthetics. Shusterman argues that the western aesthetic tradition has blinded people to the conscious, immediate, non-interpretive bodily experience that was stressed in Eastern-Asian thought. "Since we live, think and act through our bodies, their study, care and improvement should be at the core of philosophy" [18]. Applications of somaesthetics range from physically engaging mobile services to artworks that trigger reflection on bodily movements and physiological status [19,20,21].

Both the rising interest in pragmatist aesthetics and the success of Somaesthetics practices encourage us to further examine different dimensions of non-western aesthetic theories and their potential implications for design. Some researchers and practitioners, especially those from Eastern-Asian cultures, have experimented with embracing Eastern aesthetic thinking in the design of objects and installations. Examples include Chinese architect Shu Wang<sup>7</sup>, Japanese designer Kenya Hara<sup>8</sup> and Masayuki Kurokawa<sup>9</sup>. However, we found that few studies have addressed the use of Chinese aesthetics in information and interaction design, in particular, personal informatics design. This study aims to fill this gap.

As one of the oldest civilizations in the world, China has a rich aesthetic inheritance, having profound influences from various Chinese philosophies such as Confucianism, Taoism and Zen Buddhism. Chinese aesthetics covers a wide range of topics, from literature and art to the "art of living" [22,23,24], concerning the relation among nature, society and humanity [23]. In this paper, we do not aim to present all theories of Chinese aesthetics. Instead, we focus on two key concepts from Taoism - "naturalization of humans" and "harmony," as they are particularly related to designing aesthetical experiences of interactive technology involving human bodies and wellbeing.

### Naturalization of Humans

Zhuangzi is one of the most important figures in the Taoist school of thinking (Taoist metaphysics). He proposed the concept of "naturalization of humans", which requires that "men should not only have a close emotional relationship with nature, but also that our bodily form should directly resemble nature" [22]. Here "naturalization" means casting aside our animal nature to work actively in accordance with the principles of nature [24]. The famous Zhuangzi's butterfly dream (Fig. 1) is a good illustration of blurring the boundary between human being and the nature. Zhuangzi once dreamed that he became a butterfly, flying around enjoying itself. It did not know that it was Zhuangzi. When he suddenly woke up and veritably was Zhuangzi again, he could not tell whether it was Zhuangzi dreaming that he was a butterfly, or the butterfly dreaming that it was Zhuangzi.

Chinese artists adopted the idea of naturalization, resonating everyday experiences with the nature in their work. For instance, animals or plants are a common metaphor of the artists themselves in Chinese ink paintings (Fig. 1). Artists attune themselves to inspiration — a moment in which natural and spiritual beauty converge — in such practices.



Fig. 1. A Chinese painting depicting Zhuangzi's butterfly dream (<http://www.the-philosopher.co.uk/butter.htm>).

### Harmony: Complementation and Balance

Harmony is reiterated and particularly emphasized in traditional Chinese aesthetical thoughts. The state of harmony is built upon intrinsic agreement

of contradictory and heterogeneous forces. These forces are actually complementary, interconnected and interdependent, and thus can achieve dynamic balance and viable stability as a systematic whole. The human life is such a harmonious system. As Zhuangzi asserted, “to take an aesthetic, contemplative attitude towards life as a whole, one should discount gain and loss, success and failure, right and wrong, merit and demerit; forget the self and things, subject and object, the self and others, and thereby let the self and the whole universe blend into one” [24]. According to Zhuangzi, nothing is particularly good or bad. By this, he did not advocate for negating the effect of all things happening in life, but rather taking a “happy-go-lucky” attitude even towards negative things[23] “be warm like spring with all things” as he put it. Ups and downs, Yin and Yang, are as natural as the four seasons in a holistic view. In the end, one’s existence, nature and the universe all come together. Thinking like this would bring you inner peace and help you face all situations, as he claimed “being oblivious of everything, possessing everything; an infinite calm in which all beauties follow”[23].

#### 4. YU: A Design Case

##### Introduction of YU

We applied a method of Research through Design (RtD), since our attempt is to explore a design space rather than offer a solution to an existing problem. RtD [29] uses designed artifacts as a lens to examine the knowledge generated from research exploration. The knowledge intends to be “generative and suggestive” rather than provide generalization through falsification [28].

In our case, we explore new insights on how to use concepts of Chinese aesthetics to guide experience-oriented designs for wellbeing via the design process of a system called YU [27]. Yu is an interactive system of displaying the pulse and heart rate data, which was inspired by Chinese aesthetic theories of naturalization and harmony. . We created a virtual “fish” avatar as the carrier of health information to bring a new perspective of viewing the body and living.

YU is a portable all-in-one installation that includes three parts: a sensing unit, a monitoring unit, and a display unit (Fig. 2). The sensing unit is a pulse sensor on the top of a box. The monitoring unit is a screen

embedded on the side of the box. And the box itself encloses a projector as the display unit. When people put a hand on the box, the system measures the pulse/ heart rate and visualize them on the screen in the real time. People can also display the interface in their surroundings, for instance on the wall (Fig. 3). Additionally, we created another prototype where the fish can be projected in the real water of a fish bowl and appears to be a real fish (Fig. 4).

In some context, YU is displayed in the foreground, for instance, when people do exercises, yoga or massage. It enables people to be aware of their bodily condition. In other cases, YU is displayed in the background as an ambient artwork that blends into the environment and the atmosphere at home or in the workplace (Fig. 5).



Fig. 2. YU: an all-in-one installation that includes three parts: a sensing unit, a monitoring unit, and a display unit



Fig. 3. YU: Display on the wall



Fig. 4. YU: Display in the fish bowl



Fig. 5. YU: Usage Contexts (Working Place / Mobile Environment / Massage / Yoga)

### **A comparison of goal-oriented design and experience-oriented Chinese aesthetics inspired design**

To highlight the differences between metaphorical representation in goal-oriented design and experience-oriented Chinese aesthetics inspired design, we compare YU to an existing design case Fish'N'Steps [7]. Fish'N'Steps (Fig. 6) uses a similar representation but for

totally different motivations and goals. It is a fish tank-like virtual pet social game which displays pedometer data. The appearance, emotion, and movement of the animated fish avatars reflects users' progress towards meeting their daily walking goal.

A fish would smile if its user has taken enough steps, and cry otherwise. People compete to see who owns the "healthiest and happiest" fish in the tank. Following



Prochaska's Transtheoretical Model of Behavioral Change, this type of intervention promotes target behaviors by increasing users' awareness and creating a social context that is both cooperative and competitive. Evaluation showed that the game was fun and engaging, but many users who failed to conduct the desired behavior got discouraged and lost a sense of attachment to their virtual pets (crying, not growing fish). In addition, competition can be an incentive or a cause of stress. These effects are commonly seen in evaluative, goal-oriented designs.

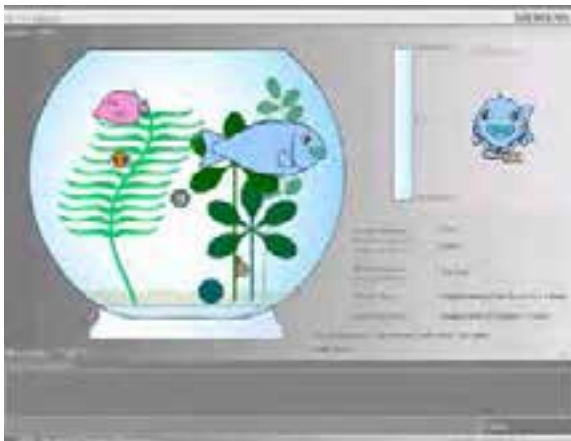


Fig. 6 Fish'n'Steps [7]

Metaphorical display in goal-oriented personal informatics design tends to draw a clear distinction between “good” and “bad” conditions with the goal of directing users to achieve a desirable state. Different from the existing metaphorical design of PI information display, our design philosophy inspired by Chinese aesthetics stresses resonance rather than evaluation, which intends to improve users' quality of life through

“appreciation of living”. In the following session, we describe how we designed the representation and mapping of YU from the inspiration of Chinese aesthetics.

Moreover, we recruited some people to experience the system, so we will also discuss the feedbacks of the participants. Although the design was much inspired by Chinese traditional art, we did not particularly focus on Chinese nationalities, as our design was aiming for providing a well-being installation that could help general self-regulation in an artistic way without considering cultural backgrounds.

### Representation

The display of YU consists of a swimming fish in a Zen pond in Chinese ink painting style. It has no numeric element. We designed the interface (Fig. 2) in the game engine Unity 3D to visualize and render a user's bio-data in real time. By doing so, live video clips of a dynamic fish swimming in the water are generated. Meanwhile, users can hear the cicada calls and the sound of water when the fish moves.

This design has its root in the Chinese culture and aesthetics. The word for fish, “YU” in Chinese, is a homophone for “abundance” and “affluence”. Fish is the symbol of good fortune and peace in many Zen stories. Red fish in particular represents success, love and domestic felicity. It is no wonder that fishponds often appear in Asian gardens. Fish such as koi, are treated as pets or treasured possessions by their owners. Drawing upon these rich symbolic meanings, YU used a fish as the naturalized metaphor to represent people's bodies and their wishes for wellbeing. Apart from a fish, the metaphor can be anything that is representationally rich. For example, we can externalize our body into the natural scenery as artists reflect their emotion upon mountains and sea in most Chinese landscape paintings. Objects or living beings such as plants and animals can also be employed in naturalization of humans. But different metaphors might have different intuitiveness based on users' cultural background. It would be more effective if the metaphor is something that users can easily resonate with.

Different from the cartoon-style fish in Fish'N'Steps, YU's Chinese ink painting-like display brings to users a peaceful experience. It lets users immerse in the beauty

of Zen through abstract forms, texture and effects with the fewest possible lines and tones. Importantly, it captures the spirit of the subject matter rather than simply reproducing the appearance.

It is worth noting that the facial expression of the fish is eliminated in our design case, since it is usually perceived as an indicator of subjective judgment and personal attitude of the designers and may backfire [7]. Reflecting upon lessons from Fish'N'Steps, instead of diagnosing abnormal condition or stress level, YU leads users to feel the vitality in pulse and heart rate data.

Participants who experienced YU expressed their interest and curiosity of mirroring their body as a fish. Some participants reported a strong sense of connection at the moment as they described the experience of interaction. We interpret the connection into two aspects: physiological connection and affective connection. Physiological connection is built on participants' sense of association between their heart rate and the fish's movement. The other aspect of the connection comes from emotional relationship with the display. This kind of connection leads to the affective closeness and empathy rather than merely the awareness of the heart rate. Several participants described their emotional changes during the process. It is worthy noting that the change could be reciprocal. The reciprocal impact leads us to reflect upon the design of the representation of the bio-data.

These findings are in accordance with the concept of the "naturalization of humans" in Taoism, which encourages one to "forget the self and things, subject and object, themselves and others, and thereby let the self and the whole universe blend into one" [24,25]. It suggests that human beings are not different from nature, since they are built upon the same elements as other things in nature. Our design case uses bio-data as a shared element to link human bodies and the Yu. The Yu's movement is driven by the pulse and heart rate of the user, which echoes the Taoist argument that "the whole universe blends into one". In addition, in ancient Chinese art and literature, nature - such as flowers, birds and fish - is broadly used as subject matter to reflect one's ideal emotion and personality. This inspires us to use similar technique, i.e. metaphorical representation of a living creature,

to design visual representation of bio-data. Our study shows this strategy performs powerful expressivity and resonates with the participants. However, some participants expressed the difficulty of considering the fish as an external representation of their bodies. On the one hand, this might due to the differences of aesthetic demands and the previous experiences among users. After all, relating to digital images is a subjective experience. Some may relate to fish but some may relate to other creatures. This also points to one of the challenges of designing aesthetic experiences for personal informatics. On the other hand, the quality of the digital images and contexts might also influence the connections. Some participants felt more connected to the fish when it was positioned in a fish bowl than on the wall. This requires further technical improvement on the effect of the image.

Interestingly, when we asked the participants to redesign representations for their heart rate, the answers were often to be found in nature, for example, butterflies, trees and plants. Even though people have various preferences, they tend to relate their body to living creatures in nature. Regarding the design of bio-data representation, our study suggests that designers could take living creatures into account for the purpose of building a strong connection with users. Through the reciprocal influence from the representation, people are more easily engaged in the interaction in order to care more about their wellbeing.

## Mapping

In accordance with our design concept of appreciating the living, the display of YU does not show any numbers or signs indicating positive, negative or standard body status. Instead, we offer users an enjoyable and holistic view to perceive their bodily status through a metaphorical display. The velocity of the fish's movement maps to a user's pulse and heart rate. From the raw data to the display, YU adopts a counter-intuitive mapping, which means that one will see a calm fish if one's heart rate is high or an active fish if one's heart rate is low. The fish plays the role of the complementary force of the participant's body. We present the opposite experience through the fish for people to perceive, appreciate and self-regulate through the process of bio-feedback.

Some participants considered the fish to be a dynamic display of his body. As one of them said, he was experiencing his heart rate in the course of observing the fish. It was unprecedented for him to enjoy the pattern of his heart rate and appreciate the rhythm of the body. We can interpret this appreciation in two ways. First, the mapping shapes participants' view on their heart rate in a dynamic balance. Second, the mapping doesn't show any positive or negative diagnosis. One will see a calm fish if one's heart rate is high or an active fish if one's heart rate is low. This kind of display doesn't provide people with any normal or unhealthy alert. All the physiological changes are natural which should not be judged as positive or negative.

This design principle was drawn from the concept of Harmony from Chinese aesthetic theory, especially from Zhuangzi's thoughts. According to him, ups and downs, stress and depression, are as natural as the four seasons which should not be judged as positive or negative. Human body is a good example of such a harmonious and dynamic system. Complementary forces interact to form a harmonious and dynamic system in which the whole is greater than its parts [26]. In our case, the Yu is designed to be the complementary force of human's body, so that people can appreciate their body from a holistic and neutral perspective. Instead of diagnosing the body in a normal range or stressed situation, we presented the heart rate in a natural and aesthetic way without any good or bad hint aiming for casting aside unnecessary stress. Interestingly, the participants applied our design principles and customized their own displays. For instance, one suggested a tree to indicate his physiological information, and another suggested butterflies to indicate energy intake. In that respect, our study serves as a good example that people appreciate a pleasing and aesthetic way to display the bio-data and manage their health, and such an approach evoked their imagination, indicating more interest.

## 5. Design Implications

Based on the comparison of two wellbeing-related design cases, goal oriented design Fish'N'Steps and experience-oriented design YU, we propose some design implications inspired by Chinese aesthetics that can be employed in future personal health information design.

Above all, we as designers could rethink the motivation of designing personal health information from a new perspective. Opening the mind and embracing the body through appreciating it instead of controlling it can bring more insights and design alternatives. This paper explores Chinese Aesthetics and Taoism to inspire a holistic experience-oriented design thinking for personal informatics.

In the design case of YU, we move from setting a specific goal for a desirable state to presenting the invisible rhythm of life through artistic visualizations. From the feedback of the participants, we found that when people treated the YU as a stress management system, they usually expected to see the specific numbers of their bio-data and diagnose of bodily status including stress. However, after we showed them the numeric interface of their heart rate and wave-like graph, they felt nervous as some values exceeded the normal range. They focused on the result of their health indication, rather than immersing themselves into the process of bodily change and appreciating the body. While some of the participants who treated the YU system as an art installation got more involved and ended up spending more time with it. They immersed themselves in the aesthetic experience and made a different connection with the fish. It is notable that the process of appreciating the body takes time, attention and engagement. These insights enlighten us that designing bio-data display systems as artwork to improve the wellbeing, for instance, in the form of artistic decorations. In doing so, people appreciate the body and even respect the life through aesthetic experience in a natural way.

How can we represent the bio-data regarding the appreciation of the body? We provide two design strategies:

1. Naturalization of humans, the concept from Eastern philosophies, which can be applied by the design of living representations from nature to achieve the affinity between participants and the displays.
2. Different means of mapping can create diverse, rich experiences. Direct illustration of an undesirable state in conventional thinking may bring unnecessary stress and kill people's imaginations and interests.

The concept of harmony between complementary forces inspires us to the design of the mapping between bio-data and the display. For the purpose of a balanced situation, counter-intuitive mapping in some context can be considered to exert positive impact over the wellbeing.

## 6. Conclusion and Future Work

Chinese philosophies have important insights into experience-oriented design of personal health information, as it encourages exploration and aesthetic appreciation of living. By comparing two design cases Fish'N'Steps and YU, we demonstrate how concepts from Chinese aesthetics can direct the design practice.

Our design has space for future improvement. First, we could personalize the mapping according to a user's gender, age, social and cultural background. Second, we could make the installation more portable in order to evaluate its long-term effect in richer scenarios. Third, methods for evaluating the experience-oriented design need to be further explored. Whether and to what extent users learn to appreciate living via interacting with the design can be subtle, personal, and incremental. Therefore, it is difficult to apply traditional usability studies to a non-task-oriented, open-ended interface [30].

## 7. References

1. Li, I., Dey, A., Forlizzi, J., Höök, K., and Medynskiy, Y. (2011) Personal Informatics and HCI: Design, Theory, and Social Implications. Ext. Abs. CHI 2011, ACM 2417–2420.
2. Li, I., Forlizzi, J., and Dey, A. (2010) Know thyself: monitoring and reflecting on facets of one's life. Ext. Abs. CHI 2011, ACM, 4489–4492.
3. Meyer, J., Simske, S., Siek, K.A., Gurrin, C.G., and Hermens, H. (2014) Beyond Quantified Self: Data for Wellbeing. Ext. Abs. CHI 2014, ACM, 95–98.
4. Linehan, C., Kirman, B. J., Reeves, S., Blythe, M. A., Tanenbaum, J. G., Desjardins, A., & Wakkary, R. (2014). Alternate endings: using fiction to explore design futures. In CHI'14 Extended Abstracts on Human Factors in Computing Systems (pp. 45–48). ACM.
5. Rooksby, J., Rost, M., Morrison, A., & Chalmers, M. C. (2014) Personal tracking as lived informatics. In Proceedings of the 32nd annual ACM conference on Human factors in computing systems (pp. 1163–1172). ACM.
6. Elkins, J., & Naef, M. (Eds.). (2011). What is an Image? (Vol. 2). Penn State Press. (pp. 55)
7. Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., & Strub, H. B. (2006). Fish'n'steps: Encouraging physical activity with an interactive computer game. In Proc. Ubicomp 2006.
8. Sanches, P., Höök, K., Vaara, E., Weymann, C., Bylund, M., Ferreira, P., ... & Sjölander, M. (2010, August). Mind the body!: designing a mobile stress management application encouraging personal reflection. In Proceedings of the 8th ACM conference on designing interactive systems (pp. 47–56). ACM.
9. Höök, K., Ståhl, A., Sundström, P., & Laaksolahti, J. (2008). Interactional empowerment. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 647–656). ACM.
10. Höök, K. (2009). Affective loop experiences: designing for interactional embodiment. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1535), 3585–3595.
11. Khut, G. & Muller, L. (2005) Evolving Creative Practice: A reflection on working with audience experience in Cardiomorphologies. In Anastasiou, P., Smithies, R., Trist, K. & Jones, L. (Eds.) Vital Signs: Creative Practice & New Media Now. Australian Centre for the Moving Image, Melbourne, Australia, RMIT Publishing.
12. Van de Garde-Perik, E., Snelders, D., & Thompson, M. (2013). Getting a GRIP on work-related stress. In Proceedings of 8th International Conference on Design and Semantics of Form and Movement (P54–64).
13. Shusterman, R. (2008) Body consciousness: A philosophy of mindfulness and somaesthetics. Cambridge: Cambridge University Press.
14. Schiphorst, T. (2005). Exhale: Breath Between Bodies, Emerging Technologies Electronic Art and Animation Catalogue, Art Gallery, Siggraph2005, ACM Press, Los Angeles, CA. pp. 62–63
15. Petersen, M. G. Iversen, O. S., Gall Krogh, P. (2004), Aesthetic Interaction: A Pragmatist's Aesthetics of Interactive Systems, DIS 2004, ACM Press, pp 269–76.
16. Shusterman, R. (2004), Pragmatism and East-Asian Thought, Metaphilosophy, Vol. 35, Nos. 1/2
17. Shusterman, R. (1992), Pragmatist Aesthetics: Living beauty, Rethinking Art, Oxford: Blackwell, 1992
18. Shusterman, R. (2000), "Somaesthetics and Care of the Self: The Case of Foucault", Monist, 83. pp.530
19. Lim, Youn-kyung; Stolterman, Erik et al. Interaction Gestalt and the Design of Aesthetic Interactions, DPPI Proc. 07, ACM Press (2007). 235–54.
20. Schiphorst, T., Soft(n): Toward a Somaesthetics of Touch. in Proc. CHI EA'09, ACM Press (2009), 2427–2438

21. Lee, Wonjun, Lim, Youn-kyung and Richard Shusterman. 2014. Practicing somaesthetics: exploring its impact on interactive product design ideation. In Proc. DIS '14. ACM 2014, 1055-1064.
  22. Liu, C and Lei, Y. (2008) The Body and Its Image in Classical Chinese Aesthetics, *Frontiers of Philosophy in China*, Vol. 3, No. 4, pp. 577-594
  23. Liu G (1995), *Ancient Chinese Aesthetics*, in Liyuan, Zhu, and Blocker, Gene, eds. *Asian Thought and Culture*, Volume 17: Contemporary Chinese Aesthetics.
  24. Li, Zehou, Majia Bell Samei translated (2009). *The Chinese Aesthetic Tradition*, Honolulu, HI, USA: University of Hawaii Press.
  25. Zhu, L., & Blocker, G. (2012). *Contemporary Chinese Aesthetics*. Lang, Peter, Publishing Incorporated.
  26. Taylor, R. L., & Choy, H. Y. F. (2005). *The Illustrated Encyclopedia of Confucianism: AM (Vol. 1)*. The Rosen Publishing Group.
  27. Zhu, B. T., Kürth-Landwehr, S., & Corbi, V. G. (2014). YU: an artistic exploration of interface design for home healthcare. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction* (pp. 332-334). ACM.
  28. Gaver, W. (2012). What should we expect from research through design?. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 937-946). ACM.
  29. Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 493-502). ACM.
  30. Harrison, S., Tatar, D., & Sengers, P. (2007). The three paradigms of HCI. alt. chi.
- <sup>1</sup> <http://well.blogs.nytimes.com/projects/activity-trackers>
  - <sup>2</sup> Fitbit: <http://www.fitbit.com/>
  - <sup>3</sup> Withings: <http://www.withings.com/us/>
  - <sup>4</sup> Samsung gear: <http://www.samsung.com/global/microsite/gear/index.html>
  - <sup>5</sup> Withings: <http://www.withings.com/us/>
  - <sup>6</sup> Phyode. W/Me: <http://www.phyode.com/healthwristband.html>
  - <sup>7</sup> Shu Wang (born 1963) is a famous Chinese architect. He became the first Chinese citizen to win the Pritzker Prize, the world's top prize in architecture. He creates modern buildings making use of traditional materials and techniques which rooted in their context.
  - <sup>8</sup> Kenya Hara (born 1958) is considered a leading designer in Japan. He has published "Designing Design", in which he elaborates on the concept of "emptiness" in both the visual and philosophical traditions of Japan and its application to design.
  - <sup>9</sup> Masayuki Kurokawa (born 1937) is a famous Japanese architect and designer. He demonstrated Eastern Aesthetics such as "dissymmetrical aesthetics" through his architectures and industrial design work.

**M. Bordegoni, S. Colombo, M. Pillan, L. Rampino**

Politecnico di Milano

# Exploring aesthetic interactions through prototyping

The role of experiential prototypes in design knowledge generation

“Writing and thinking have their limits when it comes to exploring the perceptual-motor fit and the beauty of interaction with things: the only way to evaluate these is to make experiential prototypes.” [1, p. 297]

In design research, concepts, models and prototypes help to envision unforeseen possibilities by suggesting future scenarios and by making them embodied, tangible, and, therefore, also testable. Moreover, models and prototypes can be useful in explorative studies to foster dialogue between experts with different backgrounds as well as between users and researchers. The ability of the prototype to foster dialogue has been pushed to the extreme by Boer and Donovan [2], who propose the use of “provotypes”, i.e. provocative prototypes that embody the tensions that often surround a field of interest. The “provotype” aims to support collaborative analyses and collaborative design explorations across stakeholders. In brief, prototypes can be seen as (design) research tools to investigate future scenarios.

The presence of “a series of artifacts – models, prototypes, products” [3, p. 497] is the main feature of the research through design process. Indeed, such process peculiarity lies in the fact that the generated knowledge is based on producing “design exemplars” [4] or “epistemic objects” [5], in the form of artifacts that “can be seen as the solid form of knowledge to be disseminated” [6, p. 7]. Of course, producing design prototypes is not equivalent to producing design knowledge per se. As some scholars already argued, a research through design process is typically characterized by two different forms of output [3, p. 497]: “a concrete problem framing” and “a series of artifacts – models, prototypes, products” as well as interfaces, drawings, storyboards, videos etc. These two kinds of output are intrinsically correlated; for, together, they represent two complementary facets of the same knowledge outcome.

The “problem framing” is the knowledge the researcher took pains to make explicit. Zimmerman, Stolterman, and Forlizzi [7, p. 313] clarify that such knowledge may become concrete in a “theory on design” or, more often, in a “theory for design” in the form of implications, of guidelines, of “design specifications for future products” [8, p. 140], which can be objects, interfaces, graphics, or services, or of new design processes and methods. From the epistemological point of view, the role of the prototype as knowledge generator is a sensitive and still debated issue. As Stappers [9] affirms: “The designing act of creating prototypes is in itself a potential generator of knowledge (if only its insights do not disappear into the prototype, but are fed back into the disciplinary and cross-disciplinary platforms that can fit these insights into the growth of theory).” (p. 87)

The peculiarity of the design prototype is that of being, at the same time, object d'art, technical object and object of use. Indeed, as an art object, the design prototype represents an aesthetic solution that can be inspirational for other designers (here, we mean by aesthetics the sensory appearance). As a technical object, the design prototype represents the feasibility of a given solution. As an object of use, it makes the set-up (and test) of a real interaction with the user possible. Of course, these three aspects are not independent, but interrelated and constantly overlapping. Indeed, in judging the usability of the prototype, also its appearance has an important role. In summary, the design artefact, differently from the engineering prototype, should be evaluated mainly on the basis of qualitative parameters. It is exactly its nature, in between arts and technology, which makes the role of the prototype problematic from the epistemological point of view. "Issues involving aesthetic judgments and design references are necessary elements of design, but from a scientific viewpoint, they are uncontrollable impurities. Yet, it is exactly this kind of knowledge that is at the heart of design as a discipline." [10, p. 124].

