Lin-Lin Chen, Tom Djajadiningrat, Loe Feijs, Simon Fraser, Steven Kyffin, Dagmar Steffen

# Design and semantics
# of form and movement

DeSForM 2012: MEANING.MATTER.MAKING

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# Design and semantics of form and movement

DeSForM 2012: MEANING.MATTER.MAKING

# DeSForM 2012

# Programme DeSForM 2012

## Wednesday, April 18

| | |
|---|---|
| 11.00 am – 12.00 pm | Registration and Lunch |
| 12.00 pm – 12.15 pm | Welcoming Ceremony |
| 12.15 pm – 12.30 pm | Opening Address |
| | Prof. Simon Fraser, Head, School of Design, Victoria University of Wellington |
| | Prof. Steven Kyffin, Dean, School of Design, Northumbria University, UK |

**Paper Presentation I: Immersive Environments:
Smart Systems and Interactive Spaces**

| | |
|---|---|
| 12.30 pm – 12.50 pm | Semantic Connections: A New Interaction Paradigm by Bram van der Vlist, Gerrit Niezen, Jun Hu, Loe Feijs |
| 12.50 pm – 01.10 pm | Table Manners: The Influence of Context on Gestural Meaning by Tom Djajadiningrat, Luc Geurts, Jeanne De Bont |
| 01.10 pm – 01.20 pm | Discussion |
| 01.20 pm – 01.40 pm | Persuasive Design for Energy Saving Behavior through Social Gaming by Vaijayanthi Iyengar and Madhusudhan Marur |
| 01.40 pm – 02.00 pm | Four Installations Inviting Playful Interaction by Daniel Cermak-Sassenrath |
| 02.00 pm – 02.10 pm | Discussion |
| | |
| 02.10 pm – 02.40 pm | Afternoon Tea |

**Paper Presentation II: The Emotive**

| | |
|---|---|
| 02.40 pm – 03.00 pm | Fluenci: The Expression of Expressing by Jaap Knoester, Tom Djajadiningrat, Philip Ross |
| 03.00 pm – 03.20 pm | Fictional Emotions within Emotion Driven Design by Eva Knutz |
| 03.20 pm – 03.30 pm | Discussion |
| 03.30 pm – 03.50 pm | Co-Authored Narrative Experience: Affective, Embodied Interaction through Combining the Diachronic with the Synchronistic by Carol MacGillivray |
| 03.50 pm – 04.10 pm | The Semantics of Surprise in Industrial Design by Edgar Rodríguez Ramírez |
| 04.10 pm – 04.20 pm | Discussion |

**Exhibition and Keynote Address**

| | |
|---|---|
| 05.30 pm – 06.30 pm | City Gallery Wellington, drinks and preview, Hylozoic series:Vesica |
| 06.30 pm – 06.40 pm | City Gallery Opening address: Mayor Celia Wade-Brown |
| 06.40 pm – 07.40 pm | City Gallery Keynote Address: Philip Beesley |
| 07.40 pm – 08.00 pm | City Gallery Design Led Futures/Wellington 2040: Ross Stevens |

# Programmme DeSForM 2012

### Thursday, April 19

**Paper Presentation III: Metaphors, Agency and Semantics**

09.00 am – 09.20 am     The Role of Designer Expertise in Source Selection During Product
Metaphor Generation by Nazli Cila, Paul Hekkert, Valentijn Visch

09.20 am – 09.40 am     The Actions of Things: Design, Materiality and Agency of Things
by Jorn Guldberg

09.40 am – 09.50 am     Discussion

09.50 am – 10.10 am     Embracing Relational Agency in Design Process by A. Baki Kocaballi,
Petra Gemeinboeck, Rob Saunders, Lian Loke, Andy Dong

10.10 am – 10.30 am     Beyond Metaphor in Product Use and Interaction
by Thomas Markussen, Elif Özcan, Nazli Cila

10.30 am – 10.50 am     Graphic Design and the Tyranny of Connoisseurship: An Argument
for a Semiotic Approach to Graphic Design Pedagogy by Alan Young

10.50 am – 11.00 am     Discussion

11.00 am – 11.20 am     Morning Tea

**Paper Presentation IV: Immaterial Forces: Light, Sound, Gesture**

11.20 am – 11.40 am     Grace: A Gesture Controlled Wake-Up Light by Tom Djajadiningrat,
Luc Geurts, Jeanne De Bont, Pei-Yin Chao

11.40 am – 12.00 pm     The Aesthetics of Immateriality in Design by Mads Folkmann

12.00 pm – 12.10 pm     Discussion

12.10 pm – 12.30 pm     In Pursuit of the Extraordinary by Cassie Hester

12.30 pm – 12.50 pm     Tradition and Innovation: A Study on Reconfiguration of Product Language
Through Innovative Approaches by Ozge Merzali Celikoglu

12.50 pm – 01.00 pm     Discussion

01.00 pm – 01.40 pm     Lunch

**Paper Presentation V: Gestures and Touch**

01.40 pm – 2.00  pm     Controlling Smart Home Environments with Semantic Connections
by Bram van der Vlist, Gerrit Niezen, Stefan Rapp, Jun Hu, Loe Feijs

02.00 pm – 02.20 pm     An aesthetics of touch: Investigating the language of design relating to form
by Victoria Teinaki, Bruce Montgomery, Nicholas Spencer, Gilbert Cockton

02.20 pm – 02.30 pm     Discussion

02.30 pm – 02.50 pm     Learn to Make, Make to Learn: Reflections from Sketching Haptics Workshops
by Camille Moussette

02.50 pm – 03.10 pm     A Study on a Tangible Interaction Approach to Managing Wireless Connections
in a Smart Home Environment by Jeroen Peeters, Bram van der Vlist, Gerrit
Niezen, Jun Hu, Loe Feijs

03.10 pm – 03.20 pm     Discussion

03.20 pm – 03.40 pm     Afternoon Tea

**Paper Presentation VI: Fabricating Futures: Digital Manipulation, Fabrication and the Craft of Design**

| | |
|---|---|
| 03.40 pm – 04.00 pm | Yeti: Designing Geometric Tools with Interactive Programming by Daniel Davis, Jane Burry, Mark Burry |
| 04.00 pm – 04.20 pm | Towards a Responsive Architectural Morphing Skin by Chin Koi Khoo |
| 04.20 pm – 04.30 pm | Discussion |
| 04.30 pm – 04.50 pm | Digital-Physical Hybrid Design: Harmonizing the Real World and the Virtual World by Mizuki Sakamoto, Tatsuo Nakajima, Todorka Alexandrova |
| 04.50 pm – 05.10 pm | Digital Craft in Digital Space: A Paradigm Shift in the Making by Maxe Fisher, Simon Fraser, Tim Miller, Ross Stevens, Jerad Tinnin, Annelies Zwaan |
| 05.10 pm – 05.20 pm | Discussion |
| | |
| 05.20 pm – 06.00 pm | **Reception Keynote Address** |
| 06.00 pm – 07.00 pm | **Neil Leach, Keynote Address** |
| 07.00 pm – 09.00 pm | **Optional visit: late night opening, Museum of New Zealand Te Papa Tongarewa** |

# Programme DeSForM 2012

Friday, April 20: Professional Presentations

| | |
|---|---|
| 08:30 am – 09:00 am | Coffee and Refreshments |

**Professional Presentations**

| | |
|---|---|
| 09:00 am – 09:10 am | Opening Address |

**Session I: Interaction Design**

| | |
|---|---|
| 09:10 am – 09:30 am | Unlimited Realities - http://www.unlimitedrealities.com/ |
| 09:30 am – 09:50 am | Click Suite - http://www.clicksuite.co.nz |
| 09:50 am – 10:00 am | Discussion |

**Session II: Transmedia, Technology and Entertainment**

| | |
|---|---|
| 10:00 am – 10:20 am | Weta Digital - http://www.wetafx.co.nz |
| 10:20 am – 10:40 am | Pik Pok - http://pikpok.com/ |
| 10:40 am – 10:50 am | Discussion |
| 10:50 am – 11:20 am | Morning Tea |

**Session III: Immersive Environments**

| | |
|---|---|
| 11:20 am – 11:40 am | Spatial Information Architecture Lab (SIAL) RMIT Melbourne, Australia - http://www.sial.rmit.edu.au/ |
| 11:40 am – 12:00 pm | HIT Lab NZ, Canterbury University, NZ - http://www.hitlabnz.org/ |
| 12:00 pm – 12:20 pm | The Gibson Group - http://www.gibson.co.nz/ |
| 12:20 pm – 12:30 pm | Discussion |
| 12:30 pm – 01:30 pm | Lunch |