To take into consideration the typical dual form of research through design, already in 1997 the Sheffield Hallam University (UK) renewed its PhD regulations, allowing a more open definition of the thesis: "one in which artefacts are pre-eminent as the main evidence of investigation and outcomes and there is sufficient text to ensure that artifacts communicate appropriately". [11, p. 365].

Recent years have seen the design-research world moving in this direction, both with the rise of journals dedicated to the findings of research through design (the International Journal of Design, for example, cf. [12]) and with certain changes in the structure of design conferences (i.e. the Research Through Design Conference). The DeSForM section dedicated to demos follows this approach: interactive demos consist of prototypes exhibited during the conference. In order to be accepted, each demo has to be accompanied by a short commentary paper, which is evaluated through a double blind peer-review process. This reinforces the view that, as previously argued, presenting a design outcome is inseparable from making an explicit claim of knowledge. At the DeSForM 2015 conference, the main objective of prototypes is to demonstrate and test new interaction modalities between users and systems, in order to show both their usability and technological feasibility. Demos have been clustered according to four main themes, where aesthetics of interaction comes at stake to shape new relations between users and products, services, and tools.

## **Smart and active devices for health and well-being**

Health and well-being represent an ever-growing issue in the field of research in general, and, therefore, in the specific field of design research too. Indeed, in developed countries, there is a strong interest in contributing to the sustainability of the health and care systems, above all because of the trend towards an ageing population. In the transition from the idea of "health" to that of "well-being", we can trace an important reason for valuing the contribution that design can offer to the humanization of technology. Indeed, as stated by Alberto Ardisson [13] "in the existing literature while the concept of health is linked to a negative meaning [...] interpreting it as a lack of illness, the concept of well-being on the contrary is elaborated in a positive way" (p. 173) From this perspective, Pullin (cited in [14, p. 49]) shows how design can broaden the traditional medical and engineering perspective on illness by including qualities related to the user's emotions, identity, and desires in the design of medical devices. Moreover, design often encourages a non-pharmacological approach, which also is obtaining a raising interest in the medical field. According to this growing interest in well-being within the design community, five out of fourteen demos presented at DeSForM 2015 reason around it.

The demo "Family Arizing" by Croes and Feijs is a system that allows parents to "stay in contact" with their premature born babies and, in cases of child distress, provide them with a remote comforting hug. The system is made up of two components: an active necklace and the active snuggle. The child's movement is communicated

to a necklace worn by one of the parents. If the parent decides to 'comfort' the necklace, an intelligent mattress inside the child's incubator will warm up and physically hug the child.

"Aires" by Hoogeweegen<sup>1</sup>, Toeters, and Feijs is an underwear collection designed to support women in their menopause, contrasting one of the most common symptom: hot flashes. This is a sensitive issue, since according to Utian [15], cited by the Aires authors: "Women confronted with menopausal hot flashes make more use of the health care system and are confronted with other extra expenses". Aires is an active bra that proposes a non-pharmacological approach, simply cooling the woman upper-chest area by ventilation.

The demo "Sofi" by Arquilla and Fiorinelli presents a smart product-service-system for the management of Asthma, which is the most common respiratory disease in Western countries and is seriously affecting the cost of healthcare systems. SOFI consists of two medical devices (an inhaler used both for emergency and daily therapy, and a tool for DIY lungs' monitoring) and a mobile application. The two devices aim at showing patients what they need and when they need it in a user-friendly way; the application aims at improving the asthma control by the doctor, thus reducing the user's anxiety and the need for doctor-user direct interaction.

The demo "Light Bird" by Yu, Song, and Feijs deals with stress, as an important cause of several illnesses like heart disease, hypertension and stroke. In stress mitigation, biofeedback-assisted breathing training is nowadays increasingly applied. According to the authors, the majority of biofeedback systems offer the average users a 'medical style' interface, which is too task-oriented to feel relax using it. On the contrary, Light Bird is a paper-crane shaped interface. The crane's body fluctuates up and down periodically, providing the targeted breathing rate. The aim is to improve the effectiveness and the experience of breathing-training.

The last demo, "Activating Wearables" by Daems, Toeters and Feijs is an active scarf that detects the wearer's heartbeat and moves accordingly. The aim is to help the wearer to perceive his heartbeat, which helps him to express his emotional state to others. This demonstrator shows the marriage of 'hard' technology with 'soft' textiles in a subtle moving wearable product.

## **Engagement in arts by new media**

Design has often been defined as the middle earth between arts and technology. Design and arts have many common points, among which the attention to aesthetics (intended as senses delighting) and to meaning transfer by such aesthetic features. For this reason, it is common for arts and design to overlap and contaminate each other, giving birth to "artistic" design pieces, or to "functional" artworks. Recently, the boundaries between arts and design have become even more blurred, as new forms of artistic expressions, like digital arts, emerged, mixing up artistic and design approaches. Indeed, the world of arts has been significantly affected by the development of new technologies and new media. Not only has technology changed the nature of artworks (which started to include new communicative media, like sounds or animations), but it also has affected the way people enjoy and interact with artworks. As a consequence, also the space that once contained art pieces has to be redesigned and adapted to the features of these works and to the needs of a new kind of public. "Designers and artists have integrated recent advances in interactive, tangible and ubiquitous computing technologies to create new forms of interactive environments in the domains of work, recreation, culture and leisure" [16, p. 509].

Interactive installations and exhibitions are becoming a natural way to experience arts, by the integration of smart systems, movements, communication media, videos, sounds, projections, etc. "Nowadays, the focus in museums is shifting towards the use of artefacts for providing an interactive experience to visitors, in contrast to the traditional museum approach, where the focus was on the collection, display and storage of objects." [17, p. 104].



For this reason, interacting with arts becomes a multi-dimensional and multi-sensory experience, where many design competences come at stake.

Technology can be used both to create new pieces of arts (interactive, smart or generative artworks), and to provide deeper and more engaging experiences with ancient artworks, which are reinterpreted, displayed and explained in a new way.

Three of the demos presented at DeSForM 2015 discuss this wide issue, by addressing different ways in which design, arts, aesthetics and technology are blended together to create engaging interactive experiences.

Nowadays, digital media can reproduce artworks, can create a dialogue between the user and the work, or can provide additional information [18]. Indeed, technology can be used to provide information on single art pieces or on whole art periods, contexts, and artists' lives by the creation of immersive and emotional experiences. In their demo "Visualising Vincent's life: An engaging experience into Van Gogh's heritage", Calvi, Hover, Ouwens, and van Waalwijk exemplify this approach by presenting an interactive experience where the places and landscapes where the young Van Gogh lived are represented by "immersive mixed media experience combining physical and digital elements". This experience was designed in order to "connect Vincent's works with the locations where the paintings were made and [to] motivate tourists to visit those locations in person". Technology thus becomes a means to emotionally immerse the user into the painter's life, making him become the artist himself and engage into a deep experience of the painter's heritage.

Arts and design (especially some design strands, like critical design) are domains that are constantly in dialogue with society and where social issues are often discussed. In this view, aesthetics is used as means to trigger reflection over relevant questions, by acting as a provoking expressive language. By leveraging the ability of new technologies to create engaging and interactive aesthetic experiences, such provoking and reflective side of arts can be made much more effective and meaningful. The paper by Marti, Peeters and Trotto, "Ethics in Aesthetics: Experiencing Women's Rights", well expresses how the interaction design's perspectives and skills can overlap with arts and society to create immersive experiences about social issues. The demo presents an interactive exhibition that fosters the user reflect on women's rights, by using famous paintings that are reinterpreted and made dynamic.

New technologies allow the creation of new forms of visual aesthetics. Dynamicity and time become elements to create non-static and interactive artworks. These can either be re-interpretations of famous paintings or can be especially generated to exploit the potential of new technologies. The paper "Dynamic aesthetics of generative two-dimensional geometric art" by Fejis and Hu presents generative art examples based on famous visual references (Mondrian's compositions and pied de poule patterns), which are reinterpreted in a dynamic way by the use of algorithms. The artworks can be modified by the visitors, who interact with the work by changing the parameters of the algorithm generation.

## **Experimenting new interaction modalities**

"As user interfaces have turned into increasingly diverse physical forms, it becomes relevant to discuss how this shapes the way we look at user interaction, and especially the models that we use to describe such forms of interaction" [19, p. 251].

As technology is always more merged with the physical world, new paradigms for the interaction between people, computers and objects are to be defined, concerning the notion of perception, information sharing, human cognitive skills and bodily actions [19].

Recent research in interaction and industrial design has focused on conceptualizing, developing and testing new forms and modalities of interaction with computer devices and products. By focusing on the product/interface's behavior on the one side and on the user's actions on the other, designers and scholars explore how meaning is

created in interaction. Indeed, traditional forms of interaction need to be reframed and redesigned as technology merges with physical reality and new technologies allow the development of more natural, intuitive and gestural interfaces for accessing the virtual and digital world, or for controlling the products' functions. This attention towards user's actions and smart system's behavior, typical of interaction design, has been defined as the "action centric" approach, as opposed to the "data centric" approach of Human Computer Interaction. These interactive experimentations across virtual and physical can be gathered under the name of Tangible Interactions. Such approaches have different aims and features, but they all try to find new modalities for i) controlling and manipulating virtual data, by developing more natural and physical interfaces; ii) interacting with product's smart functions, by avoiding buttons and keyboards; iii) conveying digital information to users in physical ways. Four demos presented at DeSForM 2015 fit this cluster. They show how the investigation of user's or product's "behavior" can be explored by different viewpoints and can suit different tangible or intangible solutions in the design domain.

Two demos deal with the investigation of the behavior of smart and dynamic interactive products. The demo "Animism Expression: Materializing Basic Principles of Animation for Interaction Design", by Lin, Liang, Wang and Hsu explores how to create more "natural interaction experiences" by exploiting the methods, principles and approaches of animation. Authors present eight principles derived from animation that can be applied to the design of interactive living things. They demonstrate how to leverage them by designing interactive cubic prototypes showing light and physical transformations.

The demo by Elderman and Hur, titled "Exploration of Interaction Methods for Shape-Changing Interfaces", illustrates a toolkit developed to help designers to prototype shape-changing physical interfaces, without the need of hard technical or programming skills. This work shows how important prototyping is in the design process, especially when interaction modalities need to be assessed.

The other two demos focus on the actions performed by users while interacting with an electronic product (the first demo) and a digital interface (the second one). The demo "An Exploration In Kitchen Blender Interactions Aimed At Designing For Higher Levels of Engagement" by van Rheden and Hengeveld investigates how to redesign current interaction modalities with a kitchen blender, in order to generate more engaging experiences. Authors attempt to overcome the "standardization" of operational modes of electronic products (mainly consisting in buttons and menu screens) to reach richer forms of interaction, based on physical gestures inspired by the use of physical and mechanical objects.

The second demo "Unify: Sharing Digital Media Content from the Cloud through Physical Interaction" by Zoontjens, Oogjes and Hu explores new ways to interact with intangible media using digital devices. The demo illustrates how affordances of the physical world can be introduced in the interaction with cloud-based services to share digital media. Intangible media are treated as tangible elements that are subject to the law of physics, thus requiring the user to adopt natural gestures to control and manipulate them.

### **3D printing for designing enhanced interactions**

Nowadays, a widespread debate is going on about how much the possibilities offered by new digital manufacturing technologies are affecting the way in which product design is perceived, practiced, manufactured, traded, taught, and learned. Fab-labs, makers, new-craftsmanship, Do-It-Yourself, micro-production are just a few of the related topics. "It is an emerging socio-technical paradigm characterized by new forms of advanced, open and distributed manufacturing." [20]

In parallel to the theoretical debate - and in order to nurture it - several experimentations are occurring. Their aim is to test both the limits and the possibilities offered by 3D printing.

Two of the demos presented at DeSForM 2015 belong to this category, both proposing an approach to integrate digital manufacturing in the design process in order to design enhanced interactions. The first demo focuses on how to test the aesthetic appreciation of a tangible product, the second one on how to translate data coming from the product use in its form, in order to create a unique and personalized user-product interaction.

In the demo “A Design Research Methodology using 3D-Printed Modular Designs to Study the Aesthetic Appreciation of Form and Material” Post, Saakes and Hekkert study how small changes in form and material properties influence the aesthetic appreciation of a product. In this appreciation, both visual and tactile properties strongly interact. Indeed, while our first impression of a product is often visual, later on tactile exploration of the product’s qualities such as weight, texture, and temperature becomes essential. In their previous research, the authors of this demo have shown that the principle of “unity-in-variety” applies not just to visual aesthetics, but also to tactile aesthetics. To explore this principle, the possibility to create detailed and customizable haptic stimuli offered by 3D printing has been exploited, designing and manufacturing a set of car keys that systematically change in form and material.

In the demo “Exploring computational aesthetics for golf club design”, Neu and Irvine describe a design process in which the integration of an interactive application, parametric modelling and additive manufacturing allows to personalize the design of golf clubs heads, resulting not only in an innovative object but also in a unique golf playing experience. According to the authors, “There is substantial research into parametric modelling, individual digital data collection and additive manufacturing independently in design. However, very little research exists which investigates the combination of these tools as an adapted design process”. The integration of these three elements offers a new approach to the mass customization of golf clubs, envisioning a completely new way of designing and manufacturing them.

## References

- [1] Djajadiningrat, T., Wensveen, S., Frens, J., and Overbeeke, K.: Tangible products: redressing the balance between appearance and action. *Personal and Ubiquitous Comp.* 8, 5 (2004), 294-309.
- [2] Boer, L., Donovan, J. (2012), Provotypes for participatory innovation in: *Proceeding DIS '12 Proceedings of the Designing Interactive Systems Conference*, 388-397
- [3] Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research Through Design as a Method for Interaction Design Research in HCI. In *CHI '07 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 493-502). doi: 10.1145/1240624.1240704.
- [4] Zimmerman, J., & Forlizzi, J. (2008). The Role of Design Artifacts in Design Theory Construction. From Human Computer Interaction Institute, Paper 37, Web site <http://repository.cmu.edu/hcii/37/>
- [5] Mareis, C. (2012). The Epistemology of the Unspoken: On the Concept of Tacit Knowledge in Contemporary Design Research. *Design Issues*, 28.2, 61-71.
- [6] Bang, A. L., Krogh, P. G., Ludvigsen, M. & Markussen T. (2012). The Role of Hypothesis in Constructive Design Research. In *The Art of Research 2012: Making, Reflecting and Understanding*. Helsinki : Aalto University School of Arts, Design and Architecture. Retrieved September 30, 2013, from [http://designresearch.aalto.fi/events/aor2012/download\\_content/selected\\_papers/anne\\_louise\\_bang.pdf](http://designresearch.aalto.fi/events/aor2012/download_content/selected_papers/anne_louise_bang.pdf)
- [7] Zimmerman, J., Stolterman, E., & Forlizzi, J. (2010). An Analysis and Critique of Research through Design: towards a Formalization of a Research Approach. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 310-319. doi: 10.1145/1858171.1858228
- [8] Frens, J. (2007). Research through Design: a Camera Case Study. In R. Michel (Ed.) *Design Research Now: Essays and Selected Projects*, 135-155. Basel: Birkhäuser
- [9] Stappers, P. J. (2007). Doing design as a part of doing research. In R. Michel (Ed.), *Design research now* (pp. 81-91). Basel, Switzerland: Birkhäuser

- [10] Koskinen, I., & Krogh, P. G. (2015). Design accountability: When design research entangles theory and practice. *International Journal of Design*, 9(1), 121-127.
- [11] Rust, C., Roddis, J., & Chamberlain, P. (2000). A practice-centered approach to research in industrial design, in Pizzocaro, S. Arruda, A., de Moraes, D. (eds.) *Design Plus Research: Proceedings of the Politecnico di Milano Conference*, May 18-20, 2000 (pp. 358-365)
- [12] Chen, L. (2007). *International Journal of Design: a Step Forward*. *International Journal of Design* 1.1, 1-2.
- [13] Ardissone, A. (2014) "From health to well-being, from government to governance: epochal transitions" in *SALUTE E SOCIETÀ*, Fascicolo: 2EN Lingua: Inglese, pp. 173-177 DOI: 10.3280/SES2014-002013EN
- [14] Kanstrup, A. M. (2014). Design concepts for digital diabetes practice: Design to explore, share, and camouflage chronic illness. *International Journal of Design*, 8(3), 49-60.
- [15] Utian, W.H. (2005): Psychosocial and socioeconomic burden of vasomotor symptoms in meno-pause: a comprehensive review. In: *Health and Quality of Life outcomes*, Vol. 3, No. 1. Health and Quality of Life outcomes, London
- [16] Morrison, A. J., Mitchell, P., & Brereton, M. (2007, September). The lens of ludic engagement: evaluating participation in interactive art installations. In *Proceedings of the 15th international conference on Multimedia* (pp. 509-512). ACM.
- [17] Danks, M., Goodchild, M., Rodriguez-Echavarria, K., Arnold, D. B., & Griffiths, R. (2007). Interactive storytelling and gaming environments for museums: The interactive storytelling exhibition project. In *Technologies for E-Learning and Digital Entertainment* (pp. 104-115). Springer Berlin Heidelberg.
- [18] Baldissini, S. (2015). Digital media and architectural drawings: a case study from Bramante. *SCIRES-IT*, 5(1), 25-30.
- [19] Fernaeus, Y., Tholander, J., & Jonsson, M. (2008). Beyond representations: towards an action-centric perspective on tangible interaction. *International Journal of Arts and Technology*, 1(3-4), 249-267.
- [20] Menichinelli M., Bianchini, M., Carosi, A., and Maffei, S. (2015) "Designing and making at school. A first systemic overview of Makers in Italy and their educational contexts" in L. Collina; L. Galluzzo; A. Meroni (eds.) "The Virtuous Circle. Design Culture and Experimentation", *Proceeding of The Virtuous Circle. Cumulus Conference 2015*. Milano. McGraw Hill

# The role of design in the development of interactive product service system for the next generation of asthma treatment

## The SOFI case

### Abstract

This paper reflects on the role of design in the development of SOFI, a new product service system for the management of Asthma<sup>1</sup>.

Starting from the idea of *humanization of technology*<sup>2</sup> this project presents an original approach that goes beyond the traditional co-design method where the innovative qualities of the project arise from a process of introspective analysis that sees the researcher as having the dual role of both designer and user, demonstrating an empathic and evolved design approach.

This paper shows how starting from a direct knowledge of the topic, deepened by the scientific literature and the interaction with specialists and researchers, the design can, in a contemporary way, create technology based products [1], and services [2] that have a higher standard quality and that build desirable and emotional elements for people [3][4] producing an advanced and smart narrative ecosystem [5].

### Keywords

Product service system design, empathic design, smart medical devices, asthma, data driven design,

### 1 The contemporary scenario of medicine and chronic diseases

Nowadays society consumes higher amounts of

medications. This phenomenon could be explained by easier access to medical knowledge that lead to increased hypochondria among society [6].

Meantime we can observe the medical practice depends more and more on technological innovations and on the digital revolution, driving medicine to focus primarily on prevention [7]. The way this new *smart medicine* [8] is evolving opens up both new opportunities and critical issues: on one hand it is developing quickly and efficiently, on the other hand it is becoming too objective and less focused on the subjectivity of human beings and how they handle information.

We therefore suggest that new medical technology should support patients rather than confuse them with too much data.

Design, with its ability to analyse user needs and translate them into affordable products and services [4], plays a key role in the pursuit of alternative solutions, and the creation of a new system that can harmonize products and services with patients' lives [3].

### 2 Design and asthma control

Asthma is a chronic lung disease, affecting people of all ages and its rate is increasing year after year. With almost 300 million cases diagnosed, it is the most common occupational respiratory disease in Western countries and is seriously affecting their healthcare

systems. Asthma has no cure, even when the person does not present symptoms, he/she still has the disease and it can flare up at any time. The complexity and heterogeneity of asthma make both its clinical management and investigation challenging [9]. In this paper we showed how design could aid the long term control of asthma, which involves the reduction or removal of symptoms and a full adherence to the therapy, in order to better manage a long period of uncontrolled asthma [10].

The aim is to inform asthmatic people about their illness, decrease their perception that asthma tools as a barrier to their daily lives, help them find the right harmony and create a smart experience during the complex process of therapy [3].

As an asthmatic herself, the researcher employed her 'privileged' point of view, becoming both observer and designer, exploiting user analysis tools, according to the principles of empathic design [11] where: "the more the designer can live and experience the user's emotions, the better can transform the ideas and constraints into appealing and pleasing design solutions".

### 3 The SOFI design process

During the design process we used a classical 4-stages design method [1].

#### 3.1 Investigation of the relationship between users and asthma control medications

We begun by investigating the most common drugs used to treat asthma, types of delivery and the duration and frequency of treatments. Most medications were administered by aerosol spray or by dry inhalator powder and can be either used for acute asthma attacks or for prevention and control. In particular, a new generation of experimental drugs worked in both circumstances, thanks to an innovative solution of extrafine dry powder [12].



Fig. 1. Inhaler comparison

From our investigation it emerged that asthma is usually managed through a long-term control treatment, aimed to minimise possible triggers and guarantee a high quality of life. Confirmed with the specialist there was no ideal medication, all options could be effective when used correctly, and indeed one of the common reasons for uncontrolled symptoms or ineffective therapy was due to incorrect use of the medication. It is therefore important to give people the right information in order to get the best treatment.

Some advancements emerged in the literature:

- Studies on epigenomics [13] of asthma provided better understanding of the disease by using complex and integrated data;
- Several studies have demonstrated that environmental exposures affected the severity of asthma and psychosocial stressors have also been correlated [14].

#### 3.2 A competitive benchmarking on existing products and mobile applications

Our research progressively extended its attention to the *smart medicine* [7] intervention for asthma: we benchmarked case studies against the parameters of innovation, functionality and integration with other tools (these criteria were chosen to better understand the aspects useful to design a desirable and smart system). The examination defined the main guidelines to design an asthma's product service: a system that connected all the global aspects of the disease by means of high-tech features and respected the human dimension of the person.



Fig. 2. Positioning map of the benchmarked case studies

#### 3.3 A focussed user research and a professional concept review

In the next stage the researcher met with other

potential users to better understand their issues and specific needs from people with asthma. The direct experience and the design tools for the user analysis allowed the designer to interact better with both medications and the doctors, who shared daily patient experiences and reviewed the product [15]. The doctors<sup>3</sup> understood the importance of hearing and visualising the right information coming from the patient/designer.

We then defined three aspects at the core of the SOFI system: the *kind of asthma*, which decided the treatment; the *patient's autonomy*, to indicate the links between the user ecosystem (the person with asthma, the doctor and the patient's close network of people) and finally the *gravity of the disease*, alias the symptoms frequency.

In order to manage asthma, it was important to combine user data with relevant environmental variables that also affected the disease, such as climate, temperature variations and pollution. With this knowledge the user could minimise the margin of error on managing their condition.

Today it is possible to access this information thanks to big open-data systems, the internet of things and the new connected *smart cities*. Also, personal health profiles created by patients are the next wave of data that will contribute to a systematic view of the biology of asthma and allergies. Health and environmental data that directly affect an individual's asthma and allergy control could be captured passively by wearable devices and health applications that let asthma person with asthma monitor their condition in realtime [14].

#### 4 SOFI from Smart to Wise

At this point we developed the idea of SOFI, a product service ecosystem that consisted of two medical devices and one application: *SOFI Care* an inhaler used for emergency and daily therapy, *SOFI Listen* a tool for DIY lungs' monitoring, and the mobile application named *SOFI App*.

Thanks to the data collected via the user research and the professional review, we isolated two different groups of data: *user-relevant information* and *system information*. Based on the results of the analysis we developed a product that expressed our data in the form of its specific physical and informative shape.

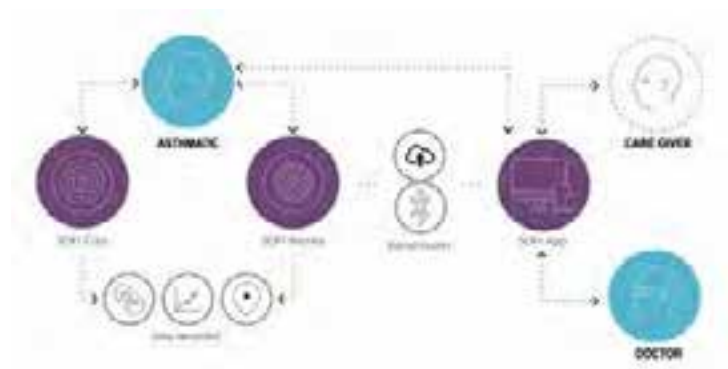


Fig. 3. SOFI Ecosystem Map

SOFI explored the possibilities of a simplified interface, and found a balance between the visual aspects of the app and the product, making for a better and pleasant interaction system.

The information collected from the devices was divided into two main groups: *personal* and *contextual*. The personal data included: breathing status or asthma condition (detected by *SOFI Listen*); asthmatic's habits (doses and frequencies of drugs consumption recorded by *SOFI Care*), and geo-localisation of the user. The localisation allowed the matching with the contextual data (humidity, weather, allergens, level of pollution and traffic patterns).

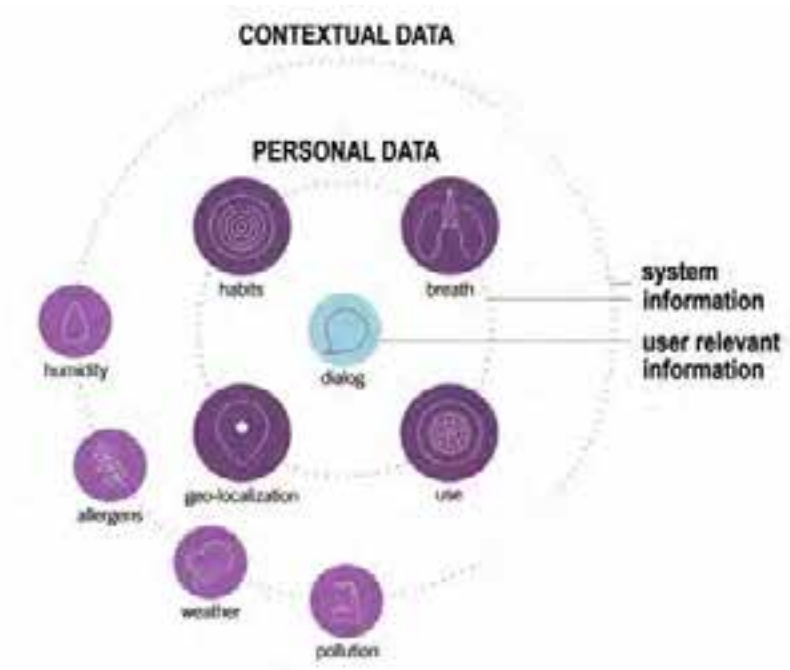


Fig. 4. SOFI Data Flow

The design of the devices was aimed to create a less invasive product:

- *SOFI Care* was based on a new pharmaceutical formula<sup>4</sup>, which is effective for both asthma attacks and long term control therapy.
- *SOFI Listen* was inspired by an Acoustic Respiratory Monitoring (ARM)<sup>5</sup> and a Signal Extraction Technology (SET) [16] both by the American Masimo Corporation. The solution used a small acoustic sensor that "listened" to the user's breathing, who must not force himself to inhale (which usually happens during common spirometry tests). The benefits of *SOFI Listen* were many. The device could be used easily on non-complying patients like small children, and most of all *SOFI Listen* tests did not depend on the lungs force, making the measurement safer and user friendly.



Fig. 5. SOFI Care and Listen

Concerns about aesthetics were vital in the development of SOFI. SOFI devices were far from the common perception of medical tools: usually when we are talking about medical devices we think about cold and sophisticated objects, technically complex [17]. SOFI devices instead were more personal and close to the person, hence the treatment tools were no longer perceived like extraordinary objects but would become part of the daily life [3][4][17]. SOFI followed the person with asthma by working in the background with a hidden high technology, offering a system easily accessible by any kind of user in their own contexts. This is what data driven user experience design is all about. [19]



Fig. 6. SOFI Care and Listen main functions and interaction patterns

Finally, all the information was transmitted wirelessly to the SOFI App and could be displayed on user interface devices, such as smart phones or tablets. The application worked discreetly in the background and used the stored information to remind for example of doctor's appointments, daily doses, recommend the replacement of the medication, and report critical aspects with notifications. The causes that could result in negative notifications are: overuse of the drug or failure to use, unsatisfactory breathing test results and using the device too much<sup>6</sup>. The application also had an emergency function to signal important issues. In order to avoid hypochondriac reactions from people, the function was only available when the system detected an obvious problem (with a negative average over the previous weeks) that required the specialist intervention.



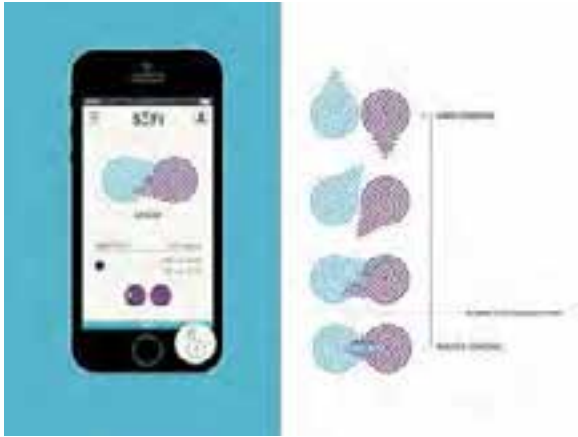


Fig. 7. SOFI App

An important aspect of the design was the visual coding: the designers transformed the data in a graphic pattern that went beyond its functional purpose. The same visual coding defined the device interfaces, and it communicated only user-relevant data: essential knowledge useful to the patient. In this way the information became tangible, it enriched the patient's experience and gave a new sense of the therapy to the user.

The data recorded during the breathing test fell into the system data category and were not visualized by the person with asthma. The system data however contributed to the daily App valuation of the asthma control. In this way the user received a simple and immediate feedback of their state, without being influenced by the result of the individual test; instead, the doctor received details accessible in the profile of each patient. Removing the overloaded communication, The SOFI system can reduce a possible hypochondria. The union of physical and digital space was made possible by the advanced technologies. In SOFI the technology pervaded the asthmatic depending on the frequency of the treatments, but at the same time it worked tactfully thanks to the discreet design of the objects.

## 5 Conclusions

This project explored several topics, such as user experience, meaningful everyday practices and emotions, turning them into an innovative solution. SOFI is a smart system, based on the deep understanding of the wants and needs of customers. SOFI aimed to make the therapy more efficient, easier to communicate and remember, as it paid

attention to the subjective perception of the illness. The use of intuitive terms and icons helped to process information easily, through empathic design that combined subjective and objective approaches. SOFI, as a product, showed people what they needed and when they needed it in a user-friendly way but also, as an application ecosystem, helped the doctor improve the asthma control, and reduce the anxiety and the direct interactions with the user.

SOFI experimented with new languages in the healthcare context, prefiguring new fields for consolidated technologies. SOFI is a way of managing asthma in a more empathic, desirable and sustainable way. By applying design to new fields, such as biomedicine, we defined new desirable scenarios where design became a "Future-Making" tool [20].

The pharmaceutical and technological progress will always change society and its cultural. Therefore, design can produce wise user-centered solutions, which can match patients' needs and effectively challenge their fears defining new narratives [5].

## References

1. Ulrich K.T., Eppinger S.D.: Product Design and Development. McGraw-Hill (2008)
2. Stickdorn M., Schneider J.: This is service design thinking. John Wiley & Sons, Inc., Hoboken, New Jersey (2011)
3. Parameswaran L., Raijmakers J.: PHILIPS DESIGN, People-focused innovation in healthcare. [http://www.newscenter.philips.com/main/design/news/publications/PhilipsDesignPublication\\_people\\_focused\\_innovation\\_in\\_healthcare.wpd#.VUIHJRfzTmR](http://www.newscenter.philips.com/main/design/news/publications/PhilipsDesignPublication_people_focused_innovation_in_healthcare.wpd#.VUIHJRfzTmR) (2010)
4. Norman D. A.: Emotional Design: Why We Love (or Hate) Everyday Things. New York: Basic Books (2004)
5. Cautela C., Zurlo F.: Design Strategies in Different Narrative Frames. In: Rizzo F., Deserti A., Cautela C., Zurlo F.: Design Issues Winter 2014 Special Issue: Design and Innovation: How Many Ways?. Vol. 30, No. 1, Pages 19-35. MIT (2013)
6. Kaplan W., Mathers C.: THE WORLD MEDICINES SITUATION 2011. World Health Organization, [http://www.who.int/medicines/areas/policy/world\\_medicines\\_situation/en/](http://www.who.int/medicines/areas/policy/world_medicines_situation/en/) (2011)
7. European Commission (White paper), Together for Health: a strategic approach for the UE 2008-2013 (2014)
8. Brock, D. L.: Smart Medicine—The application of Auto-ID Technology to Healthcare. Auto-ID Center, Mass. Inst. Technol., Cambridge, (2002)

9. Global Initiative for Asthma. (2014), POCKET GUIDE FOR PHYSICIANS AND NURSES 2014, <http://www.ginasthma.org/documents/1> [Accessed: 14th January 2015]
  10. Zafari, Z., Lynd, L. D., FitzGerald, J. M., & Sadatsafavi, M.: Economic and health effect of full adherence to controller therapy in adults with uncontrolled asthma: a simulation study. *Journal of Allergy and Clinical Immunology*, 134(4), 908-915. (2014)
  11. Mattelmäki, T., Vaajakallio, K., & Koskinen, I.: What Happened to Empathic Design?. *Design issues*, 30(1), 67-77. (2014)
  12. Smith, I. J., & Parry-Billings, M.: The inhalers of the future? A review of dry powder devices on the market today. *Pulmonary pharmacology & therapeutics*, 16(2), 79-95 (2003)
  13. Rosenberg, S. L., Miller, G. E., Brehm, J. M., & Celedón, J. C.: Stress and asthma: Novel insights on genetic, epigenetic, and immunologic mechanisms. In: *Journal of Allergy and Clinical Immunology*, 134(5), 1009-1015. (2014)
  14. Bunyavanich, S., & Schadt, E. E.: Systems biology of asthma and allergic diseases: A multiscale approach. In: *Journal of Allergy and Clinical Immunology*, 135(1), 31-42 (2015)
  15. Veryzer, R. W., & Borja de Mozota, B.: The Impact of User Oriented Design on New Product Development: An Examination of Fundamental Relationships. In: *Journal of product innovation management*, 22(2), 128-143. (2005)
  16. Goldman, J. M., Petterson, M. T., Kopotic, R. J., & Barker, S. J.: Masimo signal extraction pulse oximetry. *Journal of Clinical Monitoring and Computing*, 16(7), 475-483. (2000)
  17. Ogrodnik P. J.: *Medical Device Design: Innovation from concept to market*, Elsevier (2012)
  18. Weinschenk S.: *100 Things every designer needs to know about people (voices that matter)*. Paperback, Berkley, Canada (2011)
  19. Phillip A. H.: *Data Driven Design, how today's product designers approach user experience to create radically innovative digital products*, R&R Publications, Stroudsburg PA (2013)
  20. Yelavich S., Adams B., *Design As Future-Making*, Bloomsbury, (2014)
- <sup>1</sup> This paper is the evolution of the Master Degree thesis of Fiorinelli G., SOFI the discreet assistant: analysis and design of a product-service design for the daily asthma treatment. Mentor Arquilla V., Politecnico di Milano, 2014
  - <sup>2</sup> According to the ICSID definition – <http://www.icsid.org/about/about/articles31.htm>
  - <sup>3</sup> The project was reviewed and developed with the supervision of Dr. Cottini M., author of several publications and internationally recognised expert member of the Società Italiana Allergologia, Asma ed Immunologia Clinica
  - <sup>4</sup> Team Consulting patent
  - <sup>5</sup> <http://www.google.com/patents/US8690799>
  - <sup>6</sup> In this paper the terms positive and negative are not derived from the medical language, therefore when the result is negative it does not mean it went well but rather the opposite.

# Visualising Vincent's life: An engaging experience into Van Gogh's heritage<sup>1</sup>

## Abstract

The paper describes the preliminary outcome of the project *Becoming Vincent*, a consultancy project commissioned by the Brabant region to promote itself by using Van Gogh as a brand image. For this project, we developed a narrative concept based on Vincent's younger years and we translated this concept into an immersive mixed media experience combining physical and digital elements. While this exact mapping of the physical onto the digital experience is still work in progress, we describe here our first result, which consisted in a virtual encounter with the child Vincent by means of the Oculus Rift. In the paper, we discuss why we chose this medium and why we think this was a good way to engage visitors of Van Gogh's heritage into an emotionally meaningful experience.

## Keywords

Storytelling, design for experience, virtual reality, emotionally meaningful experience

## 1 Introduction

2015 is 125 years after Vincent Van Gogh's death. To celebrate this iconic artist the Regional council West Brabant together with the Van Gogh Brabant Foundation commissioned our university the drafting of a tourism development plan for the Dutch region of West Brabant using Van Gogh as the connecting pin. This plan had indeed to connect the several locations in

the region that are related to Van Gogh, either because he lived there or because he worked there.

Van Gogh the artist is indeed mostly associated to Amsterdam, where the museum named after him and collecting most of his work, is located. Or to France, where he spent the last years of his life, part of which hospitalised in a psychiatric institution, and where he eventually took his own life in Auvers-sur-Oise in 1890. But few know that Van Gogh was born in Zundert, a small village in West Brabant, and spent his early life from child till young adulthood in various places in Brabant. The plan we developed takes in fact the form of a narrative concept for a tourist experience that uses the principles of storytelling to disclose Vincent, the man behind the artist, with his struggles, his strengths and weaknesses, his failures and successes. The concept offers a frame to better understand Van Gogh's art by embedding it into the life he lived in Brabant, and by showing the influence this environment had on the making of the artist we know since then, by disclosing what he felt and experienced till his mid-twenties [2]. In the next section, we outline briefly the design process we followed to understand the meaning of the concept we developed. Next, we discuss how we translated this concept into an emotionally meaningful experience for tourists, by using one specific visualization technology that is the Oculus Rift. We discuss why we chose this technology and why we think this was a good way to provide cultural tourists

of the region a new and unique view and encounter with the man behind the artist we all know, who still remains one of the most influential artists of all times. This experience, we believe, discloses and reveals Van Gogh in a way tourists had never experienced before and can be considered an improvement in their own understanding of his life and art.

## 2 Becoming Vincent

When studying Van Gogh's life and work, through for instance the more than 900 letters he wrote, we recognized the presence of many "universal" themes like love, friendship and brotherhood, the importance of family ties, conflicts, religion, loneliness, adventure. This allowed us to draw parallels with a universal storyline. So, for the narrative elaboration of the concept, we compared Van Gogh's life to a universal storytelling model consisting of twelve steps (Fig. 1) [1] that mirrors the 'hero's journey' [3] and [9], a structure that can be

recognized in many great myths, tales and legends. It is striking to see how Vincent's life completely matches the twelve steps, in terms of challenges, crises and resolution (Fig. 2).

In Figure 2, the 12 steps described in Figure 1 are indicated and each of them is linked to one location where Van Gogh lived. Additionally, for each location the corresponding period in Vincent's life is given. The 12 steps are indeed chronologically ordered. Finally, we associated to them a theme that characterizes Vincent's life in that period. For his birthplace Zundert for instance, we suggest to create the experience around Vincent's early childhood: what was it like to live as a Protestant son of a parson in a Catholic community? What did it feel like for young Vincent to visit his brother's grave every year on his birthday? A highly immersive experience like the one through the Oculus Rift makes the emotions associated with this experience stronger [8].

We did this exercise for the first 6 steps, which correspond to the period Van Gogh mostly spent in Brabant before definitely moving to France, where he eventually died. These 6 steps represent what we called *Becoming Vincent*, Van Gogh's formation years. The remaining 6 steps represent the last few years Van Gogh spent in France where he became famous as the artist we all know. His French period we labeled *Being Vincent*. This narrative concept (Fig. 2) is an overarching concept connecting the locations where Van Gogh lived one after the other and allows potential tourists to experience all corresponding locations as a coherent whole. Experiencing a certain step of Vincent's life in one place will indeed encourage the tourist to want to know more about the rest of the story, that is by moving to another location.

This narrative concept has in itself two layers. Firstly, it aims at telling the backstory of how Vincent became the person and the artist who is so well known from his French period, the *Being Vincent* part. Secondly, the concept allows tourists to identify fully with Vincent, and therefore to 'become Vincent' themselves during their experience at the above mentioned locations. Because the characteristics in Vincent's story are universal, they can appeal to tourists from any cultural background.

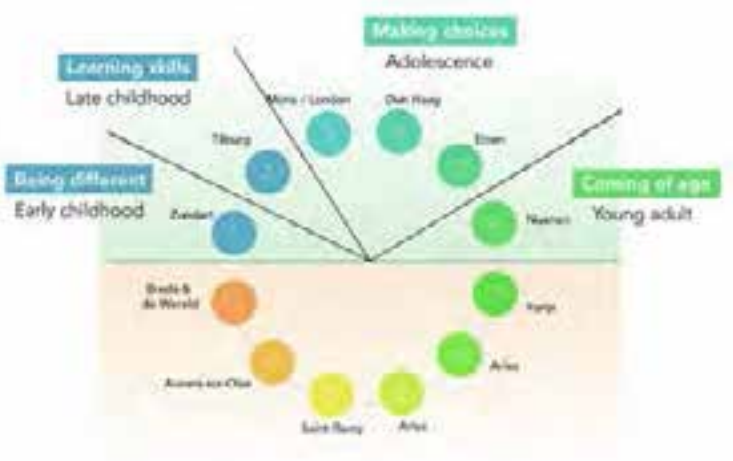


Fig. 1. The hero's journey [1]

Fig. 2. Vincent's journey

### 3 The Experience

This unique experience that we designed relies on a digital component to engage tourists in a truly emotionally meaningful discovery of Vincent. Because we want tourists to feel how Vincent felt, we want them to *become* Vincent themselves, we intend to build an engaging and immersive experience and we think that the best way to achieve this is by using mixed media to connect all locations where Van Gogh lived. Such locations had already been connected narratively via the storytelling concept (Figs. 1 and 2) and will in this way be also connected virtually and eventually physically by encouraging tourists to visit them directly once they have experienced in any way at least one of them. This is very relevant in the context of this project considering the fact that no artwork is present and exposed in Brabant (most paintings being in the museums in Amsterdam or in Otterlo) but the Brabant landscape is present in many early paintings Van Gogh made. Digitally, we can connect Vincent's works with the locations where the paintings were made and this can motivate tourists to visit those locations in person also. In this initial stage, however, we chose the Oculus Rift as visualization means (Fig. 3). We chose this platform because it gives a sense of full immersion, of engagement and involvement although in the demo we developed this is kept limited at the moment as no interactivity is foreseen.

The Oculus Rift [6] is a head-mounted display that allows immersion into a virtual reality with a 3D stereoscopic vision on a 360 degree field of view. Mainly used for games, it is gradually starting to be used with other media, like films [7].

The experience we developed takes place in the garden of the house where Vincent was born in Zundert. The experience starts with the viewer in front of Vincent's house. They can then fly into the garden and at the end of it they meet the child Vincent, who tells them about the time he spent in the garden, and what he was doing. There are children's voices in the back: those are the children going to the village school from which Vincent was removed by his father who thought Vincent did not belong there. We hope in this way viewers will feel the sadness in Vincent's voice from being excluded, and that he really loves this place as being full of beautiful memories about his mother and his brother Theo. Ultimately, we want this to be a sensuous experience as Jacucci [5] calls it, that is an experience that involves

more or all senses, to offer tourists an interaction that is both physical and emotional. Physical, so they can touch and manipulate things. And emotional, as we believe that only in this way we can ensure they can truly 'become Vincent' themselves.



Fig. 3. The experience with the Oculus Rift

In the steps to come, this kind of experience will involve active participation of the tourists. They will be encouraged to be curious, to explore, using Vincent's life and the 12 steps as guidelines. They could start at any point in the circle in Figure 2 and then explore the rest freely. This design opens up new perspectives to experience Van Gogh's heritage as a whole and to live a unique tourist experience, unique both because it connects otherwise separated locations and unique as in view of becoming Vincent.

### 4 Conclusion

In this short paper, we have shown the use we are making of novel visualizing technologies to build an emotionally engaging experience for tourists. This experience and the aesthetics thereof consist in merging the virtual and the physical and by putting both inside a narrative frame that makes it a truly meaningful experience. It is meaningful because it is touching and it is touching because it relies on universal principles that everybody can identify with and mirrors an unfolding that is a universal storyline with timeless appeal.

### Acknowledgements

We would like to thank Hans Bouwknecht for initiating this project; the Regional council West Brabant and Landstad de Baronie for financing it; Frank van den Eijnden, director of the Van Gogh Brabant Foundation, and the members of the Advisory Board, in particular Francis Witmer, for supporting our work; and finally Andy Sandham for developing the demo with the Oculus Rift.

## References

1. Bouma, M.: *Storytelling in 12 stappen, op reis met de held*. Antwerpen (2010)
2. Calvi, L., Bouwknecht, H., Hover, M., Ouwens, F., van Waalwijk, J. van Schendel, A.: *Experiencing Van Gogh's heritage: A case study*. In: *Proceedings of the Electronic Visualisation and the Arts Conference 2014*, pp. 71–72. London (2014)
3. Campbell, J.: *The Hero with a Thousand Faces*. Princeton University Press (1968)
4. Hover, M.: *De Efteling als 'Verteller' van Sprookjes*. Kaatsheuvel (2013)
5. Jacucci, G.: *Interaction as Performance. Cases of configuring physical interfaces in mixed media*. Doctoral Thesis, University of Oulu, Acta Universitatis Ouluensis (2004)
6. Kumparak, G.: *A brief history of oculus (2014)* retrieved on April, 23rd 2015 from: <http://techcrunch.com/2014/03/26/a-brief-history-of-oculus/>
7. NBF: *Wereldprimeur virtual reality-film op Go Short*, retrieved on April, 23rd 2015 from: <http://www.nbf.nl/2014/04/10/wereldprimeur-virtual-reality-film-op-goshort/>
8. Visch, VT., Tan, ES. and Molenaar, D.: *The emotional and cognitive effect of immersion in film viewing*. In: *Cognition & Emotion*, Volume 24, Issue 8, (2010)
9. Vogler, C.: *the writer's journey: Mythic Structure For Writers*. Michael Wiese Productions (2007)

---

<sup>1</sup> This short paper further extends and elaborates on a previous demo paper presented at the EVA Conference in London in 2014 [2].

<sup>2</sup> Vincent was born one year to date after the first Vincent of the family was still-born. The Vincent we know was a replacement child to a certain extent. The church where the father preached and the grave of the still-born baby are still present in Zundert.

# Family Arizing

## Abstract

In this demo we show the two main components of the Family Arizing system which allows parents to stay in contact with their child and, in cases of distress, provide the child with a remote comforting hug. The two components to be shown are the active necklace and the active snuggle.

## 1 The demonstrator

The demonstrator proposed is the result of a project by Misha Croes which started with following brief:

- Design and test a product or service providing parents of premature neonates a sense of connectedness to their child, during the first period after child birth ensuring a drop in the level of stress experienced by the parents and (if possible) the premature neonate.

The Family Arizing system allows parents to stay in contact with their child and, in cases of distress, provide the child with a remote comforting hug. The child's movement (an indicator of stress) is communicated to a necklace worn by one of the parents. If the parent then 'comforts' the necklace, an intelligent mattress inside the child's incubator will warm up and physically hug the child, hence providing comfort. The neonatal aspects have been reported elsewhere [1], but here the goal is to show the working demonstrator.



Fig. 1. Necklace of the Family Arizing project.

The system consists of four components (two of which form the demo). The four components are:

- A camera to capture the baby's movements or other signs of discomfort;
- A two-way communication link including Internet connectivity and a Zigbee wireless link;
- A necklace to be worn by one of the parents which will move when the baby moves. Moreover the necklace senses when the parent squeezes the necklace (when activated) and this will be retransmitted to the neonatal intensive care unit. This movement is then translated into a movement of the active snuggle (the fourth component);
- An active snuggle.

The necklace and the active snuggle will be demonstrated at DeSForM. The necklace works with an internal servomotor whereas the snuggle is actuated by a smart memory alloy.



Fig. 2. The snuggle before and after activation

In Fig. 3 the sensing principle of the servo is explained. When the servo experiences friction or a counterforce, the DC motor in the servo has to work harder (because of the internal feedback loop). Therefore, measuring DC current is a convenient way to sense external friction or counter force.

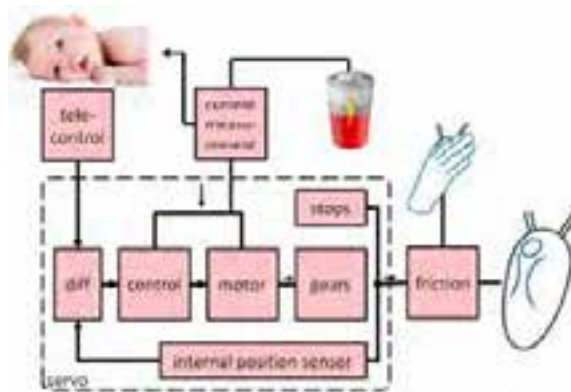


Fig. 3. Internal working of the necklace. Inside the necklace a servo mediates the (remote) child's movement. At the same time the servo senses by current measurement whether the user holds or squeezes the necklace.

## 2 Design aspects

It is outside the scope of a demonstrator description to include full user scenarios. But we like to add a few remarks about some important design choices. In particular, the reader might question the choice for a necklace (what if the father would like to use it?). Actually, the necklace was chosen with very much the father in mind, also see [2]. We thought about the movement a child generates inside the womb: the child pushes outward against the wall of womb which the mother will feel strongly. The father will feel this movement on the outside as a force pushing

outward. Therefore we explored whether the same movement can be created by using a vertical actuator pushing against an elastic surface (which was eventually implemented). As an alternative we also considered bodywarmth communication, but this seemed more fit for the mother (who is known to co-regulate temperature during kangaroo-mother care) than for the father.

The concept was evaluated in focus group sessions involving experts and parents from an association of incubator-children in The Netherlands. The focus group was organized as a means of evaluating the design concept from the user's perspective. Two examples of insights gained are mentioned here. First, typically mothers would be very interested just in the condition of her child, whereas the fathers would be also be interested in all the medical numbers and monitors to see how their child was doing. Secondly, most parents expressed the feeling of wanting to know what effect the hugging would have on their child.

Misha Croes was awarded the 2011 Dutch national prize for the best graduation thesis on innovations in healthcare. The prizes were awarded by FWG, an organisation for job rating in health care, and ZonMw, an institute supporting health care research and innovations.

## References

1. Croes, M.J.G., Bambang Oetomo, S. & Feijs, L.M.G. (2012). Designing remote connectedness between parents and their premature newly born : a design proposal. In W. Chen, S. Bambang Oetomo & L.M.G. Feijs (Eds.), *Neonatal monitoring technologies: design for integrated solutions* (pp. 386-413). Hoboken: IGI Global.
2. Lindberg B., Axelsson K. and Ohrling K. (2007) The birth of premature infants: Experiences from the fathers' perspective. *Journal of Neonatal Nursing*, 13 (pp. 142-149) .



# Activating Wearables: The Butterfly Effect

## Abstract

In this demo we show an active garment to support people in matters of emotion regulation and interactions with other people. This demonstrator shows the marriage of 'hard' technology and 'soft' textiles in a subtle moving wearable product.

## Keywords

Wearables, Fashion, Actuation, Feedback loop, Interaction Design,

## 1 The demonstrator



Fig. 1. Surface detail of the demonstrator: rubber with cotton fabric. (© Ruben Daems)

**Concept.** The Butterfly Effect is a scarf for men, activated by servomotors, which will show the person's heartbeat through the collar's movement. The movement is subtle, yet clearly visible.



Fig. 2. The Butterfly Effect in action: before (left) and after (right). (© Ruben Daems)

The scarf helps you to express your emotional state of attractiveness to another person. When you come close to some one that you like, you get nervous and your heartbeat start to rise. The scarf starts to move according to this beat in an attempt to make the other person aware of your emotional state. The design was inspired by the work described in (Feijs, Toeters 2014).

**Use-case scenario.** Public areas are places where people meet each other, possibly new people or loved ones. Some men have trouble with contacting girls they feel attracted to. They are shy or afraid of rejection and with the presents of a certain person, the feeling of nervousness rises and your heart start to beat faster. In order to create opportunities for these men to open up, the scarf starts to move according to your heartbeat. Our hypothesis, constructed by

the research of Ferguson and Katkin (1996) is that the motion of the scarf attracts the attention of the girl and possibly provokes a conversation. This way you can break the barrier that's holding you from meeting this girl and expressing your emotions to her. The heartbeat represents the relation between affection and the symbolic meaning of the heart. This scarf is meant for men, however future designs could also be applicable for women.

For a use-case scenario we refer to the movie which is online available: <https://www.youtube.com/watch?v=aLOJ-MekSNs>.

Stefan Wiens, Elizabeth S. Mezzacappa, and Edward S. Katkin (2000) stated that "heartbeat detection as an index of self-perception of visceral activity is associated with intensity of emotional experience but not with valence." This indicates that heartbeat can express the emotional state of the wearer. However, this is no indication for the type of emotional state. "Additionally, subjects who were able to perceive their own heartbeats were found to be more facially expressive than poor perceivers." (Melissa L. Ferguson and Edward S. Katkin, 1996). *The Butterfly effect* helps the wearer to perceive their heartbeat, which helps him to express his emotional state to others.