**Session IV: Culture Jamming**

| | |
|---|---|
| 01:30 pm – 01:50 pm | RESN - www.resn.co.nz/ |
| 01:50 pm – 02:10 pm | SWAMP (USA) - http://www.swamp.nu/ |
| 02:10 pm – 02:20 pm | Discussion |

**Session V: Fabricating Futures**

| | |
|---|---|
| 02:20 pm – 02:40 pm | diatom - http://diatom.cc/ |
| 02:40 pm – 03:00 pm | 77Pieces - http://77-pieces.com/ |
| 03:00 pm – 03:20 pm | Ponoko - http://www.ponoko.com/ |
| 03:20 pm – 03:30 pm | Discussion |
| 03:30 pm – 04:00 pm | Afternoon Tea |
| 04:00 pm – 04:40 pm | Panel Discussion I Blurring the Physical and the Digital |
| | Chair: Prof. Steven Kyffin, Dean, School of Design, Northumbria University |
| 04:45 pm – 05:25 pm | Panel Discussion II Designing True Interactions; Chair: Helen Baxter, Mohawk Media |
| 05:30 pm – 05:40 pm | Closing Address |
| | Prof. Simon Fraser, Head, School of Design, Victoria University of Wellington |
| | Prof. Steven Kyffin, Dean, School of Design, Northumbria University, UK |
| 06:30 pm – 09:00 pm | Conference Dinner The Waka House Te Raukura Te Wharewaka o Poneke |

# DeSForM 2012

It is encouraging to witness the growing global influence of the DeSForM conference and workshop series, and indeed to be an active part of this growth. Following on from the 2009 conference in Taipei, Taiwan and the 2010 conference in Lucerne, Switzerland, the School of Design at Victoria University of Wellington, New Zealand is honoured to bring DeSForM's sphere of influence to the Southern Hemisphere for the first time. DeSForM 2012: MEANING.MATTER.MAKING continues the tradition of diversity and exchange. In reaching out to the many innovative schools, businesses, designers, researchers and cultural organisations in the Southern Hemisphere and beyond, DeSForM 2012 will expand the organisation's community, offering new horizons, insights and audiences.

The relative isolation of New Zealand confers real advantages. Being at the edge brings freedom to improvise, to invent and to imagine. The School and its location in New Zealand's 'Creative Capital' embodies many of the core principles of DeSForM as a pioneering forum for the exchange of knowledge and ideas, unburdened by tradition and accepted ways of doing things. Our South Pacific location has inspired a commitment to digital technologies, which offer real opportunities to overcome distance with new forms of communication, interaction and enhanced experiences. As a result the city has a colourful and growing creative community of technology developers, software specialists, game and interface designers, film makers and special effects researchers, usability experts, social networking service providers and innovators in digital design, fabrication and distribution.

Against this backdrop, DeSForM 2012: MEANING.MATTER.MAKING is pleased to welcome a diversity of practice-led researchers and research-led practitioners from academia and industry, as well as representatives from the many disciplines, perspectives and interpretations integral to the design and semantics of form and movement. Design semantics – or the making of meaning through 'matter' – is of increasing relevance to the practice of design in the twenty-first century. Rapidly evolving techniques and processes are creating pathways for new modes of interactivity, expression, and experience. These modalities offer expanded opportunities and contexts for design to communicate meaning through form, movement and experience, extending the parameters of semantic interpretation. Swift, on-going shifts in the 'vocabulary' of design suggest that it is time to reevaluate our understanding of 'semantics'. DeSForM2012 poses new questions for present and future practice: What new engagements are being created and what boundaries are being crossed or blurred in the digital age? How is digital design and manufacturing changing relationships between designers, producers, and users? What role does the 'material' play in an increasingly 'immaterial' culture of design? Can we maintain notions of creator and ownership when all objects are digital and effortlessly duplicated? How will the products of design be valued when the engines of creation become both powerful and commonplace? With such questions at the fore, DeSForM 2012: MEANING.MATTER.MAKING explores

the design of physical and digital things, systems and environments, seeking novel approaches to how meaning is both created and conveyed in the twenty-first century. Emphasising future-oriented design, MEANING.MATTER.MAKING highlights a broad range of scales and approaches, from the singular to the multiple, the hand to the machine, the conceptual to the self-organising, and the sensory to the theoretical. DeSForM 2012: MEANING.MATTER.MAKING brings together researchers, designers and industry partners to share ideas, methods, and theories about the creation and communication of meaning through design semantics.