Fig. 3. Still from *The Butterfly Effect* movie, product in context (© Ruben Daems)

**Technology.** A pulse sensor (<http://pulsesensor.com/>) measures your heartbeat; this can be done either on your fingertip or earlobe (Latin: Lobule). The sensor sends its data to an Arduino Lilypad (ATmega328) sewed into a compartment, which translates the data into a beat. The software compares the beat to three different states. If one of the states is true, the software sends a signal to the four servomotors. The servomotors are placed in a clip, which is sewed into the scarf. The

servomotors set the triangles into motion by turning 80 degrees at three different speeds, according to the state of your heartbeat. The system works on 5,5V provided by a battery pack, which is integrated in the scarf.

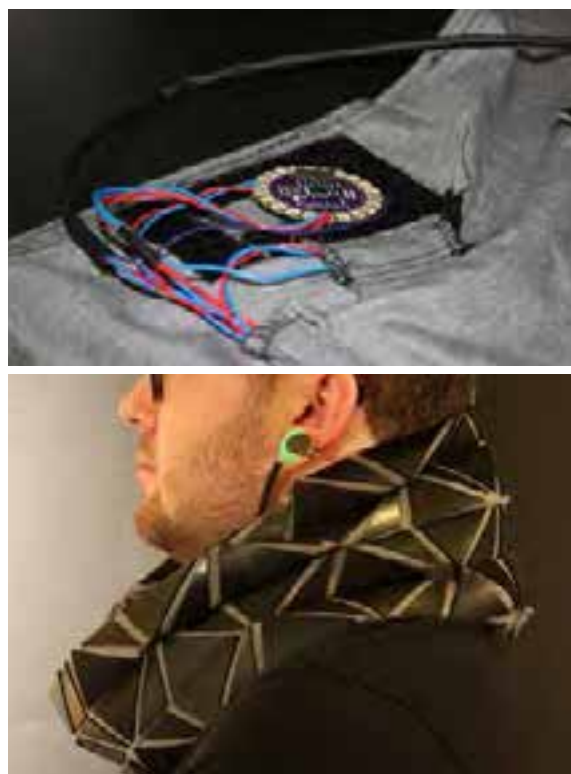


Fig. 4 & 5. Lilypad and Pulse sensor ear clip (© Ruben Daems)

**Surface design.** The scarf exists of big and small triangles. See fig. 1 and 6. When the two sets of triangles, are combined, it will act like an abstract butterfly. The motion that is generated represents the fluttering of a butterfly. The triangles also give a puzzle effect this represents the way a relationship is built. Both man and woman have to adapt in order to make a relationship work. The heavy materials (rubber and canvas textile) combined with the delicate movement results in an attractive masculine yet subtle design.

## 2 Societal impact

With the help of demonstrators like *The Butterfly Effect* we hope to inspire designers and technologists to explore and develop richer interactions via activated products. We try to help developing a dynamic language for this hardly researched field of activated wearables. And we put a lot of effort in thinking about the (long term) impact of concepts on itself for users and society. That is why we appreciate the societal thoughts behind

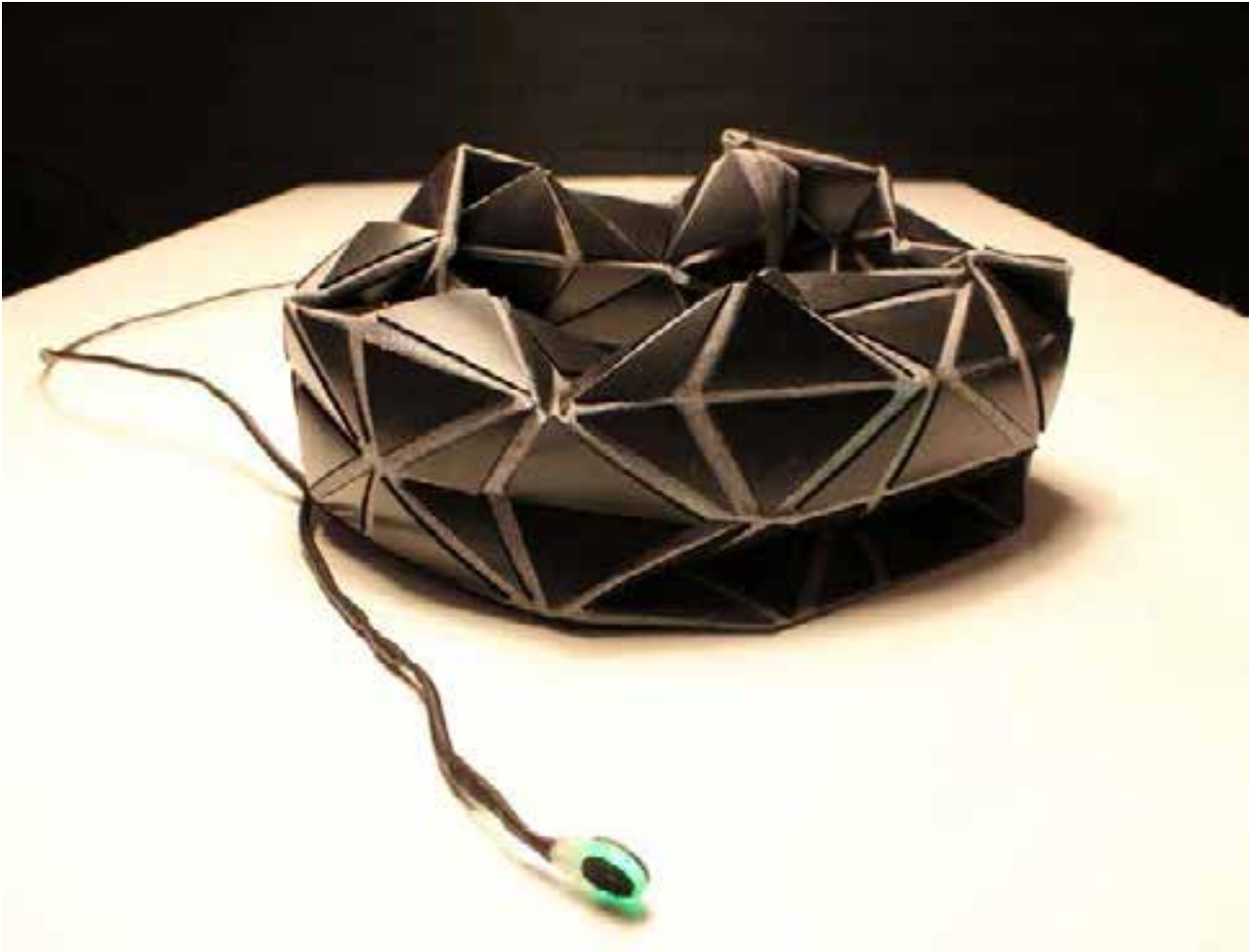


Fig. 6. Demonstrator as the complete product: sensor and activator integrated.

this concept. More research is needed to validate the impact on personal and societal level for the specific target group and their surrounding.

### Acknowledgements

We would like to thank our model Robin Heusschen and the Wearables Senses theme within the Industrial Design department of the Eindhoven University of Technology for facilitating this research and education project.

### References

1. Loe Feijs and Marina Toeters. "Actuating movement in refined wearables," Global Fashion 2014: International Fashion Conference, Ghent Belgium. Forthcoming.
2. Stefan Wiens, Elizabeth S. Mezzacappa and Edward S. Katkin.

"Heartbeat detection and the experience of emotions"

2000: Cognition and Emotion.

3. Melissa L. Ferguson and Edward S. Katkin. "Visceral perception, anhedonia and emotion." 1996: Elsevier: Biological Psychology, Interoception and behavior Volume 42, Issues 1–2, 5 January 1996, Pages 131–145

# Exploration of Interaction Methods for Shape-Changing Interfaces

## Abstract

This paper illustrates exploration processes of developing a toolkit that would help designers in incorporating shape-change technologies into their design. We propose three unique methods for designers to program motions into shape-changing interfaces without specific technical knowledge. An exploratory toolkit was created to examine these methods within design contexts. The toolkit was shown to a group of design students with various technical knowledge and asked to explore the potentials of the toolkit. The means to create motion without programming skills proved to be an empowering tool for designers with a little technical knowledge, in the process of prototyping with actuators and sensors.

## Keywords

Shape-Changing Interfaces, Ideation Tools, Design Methodology, Design Toolkit

## 1. Introduction

The idea of shape change centres around the concept of using physical mechanical movements in a tangible user interface, in order to create dynamic affordances and constraints [1]. Rasmussen [2] illustrated the potentials of the field in his overview in the shape-change design space. Further, there are significant amount of examples that demonstrates aspects of the shape changing interaction paradigm [1, 3, 4, 5, 6, 7]. As for some of these

examples, Thrifty Faucet [8] and the Morphing Hard-disk [9] feature very simple mechanical movements. These movements in turn, translate to their shape-changing abilities [1, 6]. More organic movements are seen as technically challenging [10].

User interfaces become highly dynamic when they have the ability to change their shape. These increased dynamics make the design process more complex [2]. For example, design concepts with dynamic affordances have to be experienceable to examine and optimise the interaction qualities and dynamic aesthetics. Therefore prototyping is an essential tool for the designers, who deal with shape-changing interfaces. Unfortunately this prototyping process in its current form is proven to be challenging for many of designers, technically and resource-wise [18].

To make prototyping process with electronics easier, tools such as Arduino [11] have been developed. These micro-controllers have a simpler programming language. However, these tools are simplified versions of tools developed for engineers, not designers [12]. Designers need a set of tools that enable exploration without being constrained by technology. Designers need an exploratory toolkit for designing shape changing interfaces.

Toolkits that focus on shape changing interfaces are being designed [13, 16] but it has not yet been investigated



Fig. 1. Depicted above are the created actuators, two pivoting and one rotational actuator. In the left picture a square white brick is visible, this is a light sensor module in the kit.



what alternative methods of tool interaction is best suited to prototype shape changing interfaces. The aim of this paper is to investigate which alternative tool interaction possibilities hold a significant potential as a shape-changing toolkit. With a small-scale qualitative 'Research through Design' [14] study, this paper aims to compare three different methods to program actuators and sensors as part of a design toolkit. Students with varying levels of technical knowledge, have participated, which enabled us to examine this non techcentric, experiential oriented approach. This experiential approach would introduce several benefits over tech-centric approach such as ability to focus on the qualities of interaction, and efficiency in design process.

### 1.1 Design

The toolkit is an effort to combine the best elements of existing toolkits with the ability to make interactive prototypes with sensors. To keep it mechanically simple, LEGO® was chosen as mechanism to attach elements of the kit to each other. The basic toolkit consisted of a set of one sensor and three actuators connected to a central hub. This central hub was connected to a computer which contained the graphical user interface to start and stop recording and switch between interaction modes.

The toolkit consists of three alternative programming methods; live manipulation, keyframe animation and direct sensor to actuator coupling. The programming interactions used in this paper are based on methods used in the robotics toolkits [15, 16, 17]. In the field

of robotics there have been various attempts at making toolkits to explore robotic motion for educational purposes without relying on the user to write software.

## 2. Method

### 2.1. Participants

The study consisted of 9 participants that were between the age of 19 and 27. The participants were design students (graduate and undergraduate students) from the faculty of Industrial Design at Technical University of Eindhoven. This faculty has a strong focus on HCI and tangible interaction. Five participants described themselves as having very little previous experience with electronics and programming micro-controllers, while the others had worked with micro-controllers before.

### 2.2. Testing

In the exploratory study, the participants were asked to use the toolkit to build various moving or interactive prototypes. They were given approximately 30 to 45 minutes to do this. In this time they were asked to use all interaction styles that were available at some point

	Direct Manipulation	Keyframe Animation	Sensor Controlled Interaction
<b>No experience with electronics and programming</b>	Most intuitive and easy Little translation from mental model	Conceptually more difficult Mental model needs translation step Sometimes unexpected results	Conceptually hard Learning curve Instant creative enabler
<b>Experience with electronics and programming</b>	Limited possibilities Only one actuator at a time Faster then writing code Not thinking in technical limitations	Have to start all over at mistake Faster then writing code Not thinking in technical limitations	Limit of only two keyframes Faster then writing code Not thinking in technical limitations Only one sensor in the system
<b>Both groups</b>	Good for replicating movement Good for quick explorations High level of expression possible	All actuators at the same time High level of animation control No pressure of live performance Movement not visible at creation Good for complex motion Good for critical accuracy	Good for interactive prototype Only a direct sensor to actuator link

Fig. 2. Depicted above are the impressions of the different categories of participants on the three different interaction modes of the designed toolkit.

of their experimentations. Below a more detailed description of the three interaction methods:

*Direct Manipulation:* In this mode, the user of the system moves the individual actuators by hand. This movement is recorded by the system and can be played back when the user gives the system a play command. While the user is recording one of the actuators, the other actuators that have already been programmed can playback their animation to give the user a sense of timing.

*Keyframe Animation:* In this mode, the user defines a state or position for all actuators at a specific time called a keyframe. The system interpolates through all the user defined keyframes while the system is played back.

*Sensor Controlled Interaction:* In this mode, a two keyframes are linked to a specific analogue sensor values. Depending on the sensor value the actuator positions are interpolated between the two keyframes.

After the experiment, a qualitative semi-structured interview with the participant was held for approximately 30 minutes. All experimentation and interview sessions were recorded on video and the interviews were later transcribed. Questions in this interview classified the participant as either having a technical background or as not having a technical background, while also determining if the participant had worked with shape change or movement before. Once this baseline was set the rest of the questions focused on the pros and cons with respect to each of the three interaction styles. Participants were also asked to state their preferred interaction style and how the toolkit would fit into a design process.

### 2.3 Data Collection and Analysis

Quotes from the interviews were clustered using the affinity diagramming method. The findings were clustered in various categories. Each quote was marked as coming from a person with either a technical or a non-technical background. All interviews were conducted in the native language of the participants,



which was dutch. The quotes found in this paper were translated by the author. Values found in the table were the authors interpretation of found quotes.

### 3. Results and Conclusion

Most participants agreed that the created toolkit is a valuable tool for the ideation and concept development phase in a design process. One participant noted that it is great to be able to make your initial ideas experienceable. “The tool allows me to think from the movement, instead of from the concept I’m designing”.

Most participants did not state a clear preference for a particular interaction mode with the actuators, but instead noted that all of the three proposed styles could have their benefits in certain situations. The table (Fig. 2) shows what attributes were given to each interaction style by the participants.

The results from figure 2 indicate that all tested interaction methods can be used in a design process. Direct manipulation serves as an exploration means, while the key-framing option is better at precise or complex movements. The sensor-controlled interaction is especially valuable when designing shape changing interfaces that are experienceable, but is currently limited to a very simple and direct coupling of a sensor to an actuator.

For the not technically experienced, the tool served as an enabler to create what previously was not possible while the technically experienced group where more inclined to iterate on their creation due to time saved by not having to write code. Both groups stopped thinking in technical limitations and focused on what was desired from an interaction perspective.

### 4. Discussion

This paper we have attempted to demonstrate that a modular toolkit such as this with its intuitive control interactions, could contribute significantly in making the design of shape-changing interfaces easier. Unlike other technologically oriented tools, the current toolkit was not developed as a simplified engineering tool. It was developed to allow designers to prototype shape-changing interfaces by using their bodily movements as method of creating object movements. Unlike the toolkits for robotics, this toolkit featured multiple

interaction methods from which users could choose.

This choice between different interaction methods facilitates exploration and better insights in using movements. These three interaction methods introduce varying aspects of interaction qualities [19]. These differences result in various translations from the mental model of the desired movement to the physical one.

Both technically experienced users and technically inexperienced users benefitted from prototyping without being conscious about technological constraints. For the technically experienced user, this was experienced as a means to save time. For the technically inexperienced user the toolkit enabled the creation of self actuated prototypes which would not have been possible for them to create with traditional tools.

Overall, the toolkit allowed for an experiential approach to designing shape-changing interfaces, which enables further exploration into possibilities of given design space. In order to further investigate these possibilities, the toolkit needs to be tested in the design field, where design practitioners could integrate the toolkit into their design process, which would provide us with better insights.

### References

1. Follmer, S., Leithinger, D., Olwal, A., Hogge, A., & Ishii, H. inFORM: dynamic physical affordances and constraints through shape and object actuation. In Proc. of UIST'13. ACM, 2013, 417-426.
2. Rasmussen, M.K., Pedersen, E.W., Petersen, M.G., & Hornbæk, K. Shape-changing interfaces: a review of the design space and open research question. Proc. SIGCHI Conference on Human Factors in Computing Systems (2012). 735-744.
3. Coelho, M., & Zigelbaum, J. Shape-changing interfaces. Personal and Ubiquitous Computing, 15(2), 2011, 161–173.
4. Harrison, C., & Hudson, S. E. Providing dynamically changeable physical buttons on a visual display. In Proc. of Human Factors in Computing Systems, ACM, 2009, 299–308.
5. Hemmert, F., Hamann, S., Löwe, M., Zeipelt, J., & Joost, G. Shape-changing mobiles: tapering in two-dimensional deformational displays in mobile phones. In CHI'10 Extended Abstracts on Human Factors in Computing Systems, ACM, 2010, 3075-3080.
6. Kim, H., & Lee, W. Shade Pixel: Interactive Skin for Ambient Information Display. In CHI'09, ACM, 2009, 14

7. Poupyrev, I., Nashida, T., & Okabe, M. Actuation and tangible user interfaces: the Vaucanson duck, robots, and shape displays. In Proc. of TEI'07, ACM, 2007, 205-212.
8. Togler, Jonas, Fabian Hemmert, and Reto Wettach. "Living interfaces: the thrifty faucet." Proceedings of the 3rd International Conference on Tangible and Embedded Interaction. ACM, 2009.
9. Horev, O. 'TALKING TO THE HAND' An exploration into shape shifting objects and morphing interfaces, Master Thesis, Interaction Design Institute Ivrea, (2006).
10. Wakita, A., Nakano, A., & Kobayashi, N. Programmable blobs: a rheologic interface for organic shape design. In Proc. of TEI'11, ACM, 2011.
11. Arduino microcontrollers, <http://arduino.cc/>
12. Moussette, C., & Dore, F. Sketching in Hardware and Building Interaction Design: tools, toolkits and an attitude for Interaction Designers. In Proc. of Design Research Society, (2010).
13. Parkes, A. and Ishii, H. Bosu: A Physical Programmable Design Tool for Transformability with Soft Mechanics. DIS'10, (2010), 189-198.
14. Zimmerman, John, Jodi Forlizzi, and Shelley Evenson. "Research through design as a method for interaction design research in HCI." Proceedings of the SIGCHI conference on Human factors in computing systems. ACM, 2007.
15. Raffle, H.S., Parkes, A.J., and Ishii, H. Topobo: A Constructive Assembly System with Kinetic Memory. CHI'04, (2004), 647-654.
16. Schweikardt, Eric, and Mark D. Gross. "roBlocks: a robotic construction kit for mathematics and science education." Proceedings of the 8th international conference on Multimodal interfaces. ACM, 2006.
17. Shamsuddin, Syamimi, et al. "Humanoid robot NAO: Review of control and motion exploration." Control System, Computing and Engineering (ICCSCE), 2011 IEEE International Conference on. IEEE, 2011.
18. Moussette, Camille. "Tangible interaction toolkits for designers." Scandinavian Student Interaction Design Conference. 2007.
19. Wensveen, Stephan AG, Johan Partomo Djajadiningrat, and C. J. Overbeeke. "Interaction frogger: a design framework to couple action and function through feedback and feedforward." Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques. ACM, 2004.



# Dynamic aesthetics of generative two-dimensional geometric art

## Abstract

We show two generators of abstract art works related to themes of cultural and aesthetic value (Mondrian and Pied de poule). The demonstration is not about the resulting pattern, but shows the dynamic process of the algorithm gradually building and refining the result. The generators are driven by random number generators, so each time the output is different.

## 1 Background

The areas of generative design and generative art are in the very heart of the intersection of art, design and mathematics. Examples are the seminal works by Michael A. Nol [1], Aristid Lindenmayer [2], the more recent Malevich paintings by Mirjam Haring [3], and Matt Pearson's book on generative art using processing [4]. Algorithms have the power to generate two- and three-dimensional patterns which are carriers of considerable aesthetic and cultural value or which are tools to study or revitalize existing artworks and patterns.

This plays an important role in our own research and in our teaching activities. Examples of our efforts are documented in Leonardo [5,6], Bridges [7,8,9,10] and related publications such as [11,12]. Examples designed by our students can be found in the Mathematical Art Galleries [13,14]. We use languages such as Mathematica, Processing and the turtle graphics library Oogway designed by Jun Hu [8]. Oogway ([github.com/iddi/oogway](https://github.com/iddi/oogway)) is great for Escher-style tessellations and

for fractal structures. Other popular languages are *grasshopper* for three dimensional work and *Arduino* for interactive work. For the Drapely-o-lightment interactive skirt [6], Loe Feijs joined forces with fashion designer Marina Toeters to explore the interplay between soft textiles and hard electronic components, combining the themes of drapability, sensing the body, and generative art.

In the proposed demonstrators we show the dynamic process of the algorithms gradually building and refining their result. An algorithm is not just a blackbox producing an interesting pattern, but it is an active element with intriguing dynamic behavior which can be made visible while growing (colliding, aligning, fractalising) the intermediate results. The generators also have an X-ray button to see hidden yet essential internal data.

## 2 Techniques

We found the following algorithmic techniques to be powerful and frequently usable:

1. generate and test;
2. collision detection;
3. random number generation;
4. object-oriented programming;
5. competitive growth and alignment;
6. fractals, recursion and turtle graphics;
7. symmetry theory and tessellation topologies;
8. geometric and art-theoretic analysis of existing art.

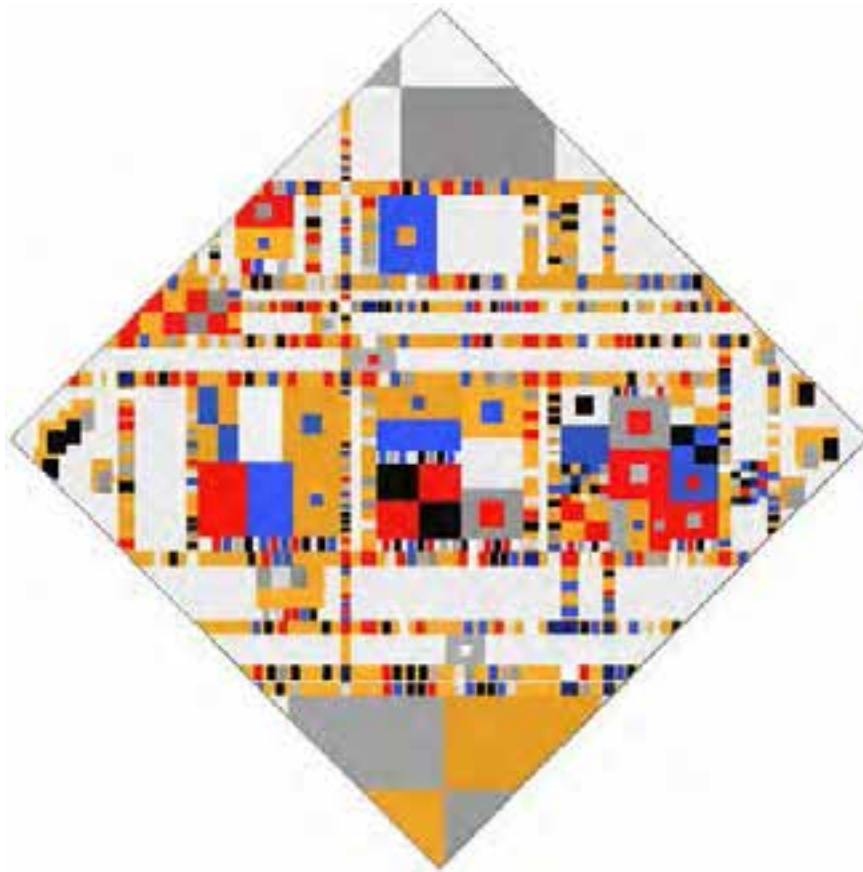


Fig. 1. Computer-generated Mondrian-style Boogie-Woogie.

Most of these techniques can be found in [15]. We add one or two lines of explanation for each technique. *Generate and test* works by invoking a random-number generator and later testing the results to select a satisfactory or optimal outcome. The result of random generators in art and design goes back to Marcel Duchamp in 1913 [16]. *Collision detection* is not only essential in generative art and design, but lies also in the heart of game design (the classic example being the pacman colliding with the ghost, one of them being eaten by the other). *Object oriented programming* and design [17] is helpful for organizing complex software in a way which is aligned with the objects' real world semantics. *Competitive growth and alignment* simulate the way cells grow in plants, pushing against each other [5]. *Fractals* are structures which are self-similar when zooming-in [18]; they are formalized by Lindenmayer [2] who found that *recursion and turtle graphics* are useful for programming generators. Other fractals we

designed are described in [9] and [10]. *Symmetry theory and tessellation topologies* are essential for Escher-style works and Islamic art such as the famous Alhambra in Granada. The classic mathematical reference is by Heesch and Kienzle [19]. *Geometric and art-theoretic analysis of existing art* has been applied for many artists, of whom we only mention Malevich [3], Mondrian [1,5,11], and Griz [20].

Other techniques such as Voronoi diagrams [6,21], trigonometric calculations, physics simulation, and transformations of color space are useful too.

### 3 Demonstrators

Two important and recurring themes in our work, both being related to famous patterns of cultural value are:

- Mondrian's non-figurative compositions;
- Pied de poule patterns, also known as houndstooth.