We are honoured to have two world renowned keynote speakers joining us for the conference:

**Philip Beesley** is Professor in the School of Architecture, University of Waterloo. His work is widely cited as a pioneer in the rapidly expanding technology of responsive architecture and spans a diverse range of expressive media, from that of architecture to sculpture and installation.

**Neil Leach**, architect, theorist and Professor at the University of Southern California, School of Architecture, has contributed significantly to the theorization of digital design, with numerous exhibitions, edited volumes and monographs broadly addressing and merging critical theory and digital design.

Another first, we are delighted to have been able to bring the premier exhibition of work by Philip Beesley to New Zealand for DeSForM 2012. Beesley's project, Hylozoic Series: Vesica, references the tradition in medieval painting of circumscribing holy figures in a luminous aura, forming a kind of liminal zone between the body and the outside world. The exhibition will be held in one of the city's key cultural institutions, The City Gallery Wellington, te whare toi, and will be shown in the prestigious Hirschfeld Gallery.

The installation features interactive kinetic systems composed of dense arrays of micro-processors, sensors and actuator systems arranged within lightweight 'textile' structures that explore emerging new technologies with digitally-fabricated components. The work conveys a subtle quality of hovering, organic movement and with gently vibrating fields of skeletal elements captures the otherwise imperceptible air currents produced by participant viewers. The integration of chemistry and biology within the composition of the sculptural body is an expression of Beesley's evolving concept of 'living architecture'. This work integrates shared values of human caring, environmental and urban sustainability with immersive creativity and experimentation. These values are framed within a philosophy that sees humanity as participant in the complex negotiations between nature, culture and technology that increase in complexity as we look into the future. In this last respect, the exhibition aligns strongly with the City of Wellington's 2040 initiative that addresses fundamental questions of future living and city making in the 21st century.

We would like to thank our principle sponsor, the Ministry of Science and Innovation for supporting this event and for their enthusiastic facilitation of research links between academia and industry in the digital creative sector. This support has been reciprocated in turn by our industry partners whose generous collaboration in the form of presentations and demonstrations adds significantly to the scope and impact of the conference.

We are also very grateful for the support of the Wellington City Council, not only as a sponsor but also for recognising the need to develop productive and innovative knowledge industries to support the vision of Wellington as a knowledge economy and New Zealand's creative capital; a vision that is shared and supported by Victoria University of Wellington.

We hereby offer the 7th DeSForM Proceedings. We would like to thank all the authors who have submitted their work to DeSForM 2012:Meaning.Matter.Making as well as the reviewers for their constructive and critical comments. We hope the presentations and demonstrations will raise many questions and inspire lively discussion and debate about the increasing sophistication and complexity of design research, theory and practice in a constantly changing global context.

Wellington, April *18* 20*1*0

*Programme Committee*
**Lin-Lin Chen**, National Taiwan University of Science and Technology, Taiwan
**Tom Djajadiningrat**, Philips Design, Eindhoven, the Netherlands
**Loe Feijs**, Technical University Eindhoven, the Netherlands
**Simon Fraser**, Victoria University of Wellington, NZ
**Steven Kyffin**, Northumbria University, Newcastle upon Tyne, UK
**Dagmar Steffen**, Lucerne School of Art and Design, Switzerland

## Introduction

Interaction requires the involvement of two entities. In a world in which the development of computational capacity, digital manufacture and ever advancing sensing technologies allows for ever more complex digital and physical interactions, people and objects cannot be seen as passive 'users' or static designs but as truly immersed participants and even co-creators. Design, auspiciously living in between technology and people, has the opportunity and responsibility to answer fundamental questions about co-designed, content rich, connected and intelligent objects within adaptive systems. It is thrilling to see the response from designers, researchers, artists, musicians and architects to these questions from the starting point of the semantics of form and movement. The studies presented in these proceedings reflect a gamut of design knowledge that embraces rigour in professional practice and beauty in research.