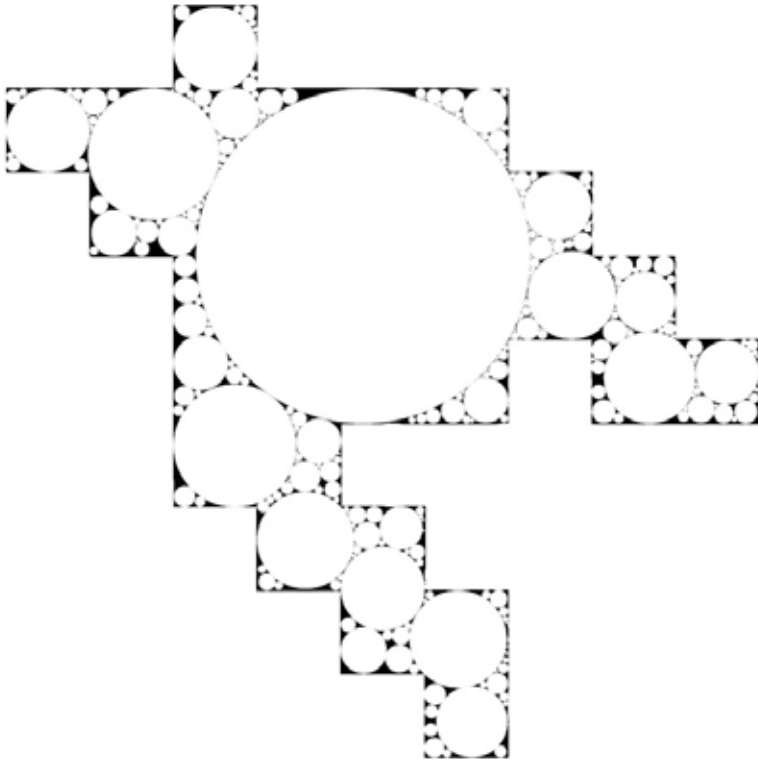


Fig. 2. Computer-generated fractal Apollonian Pied de poule.

We discuss each of these next. Besides the early 2004 generative explorations of Mondrian's works [5,11], Feijs entered the Dutch competition of programming the best Victory Boogie-Woogie in 2013. Feijs won the competition (among 34 other submissions, developed in Matlab, Processing, Javascript, Python, Java, Common Lisp, Shell, Perl, Microsoft tag, R, scratch, C#, and Php). More details can be found on the website of Setup: <http://elegant.setup.nl/> and on Github: [github.com/Elegant-Setup/](https://github.com/Elegant-Setup/). The program is described in detail in an article submitted to the Journal of Mathematics and the Arts. At DeSForM we shall show the working program as a demonstrator (Figure 1).

Pied de poule (houndstooth) is an ancient textile pattern, already applied by the Vikings in the era before BC and made famous by the tailors of the Prince of Wales in the 1930s and by Christian Dior in France in the 1950s. It is still very much alive and can be seen

on the catwalks of Paris, Milano, London and New York and in the streets all over the world. We re-interpreted the pattern in a variety of ways, notably by inventing new and fractal versions of it. Marina Toeters created novel garments with these fractals, documented amongst others in [9,10]. They are also discussed by houndstooth blogger Anti-houndstooth ([anti-houndstooth.blogspot.nl/](http://anti-houndstooth.blogspot.nl/)). Especially for DeSForM we created yet another fractal pied de poule, called *Apollonian Pied de poule*, to be shown at DeSForM for the first time (Figure 2).

During the DeSForM conference we shall alternately demonstrate the live generation Mondrian-style Boogie Woogie and the live generation of the Apollonian Pied de poule. In particular we shall demonstrate this for one Mondrian (the abovementioned award-winning Victory Boogie-Woogie algorithm) and for one fractal Pied de poule: a new variation designed and coded especially for DeSForM.

In both cases, technique numbers 5 and 6 (see the list of techniques in Section 2) which will be clearly visible: competitive growth and alignment, and recursion. The techniques 1–4 and 7–8 are used in the code too, but are less explicitly visible during the proposed demo. The program will run continuously on a computer and displayed on a beamer. The visitors can play with parameters and generate new versions within tens of seconds.

#### 4 Dynamic aesthetics

We should discuss the aesthetic qualities of the proposed demonstrators and the theoretic background of the claim that they have both static and dynamic aesthetic qualities. In *The Aesthetics of Movement* by Souriau [22], a rigorous analysis is made of movements as a source of aesthetic values. For the rhythms in nature (including our moving bodies), according to Souriau, there are natural laws such as the laws of compensation (simplified: what goes up must come down) and tendency to repetition. For mechanical beauty, Souriau discusses moderation of pace, regularity of the rhythm, muscular synergy, problems of balance, and problems of support. Although it is possible to simulate all these effects in computer-generated movements, this is not what happens in the two proposed demonstrators. Computer-generated artifacts are not bound by natural laws.

The static aesthetics qualities of a generated form can originate from cultural values (art, fashion, history), resemblance to nature (flower motifs, plant-like fractals, Voronoi structures), Gestalt qualities (balance, proportion, intriguing foreground-background), symmetries (architecture, decorative patterns, frieze patterns, wallpaper patterns), religious symbols (not my topic of studies), or societal symbols (supporting preferred relationships or leadership). In the case of the two proposed demonstrators, the static aesthetics is based mostly on the underlying cultural values (Mondrian, *pie de poule* as cultural phenomenon) and to a lesser extent on Gestalt qualities (reasonable balance and proportion).

The dynamic qualities of the two proposed demonstrators are a different matter. For a large part they appeal to the ratio: it is intriguing to see the algorithms in action, gradually filling-in the details;

and every now and then there are small surprises for emerging objects (the Apollonian circles whose complements get completely fragmented but do not vanish). At a larger time scale, the dynamics of the proposed demonstrators are not of a repetitive nature (swings or circadian rhythms with their eigenfrequencies). They are more like the eigenfrequency of a biological clock where an organism develops towards full maturity, gradually the size details which are being added getting smaller and smaller. For a discussion on eigenvalues as a source of aesthetic value we refer to [23]. Bråten [24] distinguishes three levels of human mental processes for dynamic aesthetics: sensing, rational thinking and interpretation. At the sensory level Bråten relies on Laban concepts: weight, flow, space and time. Of these, weight is relevant here, because in the two proposed demonstrators, there are heavy-weight actions in the begin phase, but gradually the actions become smaller and more light-weight. Unlike dance, the algorithms have not much classic movement, rather they show a gradual unfolding and filling-in of detail: something a dancer cannot sustain as our bodies have no fractal structure at the visible outside.

#### 5 Relation to design

Algorithmic generators are increasingly important in a design perspective as more and more, the forms of a design will not be determined by drawing or sculpting by hand or working in sculpting-style editing tools. Instead, forms are determined by algorithms, either very innovative algorithms as shown here, or by algorithms from a library with personalized parameters. Unless the algorithm follows a straightforward process (repetitive tessellations), there is added value for the end-user to see the process by which the form was created. Not only the final implementation or reproduction, (cutting, stitching or 3D printing), but even more the creation process itself is interesting.

In particular this applies when the product is delivered in a system of mass-customization (every end-user gets his or her personal product). In case of wearables, the form may carry a clear “digital signature” and then the origin of that signature is interesting for the end-user. Examples of wearables with a clear digital signature are fPDP [9], Drapely-o-lightment [6], and This fits me [13]. One way to tell the story is to show the algorithm in

action (which is an experience in itself). In other cases, the user could be not only an observer but an active contributor to the generation process. A very special example of the latter approach is the Origo system [25], where the end-users' own physiological measurements are fed into a generative art design. The art works are very, very personal. Another example is the generation of jigsaw puzzles by nervous system: featuring art by Jonathan McCabe, every puzzle has a unique image and unique pieces, as described by Rosenkrantz [26]. The pieces form in a simulation of a crystal growth by "dendritic solidifications", after which the pieces are laser cut.

## 6 Looking back

For this demo and short paper there is one claim: that not only the resulting pattern is interesting, but that also the build-up of the result during its construction. The user can become a co-designer by choosing parameters of the design (a philosophy demonstrated also by Leonie Tenthof van Noorden [13]). We envision new ways of designing in which algorithms play an essential role and the user is not only interested in the aesthetics of the result, but has access to the generation process itself and the aesthetic qualities of the process, before, during, and after the making.

## References

1. Noll, A. Michael, "Human or Machine: A Subjective Comparison of Piet Mondrian's 'Composition with Lines' and a Computer-Generated Picture," *The Psychological Record*, Vol. 16. No. 1, pp. 1–10 (1966).
2. Prusinkiewicz, P., Lindenmayer, A. *The Algorithmic Beauty of Plants*, Springer-Verlag (1990).
3. Haring, M.E., Malevich: computational simulation of an abstract artistic style, bachelor thesis, University of Amsterdam, faculty of science (2011).
4. Pearson, M. *Generative art, a practical guide using processing*, Manning publications. (2011).
5. Feijs, L.M.G. Divisions of the plane by computer: another way of looking at Mondrian's nonfigurative compositions. *Leonardo*, 37(3), 217-222 (2004).
6. Feijs, L.M.G. & Toeters, M.J. Design of Drapely-o-lightment. *Leonardo* just accepted. Posted Online August 4, doi:10.1162/LEON\_a\_00913 (2014).
7. Feijs, L.M.G. Geometry and computation of Houndstooth (Pied-de-poule). In Robert Bosch, Douglas McKenna & Reza Sarhangi (Eds.), *Conference Paper : Proceedings of the Bridges Towson Conference* (pp. 299-306). Baltimore: Bridges Mathart.org. (2012).
8. Feijs, L.M.G. and Hu, J. Turtles for Tessellations. In: (George W. Hart and Reza Sarhangi Eds.) *Proceedings of Bridges, Mathematics, Music, Art, Architecture, Culture*, pp. 241-248 (2013).
9. Feijs, L.M.G. & Toeters, M.J. Constructing and applying the fractal pied de poule (hound-stooth). In G. Hart & R. Sarhangi (Eds.), *Proceedings of Bridges 2013 : Mathematics, Music, Art, Architecture, Culture*, July 27-31, Enschede, pp. 429-432. (2013).
10. Feijs, L.M.G., Toeters, M.J., Hu, J., & Liu, J. Design of a Nature-like Fractal Celebrating Warp-knitting. In: *Bridges 2014: Mathematics, Music, Art, Architecture, Culture*, Seoul, Korea, 2014, pp. 369-372 (2014).
11. Feijs, L.M.G. Il linguaggio di Mondrian: Ricerche algoritmiche e assiomatiche. In M. Emmer (Ed.), *Matematica e cultura* (pp. 181-194). Berlin: Springer Verlag (2006).
12. Feijs, L.M.G., Bartneck, C. Teaching geometrical principles to design students. *Digital Culture & Education*, 1(2), 104-115 (2009).
13. Tenthof Van Noorden, L. This Fits Me. *Bridges Mathematical Art Exposition Seoul. Mathematical Art Galleries*. gallery.bridgesmathart.org/exhibitions/2014-bridges-conference (2014).
14. Van Lankveld, T. Man-shaped figures. *Bridges Mathematical Art Exposition Baltimore. Mathematical Art Galleries*. gallery.bridgesmathart.org/exhibitions/2014-bridges-conference (2014).
15. Bohnacker, H., Gross, B., Laub, J., & Lazzaroni, C. (2012). *Generative design: visualize, program, and create with processing*. New York: Princeton Architectural Press.
16. Tomkins, C. *De wereld van Marcel Duchamp*. Time Life International (1966).
17. Rumbaugh, J., Blaha, M., Premerlani, W., Eddy, F., and Lorensen, W. E. (1991). *Object-oriented modeling and design* (Vol. 199, No. 1). Englewood Cliffs: Prentice-hall.
18. Mandelbrot, B. *The Fractal Geometry of Nature* (1982). W.H. Freeman and company.
19. Heesch, H. and Kienzle, O. (1963). *Flächenschluss; System der Formen lückenlos aneinanderschliessender Flachteile*. Berlin: Springer.
20. Mai, J. Juan Gris' Color Symmetries. In: Greenfield, G., Hart, G. and Sarhangi, R. *Proceedings of Bridges 2014: Mathematics, Music, Art, Architecture, Culture, Tessellations Publishing* (pp. 197-204).
21. Aurenhammer, F. and Klein, R. Voronoi Diagrams. Ch. 5 in *Handbook of Computational Geometry* (Ed. J.-R. Sack and J. Urrutia). Amsterdam, Netherlands: North-Holland, pp. 201-290, 2000.

22. Paul Souriau, O., Souriau, M. *The Aesthetics of Movement*. Univ of Massachusetts Press (1983).
23. Feijs, L.M.G. & Barakova, E.I. (2007). Semantics through embodiment: a non-linear dynamics approach to affective design. In L.M.G Feijs, L.M.G. Feijs, S. Kyffin, S. Kyffin, L.M.G. Feijs & S. Kyffin (Eds.). *Proceedings of the 3rd European Workshop on Design and Semantics of Form and Movement (DeSForM 2007)* 12-13 December 2007.
24. Bråten, S.I. A Framework for Analysis of Dynamic Aesthetics, [www.ivt.ntnu.no/ipd/fag/PD9/2001/Artikler/Braaten\\_I.pdf](http://www.ivt.ntnu.no/ipd/fag/PD9/2001/Artikler/Braaten_I.pdf) (2001).
25. Kierkels, J. Experience Design for Labor & Delivery. Health Experience Design HXD2013. [healthcareexperiencedesign.com](http://healthcareexperiencedesign.com) (retrieved april 2015).
26. Rosenkrantz, Jessica (2014). Custom Jigsaw puzzles. In: Nervous system blog, [n-e-r-v-o-u-s.com/blog](http://n-e-r-v-o-u-s.com/blog) (retrieved april 24, 2015).

# Aires: a wearable for women in their menopause

## Abstract

In this demo we show an active garment to support women in matters of menopause issues, more specifically: hot flashes. This demonstrator shows the marriage of 'hard' technology and 'soft' textiles in a practical wearable product.

## Keywords

Wearables, Fashion, Hot Flashes, Support, Interaction Design

## 1 The context: menopausal hot flashes

The menopause is the period in a woman's life when she stops ovulating and menstruating. During the menopause the body goes through a hormonal change. Often physiologic and psychosocial changes are experienced. Associated symptoms are: hot flashes, bone loss, urogenital atrophy, urinary tract infections and incontinence, increased cardiovascular risk, somatic symptoms, sexual dysfunction and decreased libido, and loss of skin elasticity (Utian, 2005).

### 1.1 Hot flashes

It is estimated that 75% of women older than 50 years old will experience hot flashes. Hot flashes are seen as a response of the brain to the reduced hormones and hormonal fluctuations that happen during the menopause (Utian, 2005). Hot flashes are felt when the core body temperature crosses the upper threshold of



Fig. 1. Aires in use. (©Tamara Hoogeweegen)

the thermo neutral zone. The thermo neutral zone is when the core body temperature is between the upper threshold for sweating, and a lower threshold for shivering. Women who suffer from hot flashes tend to have a narrowed thermo neutral zone and are therefore more sensitive to fluctuations in core body temperature (Archer, D.F. et al. 2011). The frequency women experience hot flashes differs per individual; some experience it irregularly, weekly or monthly, whereas others experience the hot flashes frequently, for example hourly (North American Menopause Society, 2004).





a bra, isn't visible and can be turned on without it being obvious for others, which might be desirable as a hot flash can be experienced as shameful by some women. Furthermore the bra gives the women a sense of femininity and sensuality, because during the menopause hormones change the body, this might entail feeling bad about their body, end of fertility and end of youth.

## 2.4 Proposal for further development

To take this project to the next level improvements can be made on different levels: material and technology. For a bra the textile used needs to be stretchy to adjust to the body movements and curves, but at the same time it needs to be strong to give good support. For this specific target group the material needs to be airy, not retain heat and dry quickly. Proposed fabrics, common in sportswear, are: S.café by Singtex, Thermocool by Invista, c\_change by Schoeller. Also interesting would be fabrics with phase changing material (PCM). When PCM's change from solid to liquid state it absorbs energy, and when it become solid again it releases heat. The PCM's used in clothing change phase at temperatures close to the thermo neutral temperature of the skin (28–32°C) (Reinertsen, R.E. et al. 2008). Based on laboratory experiments Reinertsen et al. (2008) stated that their subjects rated lowering of skin temperatures positively, even though core body temperature didn't fall. This would also be interesting for women suffering from hot flashes.

Furthermore the current prototype has a ventilator which is too big. The bra could have a removable module on the back; by this you can to wash the bra and change its batteries easily. The current ventilator could be replaced by either a couple of micro fans which would still generate enough air movement.

## 3 Societal impact

With the help of demonstrators like Aires the idea is to show and inspire fashion designers and technologists to work closer together. And raise awareness of what can be done when 'hard' technology and 'soft' textiles are combined in a wearable product.

## Acknowledgements

We would like to thank our model and the Wearables Senses theme within the Industrial Design department of the Eindhoven University of Technology for facilitating this research and education project.



Fig. 3. Aires close-up showing the air channels (© Tamara Hoogeweegen)

## References

1. Archer, D. F., D. W. Sturdee, R. Baber, T. J. De Villiers, A. Pines, R. R. Freedman, A. Gompel et al.: Menopausal hot flashes and night sweats: where are we now?. In: Climacteric 14, no. 5, pp. 515-528. International Menopause Society, Camborne (2011)
2. North American Menopause Society: Treatment of menopause-associated vasomotor symptoms: Position statement of the north american menopause society: Retracted. In: Menopause, Vol. 11, issue 1, pp. 11-33. The North American Menopause Society, Mayfield Heights (2004)
3. Nelson, H.D., Haney, E., Humphrey, L., et al.: Management of Menopause-Related Symptoms. Evidence Report/ Technology Assessment. In: Agency of Healthcare Research and Quality March, No. 120. Agency for Healthcare Research and Quality, Rockville (2005)
4. Nelson, H.D.: Menopause; seminar. In: The Lancet, vol 371, Issue 9614, pp. 760-770. The Lancet, London (2008)
5. Reinertsen, R.E., Færevik, H. Holbø, K.: Optimizing the Performance of Phase-Change Materials in Personal Protective Clothing Systems. In: International Journal of Occupational Safety and Ergonomics, Vol. 14, No. 1, pp. 43-53. International Journal of Occupational Safety and Ergonomics, Warsaw (2008)
6. Utian, W.H.: Psychosocial and socioeconomic burden of vasomotor symptoms in menopause: a comprehensive review. In: Health and Quality of Life outcomes, Vol. 3, No. 1. Health and Quality of Life outcomes, London (2005)

# Animism Expression: Materializing Basic Principles of Animation for Interaction Design

## Abstract

Input technologies using natural communication skills (e.g., voice and gesture recognitions) have been developed to a mature level, while daily experiences with such skills are mostly with 'living subjects' rather than 'inert objects.' On the other hand, the general mindset of interacting with (inert) objects is usually based on functional movements such as button pressing. We argue that there is a novel cognitive perspective needed to be addressed in order to create natural interaction experience, and animism can be leveraged to develop an interactive mindset of interacting with artifacts, thus creating living things that users would perceive. Drawing on animation principles of how animators make still things alive, we propose eight principles of designing animistic interactive artifacts. We further conceptualize how these principles can be implemented in terms of light changes and physical transformation with cubic prototypes. Materializing these principles with lighting examples, we present interactive artifacts as *live-things* that bring animistic metaphors in tangible interaction design, where participants could perceive perceptual crossing promoted by the phenomenology of perception as well as how Ihde frames technology as 'quasi-other.'

## Keywords

Embodied interaction, designed animism, phenomenology of perception, alterity relations, tangible interaction, animation, poetic interaction.

## Introduction

We've seen new technology rising up and maturing over the past decade, but we still keep the usual practice in everyday life: we control electronic objects with switches and buttons. Although voice recognition and input technologies have been developed to a mature level, we as human, whose common communication experiences with our nature skills are with 'living subjects', rather than 'inert objects'. On the other hand, the general mindset of movement on interactive objects is merely 'on & off' based on 'digitalized input & output.' We argue that there is a novel cognitive perspective needed to be addressed, and animism can be leveraged to develop an interactive mindset of designed objects, thus creating living things that users would perceive. For example, when the GPS Table [1] is indoors, and cannot communicate with the satellite, it will just shows "Lost". The table invites users to intervene the dialogical contexts, to start to understand its needs, to recognize its subjectivity, and then to change the relation between the table and users.

Ihde had proposed three human-technology relations, namely, embodiment relations, hermeneutic relations, and alterity relations [2]. In this study, we conceptualize interactive artifacts as animated things or intentional subjects to support the perspective of "alterity relations" in Ihde's viewpoint. Technology of object that we present is experienced as shifting from functionality into 'quasi-other,' [2] embodying as a perception

of human-like status. James Pierce also proposed a manner of ‘Amplifying the Agency of Things’ [5] that could provoke deeper experiential and material level reflections. We aim at creating some tangible objects as well as rousing embodied metaphors in tangible design. With a new interactive mode, we wonder how interaction bridges the abstract and concrete cognition during the manipulation and feedback, where a new set of knowledge and learning systems could emerge. Therefore, the reciprocal nature of perception promoted by Merleau-Ponty [4] gradually becomes more prominent. When we are able to perceive a design artifact as a living thing, an intentional subject, we could naturally interact with it in new scenarios through our familiar vocabulary of body movements.

Therefore, the relationship between human and technology in interaction design with animistic perspective in our study is highly related to the ‘poetic object’ that can be used to investigate the culture of everyday practice [3]. Adding poetic imagination to a mundane function of an object would introduce a new design practice of creating *living-with-thing* scenarios. Echoing to the argument that “poetic interaction design could change common impression of everyday objects from instrumental rationality to poetic imagination [6],” we could explore how animism transforms interactive artifacts to evoke poetic imagination. As van Allen points out that “through animistic metaphors, designers can embrace and facilitate people’s intelligence and imagination [8],” this paper argues that designed animism is a useful technic to create poetic imagination on expression of a thing, which is the core element for poetic interaction [6].

## Design Process

Disney animators, Frank Thomas and Ollie Johnston, have sought to create believable characters and conclude live-giving methods that could animate characters, where after they proposed ‘the 12 basic principles of animation’ in the book *Illusion of Life* published in 1995 [7]. These principles could be a reference when we expect to create an artifact with animistic perspective to challenge user’s mindset in interaction. We translate the 12 basic principles to responsive expressions of interactive artifacts. Within the 12 principles, there are 4 principles unable to be applied to animating interactive artifacts. *Solid drawing* means giving volume and weight onto drawings.

While volume, weight, texture are inherent in material objects, giving users the sense of “physicality”, it seems unnecessary to apply solid drawing in embodied interaction. *Straight ahead & pose to pose* are two principles concerning the process of making animation, where animators set key frame animation along the time axis. However, this principle seems useless since the dynamics of interaction design is essentially non-linear, and it changes according to the users. *Timing* and *slow in & slow out* in our experiment are somehow alike in terms of interpreting the dynamic forms. In our experiment, we also found it is hard to embody *Arcs* on physical objects. In the end, we conclude with 8 principles below:

<b>Nonlinear Timing</b>	The dynamics of an object can be split into <i>In</i> and <i>Out</i> , with different paces of <i>Fast</i> and <i>Slow</i> . Therefore, we have 2x2, 4 different kinds of transition as expression.
<b>Squash &amp; Stretch</b>	Using soft or deformable material coordinated with inner mechanism to perform stretch and squash, would break the original feeling of stiffness.
<b>Staging &amp; Appeal</b>	<i>Staging</i> and <i>appeal</i> both indicate that designed objects express their inner feeling, while <i>staging</i> focuses on the objects themselves as subjects, and <i>appeal</i> expresses through environmental or assistive movements.
<b>Beforehand</b>	A designed object performs a preparation movement before the actual interaction, usually an assistive movement before a main movement.
<b>Follow Through:</b>	Parts of a designed object continue and delay their movements in line with a main movement.
<b>Echo</b>	Echo indicates repetition of a movement in reflect to a users’ action.
<b>Exaggeration</b>	Designed objects react to users excessively, subjectively presenting over-interpretation.
<b>Resistance</b>	A designed object rejects or resists users’ action, making users recognize it as a subject.

Table 1. Eight principles for animistic embodied interaction translated from animation.

To verify eight principles mentioned above, we created a sphere and a cube as our fundamental form at the beginning. While in the first prototype, the spherical shape was more similar to the natural shape that could be sensed as a living thing in users’ perception. Thus, we decided to use the cubic shape in the following design to avoid the effect from shapes that imply living things. In the second step, we use lighting, physical transformation, and projection to develop our animate prototypes. The performance of projection worked well, but it does not suit our purpose that the artifact acts itself. It needs image projection to support narratives in the environment where the technology is

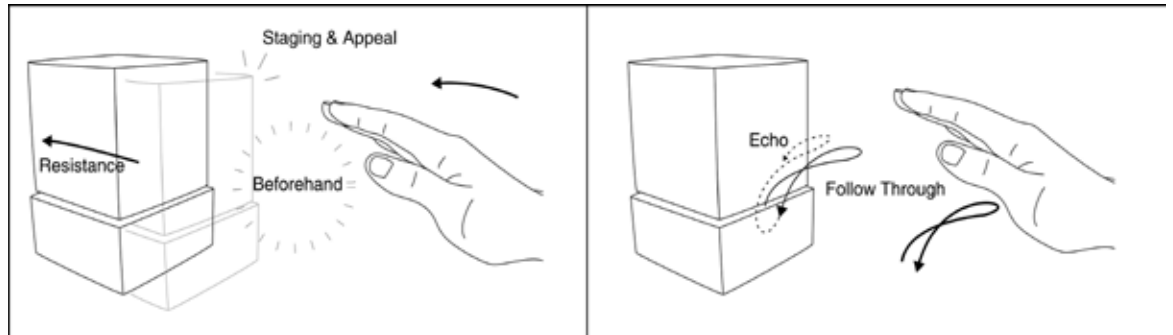


Fig. 1. Two sketch examples of animistic artifacts embodying animation principles

most similar to *projected reality*. Although the projection can achieve rich variations, it presents effects beyond the nature of an object itself. Therefore, this study focuses on the performances of lighting and physical transformation.

At last, we sketched fifteen prototypes with the same size (e.g., Fig. 1). Due to the limited time and resource, we only present seven lighting prototypes in the present paper (<http://vimeo.com/user36905151/videos>). We made seven lighting interactions with matte acrylic since the event of *squash and stretch* can not be well presented as the other eight physical transformative interactions do. In the physical transformation sketches, the main prototype comes with one small box that emphasizes the reaction of appendage. These fifteen sketches

all work through the principle of animistic metaphor in action (Table 2). For examples, in the event of *Beforehand*, the lighting prototype will pre-flicker when a hand is approaching and the physical transformation prototype will retreat at first but produce a different reaction after really touching the cube (Fig. 1, left). These two interactive feedbacks would let participants look forward to the next state. In the event of *Exaggeration*, the prototype will have vigorous reaction after hitting it such as the lighting prototype quickly flashing as well as the physical transformation prototype shaking dramatically and the small object nearby bouncing up as people get shocked.

## Conclusion

In this study, we propose the animate dynamic transformation as our interactive design principles. Through these principles we could build an interactive artifact as a live-thing that brings animistic metaphors in tangible interaction design. We choose the cubic shape to develop our fundamental interactive prototypes that present lighting and physical transformation. During the process, we want to achieve the aim that participants don't need to prior learn about the symbols but are able to interact with the object naturally. Therefore, participants could better experience perceptual quality promoted by the phenomenology of perception based on how Ihde frames technology as 'quasi-other' [2] to carry out more possibilities in interaction design.