Immersive environments within adaptive systems and interactive devices are studied through the design and analysis of several haptic and gesture controlled environments and objects. We learn that while gesture control can be regarded as an exciting, beautiful and useful feature in interactive devices, it can also be considered as intrusive through the connotations it brings and even violate personal space. The appropriateness of gestures is strongly dependent on socio-cultural contexts, which authors urge designers to evaluate. Fortunately, authors also suggest ways in which designers can use theories from Gestalt psychology to help people create accurate representations of tangible interactions. Several papers make a strong case for the importance of digital manipulation, fabrication and the craft of design. A 'soft' approach to responsive architecture suggests the use of lightweight form-changing materials for architectural morphing skins. Interactive programming is suggested as a way to design geometric tools. A documentation of industrial design projects describes how digital technologies offer designers the opportunity to experiment with new ways of expressing and manufacturing while reviving and expanding traditional notions of craftsmanship.

Human emotions offer a vast area for investigation, which authors address through suggesting co-authored narrative experiences in which audiences to affective and embodied interactions move from being users to being co-creators. Papers also suggest strategies experienced designers use to elicit surprise in people. A study on the design of a breastfeeding pump that mimics many of the stimulating triggers provided by a baby and allows for a natural, intimate and emotional experience suggests concepts such as 'anthropomorphic form'. This invites people to engage with a product as if it were human, without what some people would consider potentially disturbing anthropomorphic product appearance.

Papers also undertake the essential study of metaphors in semantics and suggest revealing differences on how novice and experienced designers select sources of metaphors. The concept of 'semantic connections' is suggested as an approach to overcome the move from device-oriented paradigms to more task-oriented paradigms.

The topics, questions and findings addressed in these proceedings show state-of-the-art research that is just scratching the surface of a rapidly evolving area. It can only make us excited about what we will experience in our future and in subsequent DesForm workshops.

**Edgar Rodríguez Ramírez,** Editor, Proceedings, Victoria University of Wellington, NZ

**Keynote speaker - Philip Beesley**

# Diffusive form and near-living environments



## Abstract

Philip Beesley's Hylozoic Series explores how synthetic environments might offer near-living qualities. New installations in Wellington, Sydney, Madrid and Trondheim demonstrate the technical progress and design methods currently being developed at his studio which further pursue integrated protocell chemistry, distributed kinetics and acoustics, and evolutionary control systems. The presentation will trace the origins of Beesley's Hylozoic Series, from archeological sites beneath the Palatine Hill in Rome to land based geotextile installations in the woods of Maine and coastal Nova Scotia. Links will be drawn between these works, conceived as regenerative ground coverings, and the more recent focus on suspended, interactive environments. Illustrated projects will include Beesley's entry into the 12th Venice Biennale in Architecture, Hylozoic Ground (2010), the light-based Aurora Series (2010), and the Epithelium Series (2008-2009) which included air-muscle powered suspended meshworks populated with densely massed whisker-like mechanisms.

A detailed tour through of this work will discuss design methodology in relation to the components and systems that constitute the anatomy of this expanded physiology. These hovering filter environments, composed of tiny laser cut acrylic elements, create diffusive boundaries between occupants and the surrounding milieu. The structures prefer deeply reticulated skins, turning away from the minimum surface exposures of reductive crystal forms as they seek to maximize interchange with the atmosphere and other occupants.

The discussion will also position this body of work within cultural and theoretical discourse, drawing connections to Roman and Greek atomists and Romantic theory. Building upon French art historian George Didi Huberman's sensitive analysis of marginal spaces seen within mediaeval paintings, Beesley will discuss how the behaviours of his installations challenge Humanist conceptions of environment and expansion of human domain. The presentation will argue that diffusive, deeply reticulated forms and unapologetically sentimental empathetic responses can serve as effective design models for renewed public architecture.

▶

Philip Beesley is a Professor in the School of Architecture at the University of Waterloo. A practitioner of architecture and digital media art, he was educated in visual art at Queen's University, in technology at Humber College, and in architecture at the University of Toronto. At Waterloo he serves as Director for the Integrated Group for Visualization, Design and Manufacturing, and as Director for Riverside Architectural Press. He also holds the position of Examiner at University College London. His Toronto-based practice PBAI is an interdisciplinary design firm that combines public buildings with exhibition design, stage and lighting projects. The studio's methods incorporate industrial design, digital prototyping, and mechatronics engineering.