## References

1. Dunne & Raby Placebo Project: <http://www.dunneandraby.co.uk/content/projects/70/0>
2. Ihde, D.: Technology and the Lifeworld: From Garden to Earth. Indiana University Press (1990)

Table 2. Fifteen sketches of animistic artifacts: seven lighting and eight physical artifacts.

	Lighting	Physical
Nonlinear Timing	Four different modes of light changes. (fast/slow, in/out)	The sub-object moves on the object.
Squash & Stretch	void	Deformable material is coordinated with inner mechanism to perform stretch and squash.
Staging & Appeal	Faintly blink at first, and flash fully some moments.	Sub-object bounces on the main object.
Beforehand	When a hand approaches, the light changes its color frequently. When a hand touches, the light stops at a random color.	When a hand approaches, the object draws back a little bit. When a hand touches, the object goes forward slightly to get close to the hand.
Follow Through	The touched side lights on.	When the main object moves, the sub-object follows the movement.
Echo	When a hand touches, the light gradually disappears.	When an object is touched, it shakes.
Exaggeration	When a hand touches, the light flashes very dramatically.	When a hand touches, the main object shakes while the sub-object jumps.
Resistance	When a hand touches, the light disappears in a sudden and then gradually lights on.	When a hand approaches, the object escapes to the opposite direction.

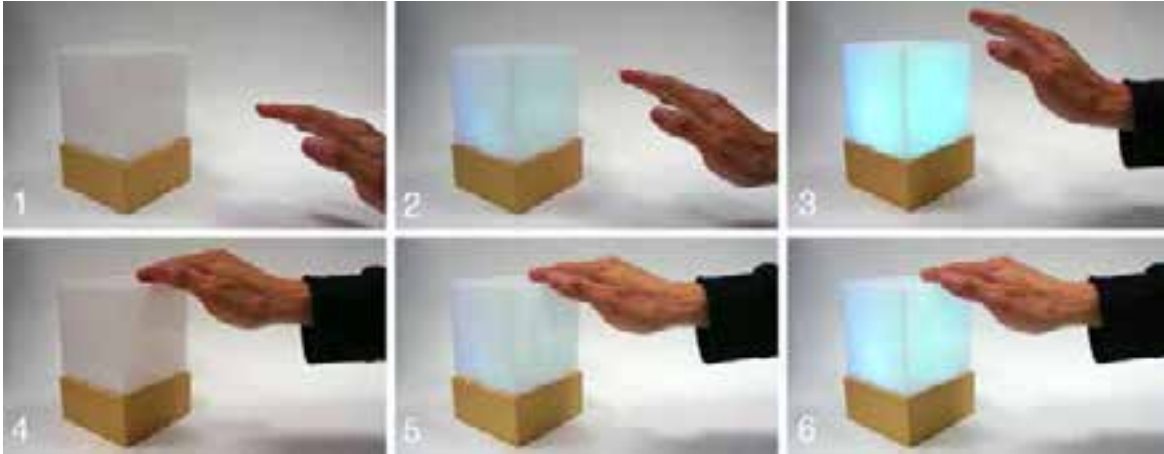


Fig. 2. Multiple principles applied to create a rich animism expression: beforehand (1, 2, 3), then resistance with fast-out/slow-in (4, 5, 6)

3. Ionascu, A.: Poetic Design: A Theory of Everyday Practice, doctoral thesis (2010)
4. Merleau-Ponty, M.: Phenomenology of Perception (C. Smith, Trans). London, UK: Routledge (1958) (Original work published 1945)
5. Pierce, J.: Material Awareness: Promoting Reflection on Everyday Materiality. In: Ext. Abs. of CHI '09, pp. 4459-4464. ACM Press, New York (2009)
6. Liang, R.-H.: Pragmatist Poetics in Interaction Design. In: 5th IASDR, pp. 2521-2532. (2013)
7. Thomas, F., Johnston, O.: The Illusion of Life: Disney Animation. Abbeville Press, Walt Disney Prouctions, New York (1981)
8. van Allen, P., McVeigh-Schultz, J., Brown, B., Kim, H.M., and Lara, D.: AniThings: Animism and Heterogeneous Multiplicity. In: Ext. Abs. of CHI '13, pp. 2247-2256. ACM Press, New York (2013)

# Ethics in Aesthetics: Experiencing Women's Rights

## Abstract

In this paper, we describe an interactive exhibition entitled *Ballade of Women* that explored perspectives on women's rights. The installation was designed as an immersive experience aimed at engaging visitors to trigger meaningful and personal reflections on women's rights. Visitors moved through a dynamic environment, where they experienced three themes: violence, emancipation and self-determination, represented by three artworks. Digital representations of the three paintings were fragmented in moving panels. The movement of the panels was determined by the movement and presence of visitors as well as by the input received by online communities discussing the topic of the exhibition. The installation created awareness, and stimulated reflection through a bodily involvement, demonstrating how complex and controversial taking a position on such topics can be. The experience concurred in stimulating and re-inforcing a reflection on their relevance, complexity and universality.

## Keywords

Ethics, Aesthetics, Embodiment, Interactive installation.

## 1. Introduction

In this paper, we present an interactive exhibition, entitled *Ballade of Women*, that explored contemporary issues of women's rights (Video: [1]).

The design approach leveraged concepts of embodiment [2] and active perception to create an interactive installation that highlights complex socio-cultural themes to the public. By making the topic on women's rights experienceable, the work actively engaged visitors rather than intellectually instructing them [3]. This forced them to take a stance based on their personal perspectives and reflections regarding the issue at hand. In what follows, we briefly present the design's concept and implementation of *Ballade of Women*, describing the engagement that the installation elicited both offline (in presence) and online (remotely). We conclude with reflections on how the work engaged visitors and triggered personal reflections on the issue of women's rights.

## 2. Concept and Implementation

The content for the installation was based on three historical characters, depicted on paintings selected from the extensive, private art collection of the *Fondazione Monte de' Paschi di Siena*. The three characters and paintings were: Maria Magdalena (by Rutilio Manetti, XVII century), Lucia from Siracusa (by Maestro dell'Osservanza, XV century) and Cleopatra (Marco Pino, XVI century). They were chosen to support the three themes of the exhibition: Cleopatra was known for her seductive skills and her ravaging intelligence. The painting supported the theme of emancipation; Maria Magdalena changed her life to embrace Christianity. She represented the theme

of self-determination.; and Santa Lucia who was prosecuted for her religious beliefs. She symbolized the theme of violence [4].

The installation was conceived as a dynamic space. Digital acquisitions of the paintings, provided by *Fondazione Monte de' Paschi di Siena*, were fragmented and floated in the space, projected on moving panels. Acrylic panels were cutout according to the contours of the three paintings. These contours were scaled and suspended in three-dimensional space, hanging from a triangular aluminum structure (See Figure 1).



Fig. 1. Visitors exploring the installation during the opening.

Each panel was connected to a motor, controlled by an *Arduino*, allowing it to rotate individually. The motors could turn the panels to deny or reward the viewer with a view of the full painting when projected. The fragmentation was used to evoke the information that we have about the subject, which has been fragmented by history, politics and the speed of our world. Three *Kinect* cameras mounted on the structure were used to track movements of visitors around the installation and influence the behaviour of the panels. The image of the painting was projected onto the panels, along with continuously changing representations of sentiments and statements regarding the exhibition themes, sourced from the web by a software crawler, *WhatsOn* (see below for details).

### 3 Bridging the Real and Virtual

The movement of visitors in the space activated the motors that controlled the rotation of each panel, resulting in the paintings effectively hiding or revealing themselves from visitors as they explored the space. Only when aligned, the panels revealed a complete view of the painting. A single person, standing for

more than 5 seconds in a specific point in the room, triggered the alignment.

Without instructions on how to interact, visitors were triggered to move around the space and through this bodily engagement, explore the responsive behaviour of the installation in an ambiguous dialogue. The dynamics and fragmented visuals and audio created a complex, immersive whole. This elicited visitors to relate all of the fragments to form a personal narrative on the exhibition themes. By bodily engaging with the installation, they were triggered to take a personal perspective on the relationship between the historical narratives, contemporary statements and their dynamic interplay.



Fig. 2. A sequence showing the panels of *Santa Lucia* lining up to reveal the painting. The image on the far right is overlaid with a statement on violence against women, sourced from Facebook by *WhatsOn*.

*Ballade of Women* was a mixed reality experience and a dynamic space. The projections of the paintings had graphic overlays containing information streamed directly from the Internet and social media, together with facts, statistics and graphs pertaining to the issues highlighted. This information flow was enabled by the software crawler *WhatsOn*, developed by *QuestIt*, which continuously monitored news regarding the topics of self-determination, emancipation and violence. Sentiments and statements related to the themes, detected by the crawler, were used to move the motors handling the panels and modify the content projected on them. The theme that gathered the biggest number of new posts resulted in a slight movement of the motors. Allowing online behaviour to influence movements, made the embodied dialogue between visitors and the physical installation even more ambiguous. This particular combination of embodied interaction with social computing fits with certain views of embodiment (e.g. [2]).

#### 4 Conclusive Reflections

The exhibition took place in Siena from 18 June to 2 July 2013. It offered a space for bodily reflection for visitors and designers on the relationship between gender and human rights. Visitors had to take an active stance in the exhibition. Their movement in the space influenced the aesthetics of the installation, and different choreographies were produced by the online debates occurring in real time. The ambiguity of interpretation elicited by the interactive installation was connected to the ambiguity of information and its controversial nature, offering different points of view and suggesting the need for a clearer understanding and embodiment of these issues.

Worth mentioning is the interplay between online and offline behaviour in highlighting the themes and provoking personal thoughts and discussions. In addition to the posts monitored before and during the showcase, several tweets were generated by visitors on the twitter account *@BalladeOfWomen* and overlaid on the panels. Some of these posts concerned generic comments on the exhibition, but others presented explicit references to political or social events connected to women's rights. For example, a discussion thread was related to the Istanbul convention adopted by the Council of Europe Committee of Ministers on 7 April 2011. The purposes of the Convention is to protect women against all forms of violence and to contribute to the elimination of all forms of discrimination against women through the design of policies and measures. This was discussed online during the exhibition. For example, a post "*the Istanbul Convention is now law of the Italian state*" was displayed and overlaid on the digital fragments of the Santa Lucia painting. Another observation that is worth to mention is the list of followers of the Twitter account. Both the Italian Minister of Education Maria Chiara Carrozza and the Minister for Integration Cécile Kyenge followed *@BalladeofWomen* Twitter account.

These observations suggest that the installation's synthesis of both offline and online behaviour was able to actively involve people to take a personal stance connecting local and global with historical and contemporary perspectives on women's rights.

#### References

1. Video available at: <https://vimeo.com/83584195>
2. Dourish, P.: *Where the Action Is: The Foundations of Embodied Interaction*. The MIT Press, Cambridge, MA. (2001)
3. Marti, P., Trotto, A., Peeters, J., Hummels, C.C.M.: *Instilling Cultural Values through Bodily Engagement with Human Rights*. In: *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI (CHIItaly '13)*. ACM, New York, NY, USA. (2013)
4. Papworth, N. Marti, P. Trotto, A. Peeters, J. *Ballade of Women: The Expedition*. *PerDis '14 Proceedings of The International Symposium on Pervasive Displays* Pages 25 ACM New York, NY, USA ©2014.



# Exploring computational aesthetics for golf club design

## Abstract

In this paper, we describe how the integration of an interactive application in the design process can be used as the basis of defining and personalising the design of golf clubs, particularly golf club-heads. By syncing an individual player's swing data with a unique combination of contemporary digital tools, we are able to modify the traditional design process and expand the range of forms to meet individual needs and demands. We will showcase through an interactive demonstration, how this novel approach to golf club-head design (conception, ideation, form exploration and making) might result in not only an innovative object but also a unique, sensorial golf playing experience. The interface utilizes the variable input of a golfer's swing data to control and determine the value of parameters in a parametric model. These parameters explore the interdependencies between the functional and aesthetic aspects of weight distribution in golf club-heads. This offers a new approach to the mass customization of golf clubs, extending from the current options of shaft flexibility and length, grip type and prefabricated club-heads.

## Keywords

Golf club design, Parametric modeling, Individual data, Mass customization, Additive manufacturing

## 1 Learning from the history of golf clubmaking

“Since golf's origin over 500 years ago, golf clubs have undergone tremendous change and development. Alongside improvements in materials, shapes and methods of manufacturing, a variety of ingenious clubs have been developed to encounter specific situations on the course.” (Ellis, 1997). This evolutionary design process has seen the introduction of new technologies and materials, which in turn present new design possibilities.

One example is the introduction of titanium as a manufacturable material. Titanium's unique properties have resulted in innovative club-head designs, and a new level of performance present in the modern game. As stated by Marc Jenkins (Jenkins, 2009), “titanium is 45 percent lighter than steel. A titanium club does not surrender any power on a stroke because of the lightweight feel it provides.” Titanium drivers are now standard in contemporary golf equipment.

Golf clubmaking can be described as an evolutionary design approach with a rich history of revolutionary innovative elements. The use of digital tools in the design and making/manufacturing process of golf clubs is therefore a logical evolutionary addition to existing fabrication techniques such as forging, casting and hand crafting.

By exploring what contemporary technologies offer, we can respond to the needs and demands of modern golfers, which can be broken down in the following two relationships:

- 1) How the look and feel of the club emphasizes the individual swing style.
- 2) How the performance of the club (consistency & control) enhances the overall golf playing experience.

## **2. The golf club as an emotional experience**

Throughout a series of design experiments, using digital tools in an interactive design process, we aim to investigate how we can enhance the relationship between the golfer, the club and the overall playing experience. In 1908, Garden G. Smith (Smith, 1908) said that, "A man's club's become almost members of his body, and certainly, if their capacity for conveying pleasure and pain to the senses is to measure the matter, the comparison is not overstrained." This reinforces how much an individual club can mean to the 'avid golfer', and how the golf club is no longer just an object, it's a personal, individual experience.

Asensio & Schleifer argue that "we expect the design of sports equipment we use to reflect and be an expression of our personalities" (Asensio & Schleifer, 2004). This recognizes that the emotional and sensorial feedback of sports equipment is as important as the performance feedback an athlete receives and that athletes' equipment should mirror their personalities to truly represent meaningful design relationships.

## **3. Using digital tools as performance and experience factor**

"The computer certainly is the most encompassing and dynamic tool that an architect ever had at his disposal." (Hemmerling & Tiggemann, 2011).

As discussed by Hemmerling and Tiggemann, Computer Aided Design (CAD) in architecture and design has set a new standard for developing and presenting design concepts as well as offering greater freedom for the development of design. We have put this theory into practice to investigate the potential of three driving factors for mass customization of golf apparatus. We use the individual golfers swing data, parametric modelling and additive manufacturing to determine if a combination of these factors will allow us to create

a more personal, sensorial yet practical golf playing experience for the modern golfer.

There is substantial research into parametric modelling, individual digital data collection and additive manufacturing independently in design. However, very little research exists which investigates the combination of these tools as an adapted design process. The creative formation of parameters and how they determine the design and build of a parametric model is of particular interest. "Parametric models have explicit rules and implicit geometry. The relationships and rules between the parts determine the geometric outcome." (Warren & Mahoney. 2013). The nature of an implicit geometry with explicit rules mean the output is only limited by the specific parameters chosen. Using both functional and aesthetic based parameters, we are able to simultaneously explore levels of performance and player experience with the aim of enhancing the relationship between golf club, designer and player, in reference to individuality and mass customization.

By focussing on the creative formation of parameters and how they determine the design, we have formed a demonstration of a parametric model that involves an interface showcasing the adaptability and workability of our digital experiments, in relation to particular functional and aesthetic parameters. Due to the personal nature of the relationship between players and their golf clubs we have favoured the putter as our test golf club. The putter can be considered the most important club for a player defining make-or-break situations in the game and often develops an emotional connection to the club. A replacement of this club is both a performance driven and emotionally driven decision.

This will be assessed against our three factors outlined above.

### **3.1 Parametric modelling**

We have used parametric modelling as the driving interface for our iterative, interactive design exploration. The aim is to produce a model that is easily adapted for mass customization, based on individual preferences and playing styles. For example, customization of a club head requires ideal weight distribution for an individual's swing. As discussed in 'The ultimate putting program' by Henry Stetina

(Stetina, 2013), weight distribution within a club-head affects the performance of both the club and the player during the golf game. "The combination of a golfer's stroke type and the weight distribution of their putter significantly influence their ability to control the speed of their putts." (Stetina, 2013).

With the following set of parameters we explore this relationship. They are based on the functional and aesthetic aspects relating to both performance and experience factors felt while using a golf club. Weight distribution through form and mass are explored through voronoi, geometric, curvaceous, lattice and organic structures. Our focus on functional parameters is dependent on the consistency of an individual's swing and resulting ball path of a series of putts. Our focus on aesthetic, yet practical parameters is a range of shapes and sizes that indicate user preferences for shape and style, while also adapting to the variable in mass.

As discussed by Michael Kilkelly, "a parametric approach only works when the problem is well understood" (Kilkelly, 2015). As architecture firm Warren & Mahoney explain (Warren & Mahoney, 2013), "a parametric model is defined by rules and constraints, which define aspects of a design and their relationships with each other." We apply this idea when establishing connections and relationships between parameters in our model. A set of parameters are more valuable when they complement each other to enhance the merit of the variable input, in this case individual user data. According to a player's data and style of play, these parameters take into account where the weight needs to be distributed to correct any inconsistencies in a swing.

### 3.2 Individual player swing data

"Data is really the new voice of the athlete, and by listening to that voice, we can challenge the current paradigms and do something previously unimaginable" (Nurse, 2014).

The invention of mobile golf data tracking devices has resulted in a range of new tools that record, measure and display comparable data such as swing rhythm, tempo, speed as well as club plane angles, positions and direction. To appropriately determine effective parametric inputs, we have obtained the Swingbyte 2 device that captures and displays individual golfers swing data in a visual, easily understandable way. Swingbyte 2

and other similar devices are currently used by a vast number of professional golfers and coaches as a training tool to improve and monitor their swings.

To control these inputs appropriately we have defined our parameters around the size and shape restrictions as set by the United States Golf Association (USGA). The USGA is the United States' national association of golf courses, clubs and facilities and the governing body of golf for the United States, who together with the R&A (Royal and Ancient Golf Club of St Andrews) produce and interpret the International Rules of Golf world wide (USGA, 2015).

### 3.3 Additive manufacturing

Our third factor is additive manufacturing (AM), coined to be 'the next industrial revolution' (Barnatt, 2013). AM provides the ability to fabricate almost any complex geometry, in a range of materials, without great cost. The reduced need for existing tooling and efficiency of material make it a powerful tool in both manufacturing and design. We consider AM as a digital tool that offers unexplored possibilities in the production of complex forms that further push the exploration of new computational aesthetics. Salome Galjaard, an architectural engineer who's been working with AM and digital optimization tools state's "3d printing will definitely have a big impact on the visual appearance of the world we live in." (Galjaard, 2014).

Materials in AM are also developing at a rapid rate and now include the ability to print titanium and stainless steel, two of the fundamental materials currently used in the manufacturing of golf clubs. A study was undertaken in 2011 about the 'optimal design of a golf club using functionally graded porosity' (Ray, 2011). This engineering based study into the feasibility of electron beam melting (printing with powdered alloys), was an exploration into whether existing additive materials could be functionally used in golf clubs instead of traditional processes and materials.

Our third digital factor (AM) is currently viewed on a theoretical level only, as final outputs are yet to be fabricated. We are close to the stage of our models being fabricated in both alloys (functional clubs) and white plastic models (form models), and we intend to have these as physical, aesthetic and functional objects at the time of the demonstration.



<http://i.imgur.com/YSgJaKl.jpg>



<http://i.imgur.com/pPofhac.jpg>



<http://i.imgur.com/4EcDsjZ.jpg>

#### 4. Conclusions

We have described how the use of digital tools - parametric modelling, digital data collection devices and additive manufacturing can extend traditional product design processes and enrich conception, ideation, design and (theoretical) making of golf clubs. We have

explored a new pathway to determining valuable and meaningful human-object-experiences. Our view is that object to golfer relationships are determined by a players performance, players swing data, individual choice of design and make of equipment. Through an interactive interface, we aim to test how the integration

of computational design aesthetics as a digital design tool, will work as a new valuable functional design element that will result in quality customized choices for the player and eventually enhance the whole golf playing experience. We argue that any interaction between player and equipment starts with the look and feel of the golf club in relation to the players swing. During the conference we will present an interactive demonstration visualizing how we use individual user data with parametric modelling and 3D printing for the putter clubhead. We will invite the audience to actively participate in this demonstration by taking an individual's swing data and applying it to our model. We also understand that we must gain feedback from individuals in the industry once we have fabricated our final models to understand how a digital/personalized club may alter an individual's experience.

## Bibliography

- Asensio, Paco, and Simone K Schleifer. Sport design: four elements. New York: TeNeues, 2004.
- Barnatt, Christopher. 3D Printing: The next Industrial Revolution. [Nottingham, England]: ExplainingTheFuture.com, 2013.
- Ellis, Jeffery B. The Clubmaker's Art: Antique Golf Clubs and Their History. Oak Harbor, Wash: Zephyr Productions, 1997.
- Gaijaard, Salome. "3D-Printed Structural Components Will Lead to 'New Building Shapes,'" 2014. <http://www.dezeen.com/2014/12/17/movie-3d-printed-building-components-new-building-shapes-salome-gaijaard-arup-video-interview/>.
- Hemmerling, Marco, and Anke Tiggemann. Digital Design Manual. Berlin: DOM Publ, 2011.
- Jenkins, Marc. "The Advantages of Titanium Golf Clubs." Golf Link, May 5, 2009. [http://www.golflink.com/facts\\_597\\_advantages-titanium-golf-clubs.html](http://www.golflink.com/facts_597_advantages-titanium-golf-clubs.html).
- Kilkelly, Michael. "Are Computers Bad for Architecture?" ArchDaily, April 13, 2015. <http://www.archdaily.com/618422/are-computers-bad-for-architecture/>.
- Nurse, Matthew. A Look Inside Nike's Sport Research Lab, 2014. <http://news.nike.com/news/a-look-inside-nike-s-sport-research-lab>.
- Ray, Phillip. "Design and Personalization of Golf Club Heads Using Electron Beam Melting, Functionally Graded Porosity, and Numerical Analysis." M.S., Southern Methodist University, 2011.
- Stetina, Henry. "The Ultimate Putting Program (Part 2): Putter Weight Affects Speed." GolfWRX, December 15, 2013. <http://www.golfwrx.com/151102/the-ultimate-putting-program-part-2-putter-weight-affects-speed/>.
- Smith, Garden, G. "There Is Nothing so Fascinating to a Golfer as His Clubs." Golf Illustrated, July 31, 1908.
- USGA. "Rules and Decisions of Golf Clubs." United States Golf Association, 2015. <http://www.usga.org/rules/rules-and-decisions.html#!rule-04>.
- Warren & Mahoney. "Parametric Infrastructure Design." Warren & Mahoney Perspectives, October 28, 2013. <http://www.warrenandmahoney.com/en/perspectives/parametric-infrastructure-design/>.

# A Design Research Methodology using 3D-Printed Modular Designs to Study the Aesthetic Appreciation of Form and Material

## Abstract

Products are typically aesthetically appreciated using multiple of our senses. However, studying the aspects that influence multi-sensory product aesthetics is complicated because of the interaction of visual and tactile product properties, such as form and material, which underlie the aesthetic experience. Illustrated by our ongoing study on the tactile and visual aesthetic appreciation of tangible products, we demonstrate a design research methodology that is highly suitable for studying the influence of material and shape properties. Using state-of-the-art 3D-printing techniques, modular car keys were designed that systematically vary in unity and variety through changes in form and material. The modular approach of designing stimuli, in which form and material properties are customizable through the use of exchangeable components, offers a way in which multisensory aesthetics can be effectively experienced and researched. Such an approach follows the designer's natural methodology of designing, results in realistic stimuli, and gives high control over confounding factors. We argue that this novel design research method thus strongly benefits both practical and theoretical understanding of design aesthetics and related fields. Keywords: Design Methodology, Modular Design, 3D-Printing, Visual-Tactile Aesthetics

## 1 Introduction

Knowledge of design aesthetics is central to the practice

of designers as it informs the designer how form and material can be used to express meaning to the user [1]. At the same time, researching design aesthetics further develops our scientific understanding of how humans perceptually process sensory information and experience the world beyond that of product designs alone. Ideally, in the study of design aesthetics, a research methodology is used that supports the advancement of both these approaches to knowledge generation [2]. However, such research is made difficult by the different requirements these approaches have in their undertaking. While the practical application of design research requires studies to represent actual use and generalizability of research outcomes, progress on fundamental research is often facilitated by controlling as many confounding factors as possible. These somewhat opposing approaches can result in a considerable gap between theoretical knowledge and practical application when doing design research; does the isolated factor under experimental study reliably translate to the practice of design? Continuing in the line of previous studies using designers to create systematically manipulated stimuli [2-4], we present a design research methodology that uses state-of-the-art 3D-printing techniques to find the 'middle-way' between both approaches. In order to illustrate this methodology, we demonstrate the progress of our study which uses 3D-printed modular car keys to investigate the aesthetic principle of unity-in-variety.

### 1.1 Exploring Tactile Aesthetics

While our first impression of a product is often visual, tactile exploration is essential in fully perceptually grasping a tangible product. Properties such as weight, material and temperature, convey sensory information that can only be reliably assessed by touch. Understanding the way in which both form and material interact to create a multisensory, aesthetically appreciated, meaningful and emotional experience is therefore crucial when designing. Even more so considering that the importance of tactile interactions becomes dominant over visual ones after prolonged user-product interactions [5]. Despite this, knowledge about tactile aesthetic appreciation, and its interaction with visual aesthetics, is still limited.

In previous research we have shown that the principle of unity-in-variety, known to influence visual aesthetics, applies to tactile aesthetics as well [6]. Unity is the order, structure and coherence of what is felt, while variety is assessed by judging the degree and number of differences in tactile sensations. Using car keys which are in the market, we found that tactile aesthetic appreciation is dependent on the balance between the unity and variety felt and that, while unity and variety suppress each other's effect, they both contribute to aesthetic appreciation.

The principle of unity-in-variety offers a way to theoretically and practically investigate tactile and visual aesthetic experiences of products. However, in our previous study, participants judged nine car keys from a variety of brands. While diversity in stimuli adds to the generalizability of results, it becomes difficult to assess how individual properties (e.g. form and material) influence aesthetic appreciation. For designers, it is often this specific knowledge that is needed to make informed decisions about a design. While traditional research has investigated some of these haptic properties, materials are often judged separately from shapes and without free exploration [e.g. 7]. Such methodologies make generalizing results to the design field problematic. Hence, we developed a research methodology that systematically studies the influence of small changes in form and material properties on aesthetic appreciation.

## 2 Research Methodology

In the following section we use our own study on aesthetic appreciation of tactile unity and variety to

elaborate on the decisive factors of our research methodology.

### 2.1 3D-Printing for Stimuli Development

To accurately relate research outcomes to theoretical and practical knowledge in the design context, it is essential that stimuli are both realistic and diverse. It is mainly in this area that modern 3D-printing offers benefits over more traditional methods. Current suppliers of 3D-prints (e.g. Shapeways and i-materialise) allow for detailed (600-1200dpi), accurate ( $\pm 0.3\%$ ), customizable and affordable ways of creating haptic stimuli (Fig. 1). Production of these models is available in a wide range of materials (e.g. polymers, rubbers, ceramics, metals and alloys) which can be finished in different ways (brushed, polished, dyed or coated with velvet) to mimic the haptic properties of market products.



Fig. 1. Examples of detailed variations in textures of 3D-printed cups

### 2.2 Choice of Stimuli

While vision allows for a quick impression of a product's form, the different nature of haptic exploration requires taking other aspects into account. Haptic exploration of a surface is done in a combination of six to eight actions [8]. By using a variety of hand movements, properties such as texture, hardness, elasticity, thermal conductance, weight, and global and exact form can be identified. When choosing stimuli to investigate tactile aesthetics, the degree to which these forms of haptic exploration can be performed should be carefully taken into account.

Our study into the factors that influence unity and variety uses car keys. The size of a car key allows for fully enclosing the product with one hand, making

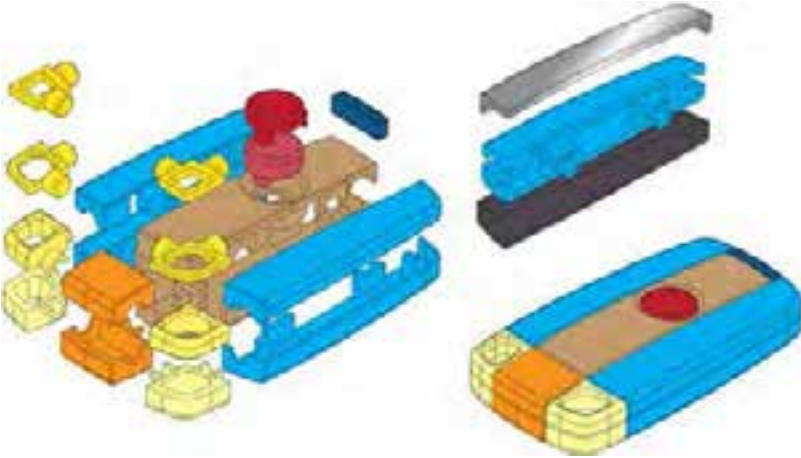


Fig. 2. Left: Exploded view of our modular car key. As indicated by their similar color tone, the key holes and buttons are made interchangeable to influence shape. Top-right: material variations are made by overmolding metal (top) or rubber (bottom). Lower-right: assembled version



Fig. 3. 3D-printed components varying in shape (key holes and buttons) and material (gray: alumide, blue & white: plastic, brown & gold: steel).

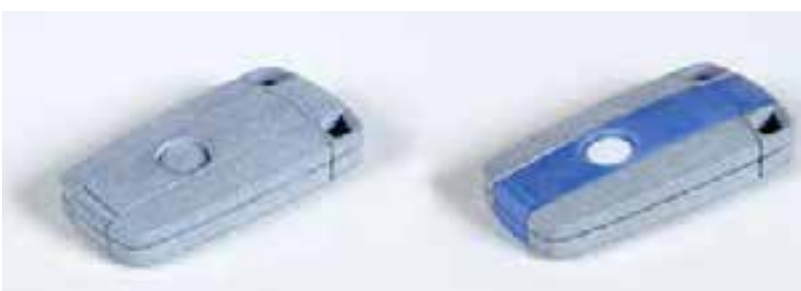


Fig. 4. Assembled model using 1 versus 3 different materials

it easy for people to assess the global shape of the product. When it comes to exact shape, modern car keys often include a certain degree of functionality that requires the presence of buttons. This creates a more interactive experience that stimulates active exploration. The weight of car keys is in a range in which subjects can reliably make comparisons. The accepted use of several different materials (e.g. plastic, rubber, metal, and in some cases wood and glass) make it possible to study large differences between texture, hardness and heat conductance. Furthermore, besides the immediate sensory impression that these products create, car keys communicate (brand) meaning through their form and material.

### 2.3 Modular Design

In order to study the effects of changes in material and form properties, it is essential that these changes are done systematically. This implies that principally the factors of interest are manipulated while other factors are being kept constant. Such can be achieved by creating modular stimuli.

The design of modular stimuli allows for small changes in form and material with high customizability. The car key we developed is a modular assembly consisting of 13 exchangeable components (Fig. 2). As our goal is to influence the degree of unity and variety that can be felt, we choose to manipulate variety by means of differences in material properties, while manipulating unity through form. Printing of each component in plastic, rubber and metal should affect variety because of differences in properties such as texture, hardness, conductance of heat and weight. Furthermore, to affect unity we manipulated the form of several components (button, keychain hole and gap spacing) along the lines of three Gestalt laws of grouping, which have been shown to also influence tactile grouping [9]. The modular design and variation of three material and shape manipulations lead to a wide range of possible designs (Fig. 3). Despite the high number of combinations, the designerly method of developing these stimuli ensures that none of these possible combinations are highly atypical, while at the same time retaining a high degree of control over the variables of interest (Fig. 4).

### 2.4 Other Considerations

The example we illustrated is based on a completely new design. This allows full customizability in which



visual and tactile aesthetic appreciation of form and material can be systematically studied. We choose not to include more complex interactive dimensions of aesthetic appreciation, yet, our design methodology still allows for studying more interactive products as well. For example, custom 3D-printed optical elements can be embedded in interactive products to allow for use of sensors and optoelectronics [10]. Furthermore, although requiring a skilled modeler, it is possible to 3D-print relatively complex mechanical structures, such as joints, without having to assemble this afterwards [11]. Lastly, while we 3D-printed a full model, in some cases it might be beneficial to use prefabricated dynamic components of a market product and only print the exterior.

### 3 Conclusion

Design research is often performed on the challenging border between practical applicability of design knowledge and theoretical progress in fundamental research. In researching the influence of form and materials on tactile and visual aesthetic appreciation of tangible products, we demonstrated a design research methodology that attempts to make reliable progress on both fields at the same time. Our use of 3D-printed modular car keys acts as an illustration of the way in which comparable design research can be performed. The design research methodology we offer here has several benefits that make it highly suitable to research design aesthetics. First, product designs can be studied in a systematic way that combines scientific rigor with a designer's natural method of product design, narrowing the gap between design theory and design practice. Second, it facilitates researching how different senses together affect design aesthetics, enabling designers to make more informed decisions. Examples of these are creating (in)-congruency between visual and tactile domains, which can heighten emotional engagement or elicit surprise [4, 12], or communicating brand identity through form and material [13]. Third, while we have looked at the way in which a modular and systematic design method of haptic stimuli can aid in researching multisensory aesthetics, the use of this approach can of course be extended to other products and design theories such as the experience of emotion [14]. The design method thus offers a way of systematically researching the influence of form and material in a wide variety of domains.

### References

1. Bloch, P.H.: Seeking the ideal form: Product design and consumer response. *The Journal of Marketing* 59, 16-29 (1995)
2. Hekkert, P., van Wieringen, P.C.W.: The impact of level of expertise on the evaluation of original and altered versions of post-impressionistic paintings. *Acta Psychologica* 94, 117-131 (1996)
3. Schifferstein, H.N.J., Otten, J.J., Thoolen, F., Hekkert, P.: The experimental assessment of sensory dominance in a product development context. *Journal of Design Research* 8, 119-144 (2010)
4. Ludden, G.D., Schifferstein, H.N., Hekkert, P.: Visual-tactile incongruities in products as sources of surprise. *Empirical Studies of the Arts* 27, 61-87 (2009)
5. Fenko, A., Schifferstein, H.N.J., Hekkert, P.: Shifts in sensory dominance between various stages of user-product interactions. *Applied Ergonomics* 41, 34-40 (2010)
6. Post, R.A.G., Blijlevens, J., Hekkert, P.: Aesthetic Appreciation of Tactile Unity-in-Variety in Product Designs. In: Kozbelt, A. (ed.) *23rd Biennial Congress of the International Association of Empirical Aesthetics*, pp. 358-360, New York, United States of America (2014)
7. Essick, G.K., James, A., McGlone, F.P.: Psychophysical assessment of the affective components of non-painful touch. *Neuroreport* 10, 2083-2087 (1999)
8. Lederman, S.J., Klatzky, R.L.: Hand movements: A window into haptic object recognition. *Cognitive psychology* 19, 342-368 (1987)
9. Gallace, A., Spence, C.: To what extent do Gestalt grouping principles influence tactile perception? *Psychological Bulletin* 137, 538 (2011)
10. Willis, K., Brockmeyer, E., Hudson, S., Poupyrev, I.: Printed optics: 3d printing of embedded optical elements for interactive devices. In: *Proceedings of the 25th annual ACM symposium on User interface software and technology*, pp. 589-598. ACM, (Year)
11. Cali, J., Calian, D.A., Amati, C., Kleinberger, R., Steed, A., Kautz, J., Weyrich, T.: 3D-printing of non-assembly, articulated models. *ACM Transactions on Graphics (TOG)* 31, 130 (2012)
12. Salgado-Montejo, A., Velasco, C., Olier, J.S., Alvarado, J., Spence, C.: Love for logos: Evaluating the congruency between brand symbols and typefaces and their relation to emotional words. *J. Brand Manage.* 21, 635-649 (2014)
13. Ashby, M.F., Johnson, K.: *Materials and design: the art and science of material selection in product design*. Butterworth-Heinemann (2013)
14. Desmet, P.M., Hekkert, P.: Framework of product experience. *International Journal of Design* 1, 57-66 (2007)

# An Exploration In Kitchen Blender Interactions Aimed At Designing For Higher Levels Of Engagement

## **Abstract**

This paper illustrates three novel kitchen blender interactions aimed at bringing about a higher level of engagement with interactive products, as a response to current, seemingly un-engaging interactions. We describe our starting points and approach after which we present the designed blender interactions. Following that, we illustrate the set-up of our first evaluation and present preliminary findings. We wrap up by outlining future work.

The experiment was performed comparing the novel interactions with the original blender interaction using Rozendaal's Richness, Control and Engagement (RC&E) Framework. The outcomes suggest that the designed interactions are indeed more engaging than the original blender interaction.

## **Keywords**

Engagement, Interaction design, Mindfulness, Human skill

## **1 Introduction**

As described by Sloterdijk [13] we increasingly live our lives in the media: instead of having proper attention to a task at hand, we get distracted more and more by the digital realm that over the past years has blended thoroughly into our non-digital one. As designers of interactive artefacts, we feel this trend of being-in-the-media is not good. We prefer being-in-the-world,

and do not stand alone here. For example, Hummels [7] analysed kitchen appliances throughout the 19th and 20th century and observed that Human-product interaction has become less physical and less engaging, partly due to uniformity. Also, Frens [4] observed that electronic products are typically operated through small, standardized actions., making that products require us to interact through buttons and menu screens, relying on mainly our cognitive skill, instead of the three skills identified by Overbeeke et al. [9], i.e., cognitive, perceptual-motor, and emotional skills. The work described in this paper connects to these observations and is specifically aimed at investigating how to design interactive artefacts in such a way that they engage us in the non-digital so that we are less consumed by the digital. We present two contributions: Three compelling examples of interactive artefacts to demonstrate the just mentioned direction and an evaluation of these artefacts. What follows is a short introduction to the designed blender interactions and a pilot study that provides initial indications that addressing all human skills might lead to higher levels of engagement.

In order to engage people we can learn from what has already been said about engagement. For example, Chapman [2] states that "*something that 'engages' us is something that draws us in, that attracts and holds our attention*". Also, engagement can go as far as being in a flow, which is when someone is fully engaged in an



Fig. 1. Three Novel Blender Interactions: Rotary, Push and Pull

activity, having intense focus and concentration on present moment, the merging of action and awareness, loss of reflective self-consciousness [3]. In the context of product design, Quesenberry [11] defined engagement as: “the degree to which the tone and style of the interface makes the product pleasant or satisfying to use.” where ‘tone’ and ‘style’ can be seen as hedonic qualities relating to the intrinsic stimulation of a product in order to use it, rather than pragmatic functional attributes of a product [5].

## 2 Designing Kitchen Blender Interactions Aimed At Higher Levels Of Engagement

### 2.1 Design process

To explore how to design for more engaging interactions through addressing multiple human skills, we developed a set of three interactions with a kitchen blender, following a Research-through-Design process, which can be described as a process in which scientific knowledge is generated through, and fed back in consequent cycles of designing, building and experimentally testing [6, 8]. In our design process we allowed ourselves to be inspired by activities from our daily lives with a special focus on bodily engagement, ranging from careful and controlled, to energized and large. We describe these below when we address the designed interactions. We translated the inspirations into meaningful and natural mappings between user input and functional output using the Interaction Frogger framework [14]. Below we describe the outcome of this process.

### 2.2 Designed interactions

**Interaction 1: Rotary.** This interaction (See Fig. 1, top left) was inspired by the precision we holds a pencil while painting. The speed of the blender is mapped to the degree to which the stick is rotated: the further

the stick is rotated counter-clockwise, the faster the motor will spin. Rotating the stick back will decrease the blender speed.

**Interaction 2: Push.** The second blender interaction (Fig. 1, Interaction 2) resembles a pump that requires continuous repetitive input. The increase in pressure applied to the handle at the top of the blender is mapped to the increase of the blender’s speed.

Releasing the pressure has no result on the motor speed. This means that the user needs to keep on pushing down in order to keep the blender spinning.

**Interaction 3: Pull.** The third blender interaction was based on a ‘top and whip’; a toy from the past in which the goal was to keep the top spinning. It has a string that can be pulled out of the top of the body, similar to starting a motorboat (Fig. 1, Interaction 3a). The acceleration with which the string is pulled is translated to the acceleration of the blender motor. The string is automatically pulled inwards this has no effect on the blending speed. In order to keep the motor spinning, the user can rotate the handle above the blender body (Fig. 1, Interaction 3b). By rotating faster, the blender speed will increase, by rotating more slowly, the blender will decrease in speed.

A movie of the working prototypes can be found at: <http://vimeo.com/118347875>

## 3 Evaluating the Kitchen Blender Interactions

### 3.1 Goal and setup of the experiment

The goal of the evaluation is to explore to which extent the designed interaction styles - addressing not only cognitive, but also perceptual-motor and emotional skills - lead to higher levels of engagement in comparison to the original push-button blender interaction. We chose for this original interaction style



Fig. 2. The Original, Rotary, Push and Pull interaction during the evaluation

as it is also can be found in a lot of other appliances. Four participants (25-37yrs) who are experts in the field of interaction design were recruited, as they are able to look beyond the flaws of the prototypes and are able to focus on the experience and interaction. All participants had experience with blending prior to the experiment. The experiment held qualitative and quantitative components. The qualitative component was conducted through observations and the think-aloud method [10]. The quantitative component consisted of a questionnaire using attributes based on Rozendaal's RC&E framework [12], which was developed to assess the level of engagement with a product. The framework is composed of three elements: Richness, Control and Engagement. Through the levels of Richness and Control the levels of Engagement can be predicted. Richness captures the level of experienced variety and complexity of thoughts, actions, and perceptions that are evoked during the activity and is strongly influenced by the product features. Control captures the experienced effort one needs to invest in order to fulfil a goal. It relates to feelings of competence and confidence during the interaction. In order to assess the experienced levels of Richness, Control and Engagement we used the attributes assigned to these elements to create a survey assessing the attributes on a seven-point Likert-scale. *Challenge, stimulating, enervating, possibilities, variety and richness* are the items assessing Richness. *Control, self-confidence, ease, clarity, freedom and personal style* are the items used to assess Control. The elements assessing Engagement were: *engagement, fun, motivation, enjoyment, challenge, excitement, freedom, stimulating, personal style*.

All four blenders were evaluated through the following procedure, consistent of two main parts. In the first part the participant firstly gets time to explore the interaction and to get acquainted with it by blending crisps to pulp. In order to give a clear goal and get the participant focused on actually blending, they are asked to blend crisps down to approximately one-fifth of their original size. Participants were encouraged to think-aloud [10]. In the second part the participant fills a questionnaire and is encouraged to motivate the answers. This way qualitative insights are gained about the experiences regarding the attributes in the questionnaire. For each blender interaction this process was repeated, varying the order in which they were presented in order to prevent influences from this order.

#### 4 Findings

Figure 3 shows the quantitative findings retrieved from the questionnaires. The bars show the medians of the results of the overall levels of Engagement, Richness and Control per blender interaction based on the attributes outlined in section 3.3.

We performed a thematic analysis [1] on the think-aloud quotes and observations. First we familiarized ourselves with the data by transcribing the recorded data, resulting in 27 quotes and 12 observations. We categorized these quotes and observations to Richness, Control and Engagement per blender interaction. We realize that a number of four participants is too low to draw solid conclusions, yet the quantitative outcome allows us to easily visualize the results in order to get a general overview our findings that we will explain using the qualitative data.

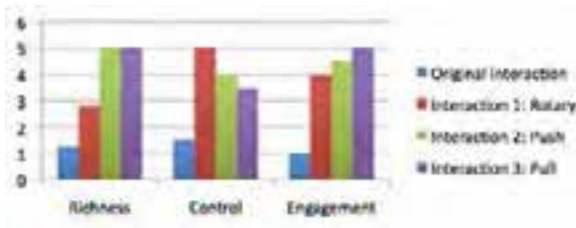


Fig. 3. Levels of Richness, Control & Engagement per Blender Interaction

The three novel blender interactions all show higher levels of Engagement in comparison to the original interaction. The Original Interaction scored in terms of Richness very low. As a participant noted *“there is only one option; pzzzz, look what it is, pzzzz, look what it is...this makes it very easy”*. Also at the level of Control the Original Interaction scores low. As one participant prompted when attempting to blend crisps into little pieces: *“I approached it gently, but the result wasn’t really gentle”*.

Overall it seemed that the Rotary Interaction was experienced to be most controllable of all interaction styles: *“it is possible to very subtly search for the right speed, and switch very subtly between slowly and just a bit faster and back to slowly”*. But it was – though more Rich than the original interaction- less challenging, exciting and enervating than the Push and Pull blenders that allowed more freedom in expressivity through their mappings. Therefore the Rotary was also less Engaging: *“Since you have this much control it is also less challenging”*. Interaction 2 and 3 were experienced to be less easy to control in comparison to the Rotary Interaction but were both experienced to be more Rich and Engaging. Where the Rotary Interaction was relatively not challenging, the Push and Pull Interactions seemed to leave room for growth and were more engaging over time: *“You need to learn to couple your proprioception to the speed of the thing”*. Though, this also resulted in lower experienced self-confidence when using the blenders with Pull and Push Interaction.

## 5 Discussion

The first evaluation showed indications that the taken design approach that not only addresses our cognitive, but also perceptual-motor and emotional skills, led to higher levels of Engagement in a short lab setting evaluation. A more rigid experiment needs to be conducted in order to be able to make actual claims.

It would be interesting to evaluate the novel blender interactions on engagement during long-term experiments. Probably the skill level of the participant would increase leading to higher levels of Control and possibly decreasing the level of Engagement. As the current exploration focuses on blender interactions, we are currently looking for other kitchen interactions in order to broaden the area of types of interactions to which the design approach would be applicable to design for interactions with higher engagement levels.

## References

1. Braun, V., and Clarke, V.: Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, pp. 77-101 (2006)
2. Chapman, P.: Models of engagement: Intrinsically motivated interaction with multimedia learning software. Unpublished master's thesis, University of Waterloo, Waterloo, Canada. (1997).
3. Csikszentmihalyi, M Finding Flow-the psychology of engagement with everyday life, ISBN 978-0-465-02411-7, pp. 28-34 (1997)
4. Frens J.W. (2006). Designing for rich interaction: integrating form, interaction and function. Doctoral dissertation, Eindhoven University of Technology, Eindhoven, the Netherlands.
5. Hassenzahl M (2004) The interplay of beauty, goodness, and usability in interactive products. *Hum Comput Interact* 19(4):319–349
6. Hengeveld, B.J. DesigningLinguabytes: ATangible Language Learning System for Non- or Hardly Speaking Toddlers. Doctoral Dissertation, Eindhoven University of Technology (2011). P99
7. Hummels, C. (2000) (p. 1.9-1.13) Gestural Design Tools: Prototypes, Experiments and Scenarios. Unpublished Doctoral Dissertation, Delft University of Technology, Delft, the Netherlands.
8. Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., and Wensveen, S.A.G. Design Re-search through Practice; From the Lab, Field, and Showroom. Elsevier (2012).
9. Overbeeke, C.J., Djajadiningrat, J.P., Wensveen, S.A.G., and Hummels, C.C.M. (1999) Experiential and respectful. *Proceedings of Useful and Critical, UIAH Helsinki*.
10. Preece, J., Sharp, H., Rogers, Y., (2007). *Interaction Design- Beyond human-computer interaction*. West Sussex: John Wiley & Sons Ltd. (observations: pp. 359-388, think aloud method: pp365-368)

11. Quesenbury W (2002) The five dimensions of usability.  
In: Albers M, Mazur B (eds) Content and complexity:  
Information design in technical communication. Erlbaum,  
Mahwah, NJ, pp 81–102
12. Rozendaal, MC., Keyson, DV., Ridder, H. de.: Product  
features and task effects on experienced richness, control  
and engagement in voicemail browsing Pers Ubiquit Comput  
13:343–354 (2009)
13. Sloterdijk (2006). Zorn und Zeit. Politisch-psychologischer  
Versuch, ISBN 3-518-41840-8, p246.
14. Wensveen S.A.G., Djajadiningrat J.P. & Overbeeke C.J.  
(2004). Interaction frogger: a design framework to couple  
action and function through feedback and feedforward.  
Proceedings of DIS2004,177-184.

# Light Bird: An Animated Biofeedback Interface for Coherent Breathing

## Abstract

Biofeedback-assisted breathing training is widely used in stress mitigation and relaxation exercise. It helps users to breathe coherently with the natural heart rate oscillation, which facilitates circulation and strengthens the capability of autonomic nervous system to adapt to stress. We present Light bird: a paper-crane shaped animated interface that presents biofeedback information and targeted breathing guidance in the same interface. We hypothesized that Light bird would improve the effectiveness and the experience of breathing training. We tested our hypotheses by comparing Light bird with a graphic interface during the 10-minute breathing training. While users gave higher subjective ratings for the experience on Light bird, their heart rate oscillation was not enhanced significantly. We discuss these results and future design insights for designing the interface of biofeedback technology in the context of coherent breathing training and stress mitigation.

## Keywords

Biofeedback; coherent breathing; interface design; relaxation

## 1 Introduction

The competitive working environment in modern society is full of stressors, which put people at risk of several stress-related illnesses like heart disease, hypertension and strokes. As we already know, doing

exercise, listening to music and watching a good movie all can help relieve excessive stress. Meanwhile, in recent years, biofeedback technology offers a new way for stress mitigation [1]. An increasing number of biofeedback-assisted devices and games have been developed for helping people to practice coherent breathing and achieve a better state of physical relaxation and mental calmness [2, 3].

Coherent breathing facilitates circulation and autonomic nervous system (ANS) balance, which could strengthen our bodies' capability to adapt to stress [4]. Several researchers had found a 0.1-Hz natural oscillation in heart rate which could be observed when people relax and breathe deeply [5]. This oscillation is the result of many nervous systems (i.e. the parasympathetic nervous system and the baroreflex system) and circulation system working together. Deep breathing could be a 'stimulus' causing heart rate to fluctuate and generate a low frequency rhythm at around 0.1 Hz. Especially when people breathe at the same rate of 0.1 Hz (around 6 circles per minute), the rhythm of breathing forms a 'harmonious' resonance with the heart rate oscillation, boosting 'relaxation responses' of autonomic nervous system. The 'relaxation responses' could balance the excessive 'stress responses' triggered by the external environment. The balance of autonomic nervous system will yield good psychological and physiological changes including mental and physical comfort, better performance, greater emotional stability, etc.

As Stephen Elliott described in a BMED Report [6] “When we are breathing “coherently”, the nervous system “relaxes”, and when it does both body and mind follow”. During a coherent breathing exercise, people observe the oscillation of heart rate from a biofeedback device and learn to regulate their breathing. Usually, they need to slow down their breathing rate into a similar pace of the heart rate oscillation for improving heart rate variability. Heart rate variability (HRV) biofeedback is developed for guiding users to inhale and exhale at the ‘right timing’ (i.e. ‘A’ point breathes-in, ‘B’ point breathes-out in Fig.1).



Fig. 1. The waveforms of heart rate and respiration during the transformation from normal breathing to coherent breathing [7]

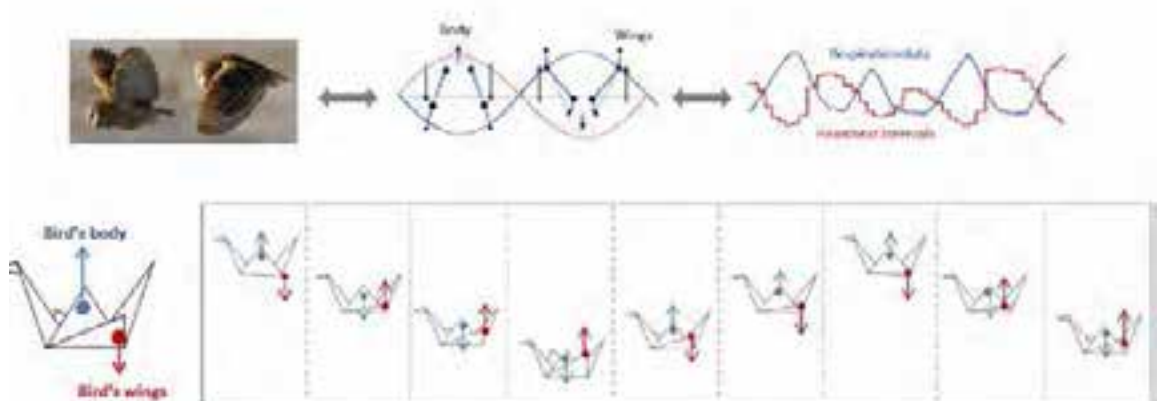
Unfortunately, most of biofeedback systems offer the average users a ‘technical style’ or ‘medical style’ interface, which seems too task-oriented to feel relax using it. As shown in Fig.1, according to specific visual cues displayed on the computer screen, users regulate their breathing to control the fluctuations of ‘Red’ heart rate line in synchronization with the ‘Blue’ respiration line. Despite high accuracy and fast responses, the graphic or numeric interfaces seem not suitable to be used in stress-coping or relaxation-inducing products due to decreasing motivation levels with time. In this study, we present Light bird, a new animated

interface of biofeedback breathing training application. Light bird is designed for physical relaxation and stress mitigation by guiding the users’ breathing into a 0.1 Hz resonant frequency. The Light bird’s body fluctuates up and down periodically at 0.1 Hz, providing the targeted breathing rate. The wings’ movements are controlled by heart rate data, presenting the real-time heart rate oscillation. Thus, by regulating the bird’s body and wings up-and-downs in a coordinated fashion, the user could acquire a better breathing pattern and achieve greater heart rate variability. We also present results from an experiment, in which the effectiveness and the experience of Light bird was evaluated.