Philip Beesley's work is widely cited in the rapidly expanding technology of responsive architecture. He has authored and edited eight books and appeared on the cover of Artificial Life (MIT), LEONARDO and AD journals. Features include national CBC news, Casa Vogue, WIRED, and a series of TED talks. Distinctions include Prix de Rome in Architecture (Canada), VIDA 11.0, FEIDAD, Katerva finalist, and the Canada pavilion at the 2010 Venice Biennale for Architecture. Beesley's funding includes core CFI, SSHRC, NSERC and Canada Council for the Arts grants.

**Keynote speaker - Neil Leach**

# Desiring machines

## Abstract

In his 1968 classic science fiction movie, 2001: A Space Odyssey, Stanley Kubrick depicts a maverick computer attempting to take charge of a mission to Jupiter, and oust the human occupants from their spaceship. The 1960s were a time of great technological advances, and within a year of the launch of Kubrick's movie the US had successfully sent the Apollo 11 crew to the Moon. Yet such was the suspicion of technology – and computation in particular – that Kubrick's apparent technophobia was no isolated incident. Indeed for several decades afterwards many schools of architecture were dominated by a phenomenological outlook, which saw technology as symptomatic of our alienated condition in the world today, and the computer as antithetical to human creativity. Indeed in some schools computers were even banned from the design studio.

With the advent of the new millennium, however, the full impact of technology on our lives has become only too evident. We now live within a hyper-technological environment with computer systems so advanced that even our individual mobile phones have more computational power than the Apollo 11 mission to the Moon. Our homes have become veritable 'machines for living in'. It is time, perhaps, to formulate a more sympathetic theoretical approach towards technology.

This paper argues for a new theoretical approach towards technology based on the materialist philosophies of Gilles Deleuze and Manuel DeLanda, looking in particular at Deleuze's concepts of 'machinic processes' and 'desiring machines' – concepts that move beyond the earlier distinction between the mechanical and the organic, and that recognize the human potential to absorb the new and the unfamiliar, and to appropriate technology as a prosthesis to human operations. The paper then goes on to look at design itself, and considers various robotic fabrication technologies that may be understood within this logic of 'machinic processes', especially 3-D printing.

The paper argues that while items within the home – chairs, tables, shoes and even clothes – are being printed these days, technologies for printing the home itself – architectural 3-D printing – are less advanced. The paper considers three rival attempts to develop the world's first commercially available 3-D concrete printer, evaluating the merits of each. It then goes on to explore the race to print buildings not just on earth, but also on the Moon, focusing in particular on the NASA sponsored project to adapt the robotic concrete fabrication technique, Contour Crafting, for printing structures out of regolith on the Moon.

▶

Architect and theorist Neil Leach is currently Professor at the University of Southern California, School of Architecture. He previously has taught at the University of Brighton, University of Bath, Architectural Association School of Architecture, University of Nottingham, Columbia University, Cornell University, SCI-Arc, Royal Danish Academy of Art, Dessau Institute of Architecture, and Institute for Advanced Architecture of Catalonia. Since 2004 Leach has co-curated exhibitions at the Architecture Biennial Beijing with Xu Wei-Guo, including Fast Forward>> (2004), Emerging Talents, Emerging Technologies (2006), (Im) material Processes: New Digital Techniques for Architecture (2008), and Machinic Processes (2010). With Roland Snooks he also co-curated Swarm Intelligence: Architectures of Multi-Agent Systems (2010) in Shanghai.

Leach has contributed significantly to the theorization of digital design, with numerous edited volumes and monographs broadly addressing and merging critical theory and digital design. These include Rethinking Architecture: A Reader in Cultural Theory (Routledge, 1997); The Anaesthetics of Architecture (MIT Press, 1999); Millennium Culture (Ellipsis, 1999); Architecture and Revolution: Contemporary Perspectives on Central and Eastern Europe (Routledge, 1999); The Hieroglyphics of Space: Reading and Experiencing the Modern Metropolis (Routledge, 2002); Designing for a Digital World (Wiley, 2002); China (Map Office, 2004); Digital Tectonics (Wiley, 2004); Camouflage (MIT Press, 2006); Digital Cities (Wiley, 2009); Machinic Processes (CABP, 2010); Scripting the Future (Tongji, forthcoming); Fabricating the Future (Tongji, forthcoming).

With Philip Yuan he also co-curated DigitalFUTURE (2011) in Shanghai.

He is currently working on a research project sponsored by NASA to design robots for fabricating structures on the Moon.

# Contents

**Bram van der Vlist, Gerrit Niezen, Jun Hu, Loe Feijs**

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# Semantic connections: A new interaction paradigm for smart environments

## Abstract

As the environments we inhabit contain a growing number of networked, interactive products, both users and designers need a better understanding of how these products can potentially work together. User interaction is changing from interaction with single products into interaction with a larger system of products. This trend faces designers with a challenge: to create meaningful interactions for users to deal with the complexity of the larger ecosystem of technologies users function in. In this article we introduce an interaction paradigm, where we view smart environments in terms of connections and associations between the actors and artefacts within the environment. In this notion of Semantic Connections, meaning is pivotal. We report on a search for a theoretical foundation for our approach in existing semantic theories. We attempt to use and extend these theories beyond their traditional focus on the appearance of objects and interaction with them in isolation, towards designing for systems of interoperating products. We illustrate our contribution by providing examples of products and design prototypes that implement our ideas. Although our research is ongoing and the theory unfinished, we believe that sharing our work can fuel the discussion on how designers may deal with the challenges in contemporary interaction design.

## Keywords

Product semantics, interaction design, smart home.

## 1  Introduction

The environments that people inhabit are occupied by a growing number of digital devices and gadgets. Many of these devices may be connected to the Internet, wireless networks or other devices. Interaction with networked devices is changing from interaction with a single device, to interaction with a larger system of devices. Some of these devices are becoming portals to information stored somewhere else (e.g. online services). Others have the potential to share information like multimedia content, data, device capabilities and services. However, we have not yet succeeded in seamlessly operating among these devices. Especially when we consider the way user interaction was envisioned in paradigms like Ambient Intelligence [1], Pervasive Computing, Ubiquitous Computing [2] and the more recent notion of an Internet of Things [3]. The key goal of ubiquitous computing[1] is "serendipitous interoperability", where devices which were not necessarily designed to work together (e.g. built for different purposes by different manufacturers at different times) should be able to discover each others' functionality and be able to make use of it [4]. Future ubiquitous computing scenarios involve hundreds of devices, appearing and disappearing as their owners carry them from one room or building to another.

[1] In this article we adopt the paradigm of ubiquitous computing, as this matches our understanding of a smart environment the closest.

Therefore, standardizing all the devices and usage scenarios a priori is an unmanageable task.

Besides the technological challenges, there also lies a challenge ahead for designing user interactions with these ecosystems of interconnected devices. When moving away from interaction with a single device towards interactions with systems of devices, designers need to find ways to communicate the relationships between the devices and the larger system they are part of. Additionally, designers need to find ways to communicate the action possibilities of new, "emergent functionalities", that emerge when devices are being interconnected. As Bill Buxton stated at the 2010 Design by Fire conference:

The real problems are not with any single device, but in the complexity, the potential complexity of the larger ecosystem of technologies that we function in. [...]
It's about how this device works with that device, whether it's from the same or a different manufacturers; it's the complexity of the ecosystem. Why aren't those things about the interoperability taking more of a point? It's about the society of appliances and how they work together, which is the new frontier [5].

An important problem that arises when designing for these systems of interactive objects is their highly interactive and dynamic nature [6]. The inherent ever-changing nature of these systems and the severely limited overview of the ecosystem in its entirety is one of the most important challenges a designer faces when designing for such systems. Additionally, such a system comprises many different "nodes" that the designer, at the time of designing, has no control over. Yet, when designing and adding new nodes to the system, making them interoperable is crucial for success.

In this article we introduce an approach to systems, focusing on the inter-device relations and connections that exist or may potentially exist. We see these relations as both real "physical" connections (e.g. wired or wireless connections that exist in the real world) and "mental" conceptual connections that seem to be there from a user's perspective. The context of the connections and the things that they connect are pivotal for their meaning. Previous work has resulted in similar approaches. Newman, Sedivy, Neuwirth, Edwards, Hong, Izadi, et al. have developed an approach, which they named recombinant computing [7].

How objects of design acquire meaning throughout their use has been the subject of design research for many years. The process of making sense of artefacts is described by theories such as product semantics [8], product language [9], semiotics [10] and the theory of affordances (a term originally coined by Gibson, but introduced to the design community by Norman [11]). While these theories provide handles for designers when designing (simple) products and to some extent also for designing interactive products, they have not yet shown their potential for providing handles for the design of systems of interoperating devices.