## 2 Design Process

In this design, we aim to bring more enjoyments into a breathing training by add-ing new aesthetics and metaphors into the interface design. We believe that the field ‘in between’ pure art visualization and technical graphic display can benefit to both breathing training and relaxation. In addition to presenting biofeedback information (i.e. heartbeat intervals), we also want to visualize an important concept of ‘coherent breathing’. Heart rate has an inbuilt oscillation around 0.1 Hz, when people breathe at a similar frequency, the oscillation will be enhanced. To present this coherence, we finally select a ‘flying bird’ as the ‘carrier’ of biofeedback; and the heart rate data and breathing guidance are mapped to its wings movements and body’s up-and-downs respectively. During a bird’s flight, its wings and body move in a coordinated fashion. This coordinated movement could properly present the coherence between our cardiac activities and breathing movements, as shown in Fig.2.

Fig. 2. The design process of the visualization of ‘Light bird’





We visualize Light bird using an image of paper cranes, as shown in Fig.2. In Asian cultures, especially in Chinese and Japanese cultures, the paper crane (Thousand origami cranes) is thought to be a sign of long life, good luck and peace of mind. Here, we assume that the aesthetic of paper cranes could enhance the experience of interface and the light-weighted visual effects will make it looks easy to move and control. On the interface, Light bird moves up and down smoothly at the rate of 0.1 Hz, indicating a targeted breathing rate of 6 cycles per minute. The position of wings is controlled by heartbeats intervals, which are the inverse of heart rate. Light bird moving from the bottom up indicates an inhalation, in which the heart rate accelerates and heartbeat intervals decrease, presented with a moving-down wings. When the user achieves a state of coherent breathing, Light bird's flight becomes well-coordinated. Figure 3 shows our biofeedback system. Heartbeat data is measured by a pulse sensor placed on the left index finger. The pulse sensor is connected to an Arduino board as the unit for data acquisition. The program of Arduino processes the raw pulse signal into heartbeats intervals data, and then transmits the data to the PC through a USB serial port. The PC runs the visualization program mapping the acquired HRV data to the movements of Light bird.



Fig. 3. Light bird interface in our biofeedback system and the graphic interface of Stresseraser

### 3 Evaluation

An experiment was conducted to evaluate Light bird from two aspects: 1. the effectiveness of breathing training; 2. the interface experience. We hypothesized that Light bird would improve the effectiveness and user experience of breathing training.

#### 3.1 Experiment design

We designed a within-subjects experiment with 20 participants. All participants completed two 10-minute breathing trainings with different interfaces. The

independent variable is the type of interface and dependent variables are users' heart rate variability and subjective rates on the interface's experience. We used the Light bird from section 2 and a commercial Stresseraser having a graphic interface for the control condition. *Stresseraser*<sup>1</sup> is a commercially marketed biofeedback device designed to enhance heart rate variability. The graphic interface of *Stresseraser* is shown in Fig 3.

#### 3.2 Measurement

The aim of coherent breathing training is to improve heart rate variability (HRV). Therefore, to gain qualitative data about the training effects, subjects' heart rate variability data was measured during both pre-training resting period and two breathing tests. We calculated SDNN (standard deviation of heartbeats intervals) as the index of HRV. Regarding interface experience, we used *AttrakDiff*<sup>2</sup> questionnaire to collect the users' subjective rates on the experience of the interface.

#### 3.3 Participants

20 volunteers (11 females and 9 males, age range: 25 to 35) participated in the study. All participants gave the written informed consent and provided the permission for publication of photographs with a scientific and educational purpose.

#### 3.4 Procedure

On arrival at the laboratory, the participants were instructed how to use the biofeedback program. Then, we fitted the participant with the pulse sensor and instructed them to breathe deeply with eyes closed. This pre-training resting period lasted 10 minutes. Next, the participants performed two 10-minute breathing training tests in a random order and they were given a 10-minute break between two tests to relax. After each test, participants completed an online *AttrakDiff* questionnaire.

#### 3.5 Qualitative results

The results of *AttrakDiff* questionnaire show that the overall scores of both interfaces are located in center area neutral (see Fig. 4). In terms of pragmatic quality (PQ), which describes the usability of an interface, the Light bird is rated higher than the graphic interface. The hedonic quality (HQ) dimension indicates to



Fig. 4. Results of AttrakDiff questionnaire

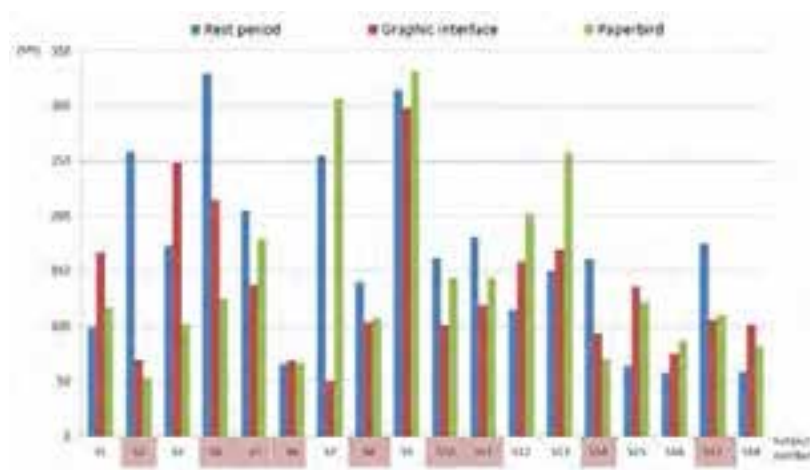


Fig. 5. Results of heart rate variability

what extent the interface can support those needs in terms of novel, interesting, and stimulating functions, contents and interaction. The Light bird also shows a higher HQ than graphic interface. The higher HQ of Light bird can possibly be explained by its visual design; several participants commented: “it looks simple and elegant”. However, in both dimensions PQ and HQ, both interfaces only reach the average level, which means there is room for improvement.

### 3.6 Quantitative results

For each participant, heart rate variability during the pre-test period and two breathing tests were calculated in terms of SDNN, which means the standard deviation

of heartbeats intervals. Heartbeats data was missing from two participants because of technical problems. In Fig. 5, SDNN values do not show a significant increase on the whole after the breathing trainings. On the contrary, for nearly half of participants, the SDNN decrease after both trainings, these subjects' number is marked as red in the figure. The rest participants show an increased SDNN value after either or both of breathing trainings.

## 4 Discussion

The results of AttrakDiff questionnaire suggest that Light bird a higher hedonic quality. More than 80% participants thought it was interesting to transform the breathing training task into the control of bird's movement. Most participants emphasized that the Light bird was easy to understand and more interesting to use in the first several minutes of training during which they were getting familiar with the interface. Therefore, we think an animated interface like Light bird might help a new user get comfortable with biofeedback techniques in the initial stage of training. But for a longterm use, the biggest challenge of visual interface for breathing training might still be an increasing feeling of boredom and decreasing motivation level with time.

Before the experiment, we assumed that Light bird would help to improve the effectiveness of breathing training, which might be reflected by an improved HRV. Although the results were quite different from what we assumed, we still obtained many valuable insights for future design. One possible explanation for the decreased SDNN might be increased mental workload and psychological stress caused by the unfamiliarity with new technologies (i.e. new biofeedback concept, new interface and new training method etc.). This explains why nearly half of participants showed best relaxation effect during the self-relaxation period without any biofeedback. We think regarding biofeedback training, no matter in design of system, device or interface; it would still be challenging but interesting to investigate how to lower the learning effort of biofeedback in early use but also keep it fun and enjoyable for long term use.

## 5 Conclusion

In this study, an animated visualization Light bird was designed to present heart rate variability and breathing guidance in a biofeedback breathing training. We try to bring new aesthetics and right metaphors into the

interface design. We described the design process of Light bird and results of the evaluation. The results show that Light bird received higher subjective rates on the user experience of interface. But there was no significant improvement of HRV being observed after breathing trainings with biofeedback. We think it is still a big challenge to design a proper form of biofeedback which can deliver feedback information adequately and clearly, but also promote relaxation experience effectively. For future research, we will develop a complete close-loop biofeedback system by integrating a respiratory sensor into the system to replace the fixed breathing guidance with the real-time personal respiration data. This will possibly contribute to the effects of training.

## References

1. Whited, Amanda, Kevin T. Larkin, and Matthew Whited.: Effectiveness of emWave biofeedback in improving heart rate variability reactivity to and recovery from stress. *Applied psychophysiology and biofeedback*, 39(2), 75-88 (2014)
2. Park, S. H., Jang, D. G., Son, D. H., Zhu, W., & Hahn, M. S.: A biofeedback-based breathing induction system. In: 3rd International Conference on Bioinformatics and Biomedical Engineering, pp. 1-4. (2009)
3. Muench, Frederick.: The Portable StressEraser Heart Rate Variability Biofeedback Device: Background and Research. *Biofeedback* 36(1), (2008)
4. Lehrer, P. M., Vaschillo, E., & Vaschillo, B.: Resonant frequency biofeedback training to increase cardiac variability: Rationale and manual for training. *Applied psychophysiology and biofeedback*, 25(3), 177-191. (2000)
5. Lehrer, Paul, and Evgeny Vaschillo.: The Future of Heart Rate Variability Biofeedback. *Biofeedback* 36(1), (2008).
6. Stephen Elliott.: An Introduction To Coherent Breathing, *Psychophysiology*, (2009) <http://www.bmedreport.com/archives/7303>
7. Lehrer, Paul M., and Richard Gevirtz.: Heart rate variability biofeedback: how and why does it work? *Frontiers in psychology*, 5 (2014).

---

<sup>1</sup>Stresseraser: <http://www.stresseraser.nu/>

<sup>2</sup>AttrakDiff: <http://attrakdiff.de/index-en.html>

# Unify: Sharing Digital Media Content from the Cloud through Physical Interaction

## **Abstract**

Sharing digital media in the cloud between our everyday smart devices has become an essential part of our workflows. The goal of the project was to explore new ways to share and interact with intangible media using specific devices such as smartphones and tablets. Many current commercial and research concepts are often technology-led. The concept presented in this paper, Unify, aims at envisioning how these technologies would fit in the users everyday life, moving from explorative to contextual concepts. Unify introduces specific affordances of the physical world to intangible digital objects by using the physical properties of tangible smart devices. In this way the device becomes a metaphorical physical container in which the digital objects are subject to the law of physics. This offers a different mindset for the user, releasing images of what users consider to be appropriate or standard behavior with smart devices. Through a qualitative evaluation it became apparent that users could envision the concept to be part of their daily routines and they do not need a lot of time to make this switch, which is promising for further development in this field.

## **Keywords**

Interaction design, cloud computing, physical affordance, intangible digital objects

## **1. Introduction**

Cloud computing offers technical benefits of saving local disk space, serving data processing and (co-) working from different locations. With a growing amount of applications such as Dropbox, Spotify and Netflix, sharing digital media in the cloud among our smart devices is becoming a part of our daily lives. Large software developers like Microsoft and Apple now also design for interoperability in their operating systems [1, 2]. Recognizing these growing systems as the next frontier of design, this work aims for physical interactions in digital cloud-based devices where artifacts from the physical environment move towards the digital world [3]. However, as cloud-based services are becoming more and more present in our daily lives and workflows, they are arguably less connected to our behavior in the physical space. This also becomes apparent through an online survey done during this project, in which the majority of respondents (n=44) indicate to prefer physical alternatives (for example an external hard disk) to digital ones (for example Dropbox) when asked what medium they would use for security-critical data. The need of an internet connection and unclear privacy issues were mostly mentioned as downsides of cloud-based services, because respondents mostly stated that they want to have a better overview of who can access their files and where they are stored.

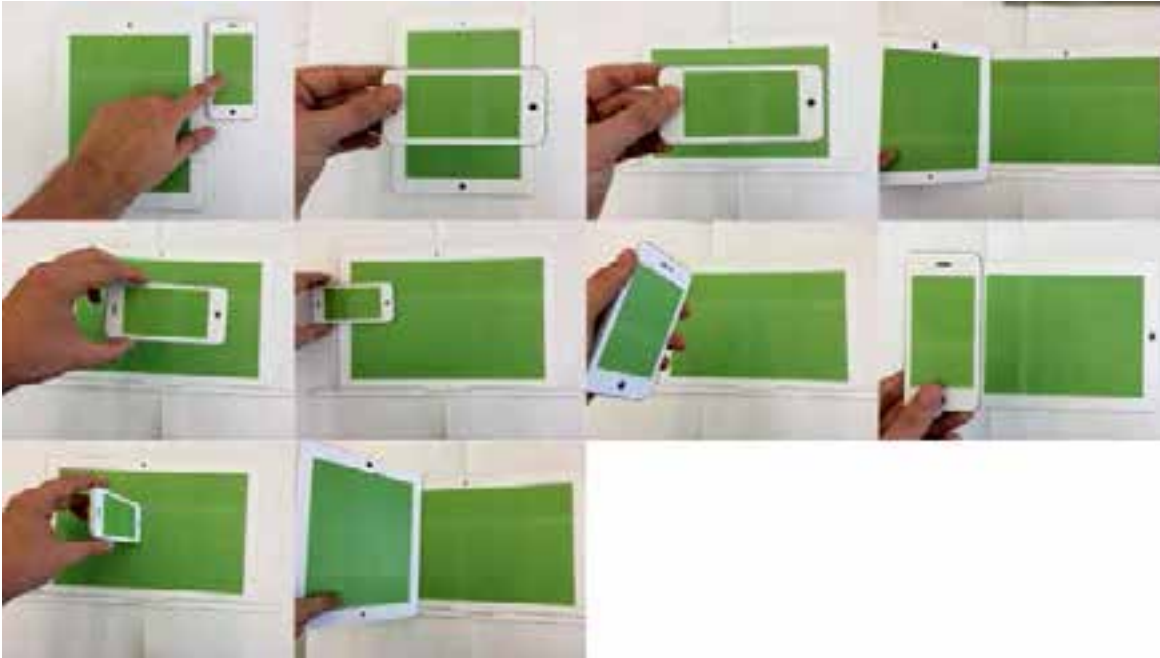


Fig. 1. Three paper prototypes were built exploring different interactions, like for instance sliding from one device to another, content can shake out, float or be pushed into another screen.

Blending the digital and physical world in interaction design opens up room for opportunities. Examples can be found in both commercial concepts such as file sharing app Bump [4], game system Sifteo Cubes [5] and Google's visual design language 'Material Design' [6], as well as in research from MIT with concepts such as THAW, Smarter Objects and Swÿp [7-9]. These concepts are often technology-led: exploring what is technologically possible. The concept presented in this paper, Unify<sup>1</sup>, aims at envisioning how these technologies would fit in the user's everyday life, moving from explorative to contextual concepts.

Through the presentation of the design concept Unify, its evaluation and a discussion, we will demonstrate new ways of interacting with cloud-based services to share digital media with others in such a way that it becomes an integral part of our daily routines.

## 2. Unify: A Concept for Sharing Media with Physical Interaction

When envisioning cloud-based services and technologies for blending the digital and physical world, our everyday smart devices are currently separate islands that are not aware of other devices in the environment. While technologies for quick file sharing are available (using for example USB sticks, Apple's airdrop and portable hard disks), these often have limitations, prompting the user to create their own personal workarounds for transferring files between devices.

### 2.1 Unify

Unify introduces affordances of the physical world to intangible digital objects using the physical properties of tangible smart devices such as smartphones and tablets. In this way the user is introduced of seeing these smart devices as a container for intangible objects, which can be handled like any container in the physical world.

The concept is aimed at linking our smart devices together using spatial relations in physical spaces or following physical laws to make them truly an extension of each other. By knowing the relative position to other devices, we are able to connect them in a more intuitive way than only enforcing digital relations in digital spaces. Unify was designed to explore how one could share media within a close environment through physical interaction, from the perspective of the physical properties of smart devices.

### 2.2 Interaction Exploration

While working with multiple screens is already a common practice in our daily routines and workflows, there are more possibilities where screens can be extensions of each other. Three paper prototypes were built exploring different interactions (Fig. 1). For example, files can slide from one device to another, content can shake out, float or be pushed into another screen. All these interactions treat digital media in a physical way, dealing with the laws of physics (for example, gravity).

In these prototyped concepts, a smartphone could be interpreted as an abstract block, which could be controlled by finger movements like for instance point, slide or pinch. Even when the smartphone's screen is off, one performs these finger actions intuitively on the flat surface. By extending two screens, the relative position of devices provides contextual and physical relevance to slide digital objects from one device to another.

The interfaces were aimed to provide a better understanding of the internal processes, like the data flow of music files. This is based on the Google Material Design guidelines [6], a metaphor in which digital objects become subject to the law of physics. In contrast to classic interface design, information doesn't just appear and disappear, but behaves to communicate contextual relevance and to give a better understanding of the behavior of digital files. To achieve this with Unify, the physical properties of the screen and other devices were implemented in the affordances of the digital interface (Fig. 2).



Fig. 2. To communicate the contextual relevance, the physical properties of the screen and other devices were implemented in the affordances of the digital interface with subtle visual clues, for instance a white blur.

### 3. Evaluation

To evaluate the concept and allow for reflection on the contextual use, an evaluation study with the envisioned user group was set up. The evaluation included a questionnaire, several given tasks, and a semi structured interview followed by an analyses. Eight

Industrial Design students from Eindhoven University of Technology were asked to participate; each filled in and signed an informed consent form before the evaluation. The participants were young adults with an average age of 22.5, native users of smart devices and due to their study background, had ample imagination to interact with the prototype.

#### 3.1 Prototype

The prototype consisted of two interfaces, one on a smartphone and the other on a desktop computer (Fig. 2). Both showed the context of a music listening application. The participant was able to scroll through a couple of songs, skip them or pause them, to mimic a real application as close as possible. If the smartphone was close enough to the notebook, the user was able to slide the current song of the smartphone to the music queue of the desktop application.

In terms of technological feasibility, our smartphones, tablets and notebooks already know their absolute position on the world via GPS and the way the user holds them via gyro meters. However, these measurements are all absolute, and give no clues about their relative position to other devices in the environment. While it would be technically possible to determine relative positions of devices through RF transmitters and indoor positioning systems, other elements of the design were considered more relevant for this specific study. For the set-up of the evaluation, a mock-up of Unify was build using an absolute positioned camera outside the main setting. This camera tracked all devices' absolute positions by using the open-source computer vision framework reactTIVision [10], and the system translated this to relative data for each individual device.

#### 3.2 Questionnaire

At the start of the session, participants were asked to complete a questionnaire. This questionnaire was meant to acquire basic information of the user group and to give an overview about their usage of smart devices in order to position acquired data.

#### 3.3 Given Tasks

After an explanation of the motivations for the concept, participants were asked to explore the prototype without overthinking their actions and to speak out

loud their immediate reactions. This think-aloud method is valuable to explore individuals' thinking processes in a qualitative research setting [11]. Within the scenario the user got six specific tasks to perform with the music interfaces, for instance transfer a specific song from the smartphone to the notebook. The last two tasks weren't even possible, for instance pull a song out of the notebook with the smartphone, aiming for creative and new input. Every task was explained as detailed as possible, but participants were free to ask any questions immediately and to take as much time as they wanted. This procedure was video recorded for later semi-structured interviews.

### 3.4 Semi-structured Interview

Participants were then asked to observe the recordings of themselves interacting with the prototype. This video self-reflection method leaves extensive room for discussion and multiple interpretations, which leads to surprising input [12]. Participants were asked to explain not only what they did, but also why they performed these actions with a reference to their feelings. The interview was semi-structured on the basis of a list of predefined questions, to produce qualitative rich and honest data [13]. The semi-structured interview was audio-recorded.

### 3.5 Analyses

For the analyses, the audio recordings of the semi-structured interview were cut into fragments. These fragments were rearranged across the participants to look for keywords, similarities and themes.

### 3.6 Result

From the analyses of the audio recordings several similarities could be found. These were in the fields of the users' perception of the context, novelty and the mindset towards the system.

**Perception of the Context and Novelty of the System.** All participants recognized the current struggles of sharing digital files in your near environment and mostly mentioned ease-of-use and speed of action as the benefits of Unify. The concept stayed within the perception of all participants: they were continuously relating to existing services like for instance AirDrop, a service to transfer files directly between a limited selection of Apple products [14].

"I use Airdrop sometimes, but that doesn't work well for constantly sharing files with others. This works more logical, which makes it more useful for me."  
(Participant 4)

"I experience it as something new, but more as a logical next step in this field than a truly out of the box concept."  
(Participant 3)

**Switching from Digital Interaction to Physical Interaction.** Unify introduces an interaction whereby the smartphone becomes a metaphorical physical container in which the intangible digital objects are subject to the law of physics. The evaluation showed that it requires a different mindset when the user is introduced to this concept. Based on the video recordings, participants needed more guidance during the first interaction with the concept, but they quickly jumped to this new mindset where they were more creative and intuitive towards the system. It is essential to be aware of the fact that this intuitivity relies on the influence of the designer's skills on the affordances of the digital interface, and on the specific type of users within this evaluation (young design students). It's imaginable that slightly different results could emerge with a different group of users, which substantiates the need for more future tests to support the results.

*"I was first looking for a button to send a file, but I quickly noticed the visual clues in the digital interface which suggested a real connection between the smartphone and the notebook."*  
(Participant 6)

*"However it was not possible with this prototype, I notice that it felt at the end logical to transfer a song by holding the smartphone on top of the screen of the notebook."*  
(Participant 1)

## 4. Conclusions

The proposed concept, Unify, offers a way to view the cloud as an opportunity for design rather than an unwieldy and abstract existence. This comes apparent in the evaluation where participants could envision the concept to be part of their daily routines.

By introducing specific affordances of the physical world to intangible digital objects, smart devices such as smartphones and tablets become physical containers

in which digital objects can be handled like object in containers in the physical world.

**This kind of interactions operates on a more metaphorical level and offers a different mindset, releasing images of what users consider to be appropriate or standard behavior with smart devices. Through the evaluation it became apparent that users do not need a lot of time to make this switch, which is promising for further development. This could offer opportunities for cloud-based services not only for ease of use, but also for assuring the user when data is security-critical.**

## References

1. Steve Ranger (2014) Windows 8: Why Microsoft's giant gamble didn't pay off [Online] Available from: <http://www.zdnet.com/article/windows-8-why-microsofts-giant-gamble-didnt-pay-off/> [Accessed 13th January 2015]
2. Apple Continuity [Online] Available from: <https://www.apple.com/nl/ios/whats-new/continuity/> [Accessed 13th January 2015]
3. Van Campenhout, L. D. E., et al. "Physical interaction in a dematerialized world." *International Journal of Design* 7.1 (2013): 1-18.
4. Catherine Shu (2013) Google To Close Bump And Flock, Its Recently Acquired File Sharing Apps [Online] Available from: <http://techcrunch.com/2013/12/31/google-to-close-bump-and-flock-its-recently-acquired-file-sharing-apps/> [Accessed 30th April 2015]
5. Sifteo Cubes [Online] Available from: <https://www.sifteo.com/cubes> [Accessed 30th April 2015]
6. Material Design, Introduction [Online] Available from: <http://www.google.com/design/spec/material-design/introduction.html> [Accessed 12th January 2015]
7. Sang-won Leigh, Philipp Schoessler, Felix Heibeck, Pattie Maes, Hiroshi Ishii (2014) THAW: Hybrid Interactions with Phones on Computer Screens [Online] Available from: <http://tangible.media.mit.edu/project/thaw/> [Accessed 14th January 2015]
8. Valentin Heun, Shunichi Kasahara, Pattie Maes (2014) Smarter Objects: Using AR technology to Program Physical Objects and their Interactions.
9. Natan Linder (2012) SWyP [Online] Available from: <http://fluid.media.mit.edu/projects/sw%C3%BFp> [Accessed 14th January 2015]
10. ReactIVision. A toolkit for tangible multi-touch surfaces. [Online] Available from: <http://reactivision.sourceforge.net/> [Accessed 13th January 2015].
11. Charters, Elizabeth. "The use of think-aloud methods in qualitative research an introduction to think-aloud methods." *Brock Education Journal* 12.2 (2003).
12. Ylirisku, Salu Pekka, and Jacob Buur. *Designing with Video: Focusing the user-centred design process*. Springer Science & Business Media, 2007.
13. Newton, Nigel. "The use of semi-structured interviews in qualitative research: strengths and weaknesses." *Exploring qualitative methods* (2010).
14. Daniel Nations, "What Is AirDrop? How Does It Work?" [Online] Available from: [http://ipad.about.com/od/iPad\\_Guide/ss/What-Is-Airdrop-How-Does-It-Work.htm](http://ipad.about.com/od/iPad_Guide/ss/What-Is-Airdrop-How-Does-It-Work.htm) [Accessed 12th January 2015].

—  
<sup>1</sup>A concept video of Unify can be found at <http://www.joinunify.com>







We would like to thank the following reviewers for their valuable contribution to the DeSForM 2015 conference:

Giuseppe Andreoni, Hideki Aoyama, Heather Barker, Alessandro Biamonti, Andrea Bonarini, Monica Bordegoni, Marina Carulli, Lin-Lin Chen, Nazli Cila, Sara Colombo, Giorgio Colombo, Mario Covarrubias, Umberto Cugini, Barbara Del Curto, Carmelo Di Bartolo, Tom Djajadiningrat, Loe Feijs, Silvia Ferraris, Venere Ferraro, Francesco Ferrise, Mathias Funk, Elisa Giaccardi, Sara Gonizi, Serena Graziosi, Luca Guerrini, Bart Hengeveld, Michael Hohl, Jun Hu, Astrid Kappers, Ilaria Mariani, Laura Micoli, Nithikul Nimkulrat, Stijn Ossevoort, Elif Ozcan, Margherita Pillan, Andrew Polaine, Ruben Post, Domenico Prattichizzo, Lucia Rampino, Edgar Rodriguez Ramirez, Valentina Rognoli, Dagmar Steffen, Secil Ugur, Simona Venditti, Axel Vogelsang, Paolo Volonté, Anders Warell, Robert Wendrich.



ISBN 978 88 6493 031 2  
All rights reserved.