In this article we present an approach to designing for user interaction in smart environments called Semantic Connections [12]. Central to this approach is the focus on the semantics – or meaning – of the connections between artefacts in such a smart environment. We report on a search for a theoretical foundation for our approach in existing design and semantics theory, and re-apply the theories to our notion of connections or associations between artefacts.

## 2 Semantic Connections

To address the problems as outlined in the introduction, this section introduces an approach to interaction with a system of devices in which the connections and associations between the devices play a central role. Before we give an extensive review of existing semantic theories and discuss their implications for our approach, we first introduce our semantic connections interaction model.

Semantic connections is a term for meaningful connections and relationships between artefacts and entities in an ecosystem of interconnected and inter-operating devices. These connections can be viewed as both the real, physical connections (e.g. wired or wireless connections that exist between devices) and mental or conceptual connections that seem to be there from a user's perspective. The context of the connections (what things they connect) is pivotal for their meaning. The term "semantic" refers to the meaningfulness of the connections. We consider the type of connection, which currently often has the emphasis when interconnecting devices (e.g. WiFi, Bluetooth, USB) not to be the most relevant, but what the connection can do for someone – its functionality (e.g. stream music, share files) – even more. Semantic connections exist in both the physical world and the

digital domain. They have informative properties, i.e. they are perceivable in the physical world and have sensory qualities that inform about their uses. However, these physical qualities might be hidden at some times, or only accessed on demand. We envision semantic connections to exist between objects, people and places. Not only objects and devices have meaning in a system of networked devices. According to [13], physical location within the home and device ownership (or usage) are of central importance for understanding and describing home networks by users. Amongst places, people and objects, we specifically consider semantic connections to exist between:
- artefacts;
- smart objects;
- sensors;
- UI elements;
- places;
- (smart) spaces; and
- persons.
Semantic connections have properties like directionality, transitivity and modality (i.e. what things they carry). Connections can be one-to-one, one-to-many, many-to-one and many-to-many. Connections can be persistent or temporary.
The rationale behind Semantic Connections is to rely on:
- the meaning of existing objects to provide meaning for the relationships between the objects and the resulting meaning of the networked objects.
- the power of natural mapping and locality, using real objects and locations to provide meaning for the connections that are created between the objects and (object) locations.
- inherent, augmented and functional feedback and feedforward to strengthen the meaning of the connections and the emerging functionality [14].
The interactions with the connections and the objects that are connected are the carriers of meaning. This meaning may be supported or augmented with informative concepts like symbols, icons and indication functions [15]. We may need to rely on metaphors and symbolic and iconic meaning, because they provide the flexibility and expressiveness of language. Affordances are crucial but limited. They invite for a certain action, but only communicate the purpose of the action to a certain extent. Communicating what will be the result of an action – feed-forward – is the real challenge as the action itself is not the goal of the user.

Crucial to our approach is to make the gap between user goal and action smaller. If we consider streaming music from one device to another, "streaming" now consists of multiple steps (actions) that do not necessarily make sense. In our view, this single high-level goal should have one (or at least as few as possible) single high-level action(s). That single action should carry the meaning of its goal. By using the physical world as interaction space and using the real location of the objects, we are reducing the need to identify the devices from a list with names or rely on other forms of representation.

### 2.1 Semantic Connections Interaction Model
A user interaction model for semantic connections is shown in figure 1. It describes the various concepts that are involved in the interaction in a smart space and shows how these concepts work together.

The interaction model was inspired by the Tangible Interaction model (MCRpd) by Ullmer and Ishii [16], which in turn was based on the Model View Controller (MVC) model. We distinguish between the physical part of the user interaction and the part that takes place in the digital domain. A user cannot directly observe what is happening in the digital domain (and should not) but experiences the effect it has in the physical world, by interacting with the various smart objects and the (semantic) connections that exist in-between them. In doing so, users create a mental model of the objects/ system they are interacting with, which only partly (or not at all) includes the digital part. Digital information manifests itself in the physical world as data, media and services. When a user interacts with a smart object connected to the smart space, he/she senses feedback and feedforward, directly from and inherent to the controls of the device (inherent feedback), digital information augmented onto the physical world (augmented feedback) and perceives the functional effect of the interactions (functional feedback). The terminology, inherent, augmented and functional feedforward and feedback is adopted from [14]. The user actions in the physical world are transformed into interaction events and events/state changes, using semantic transformations. This interaction data in terms of user intentions is stored in the smart space[2], possibly together with user preferences, defaults and context information.
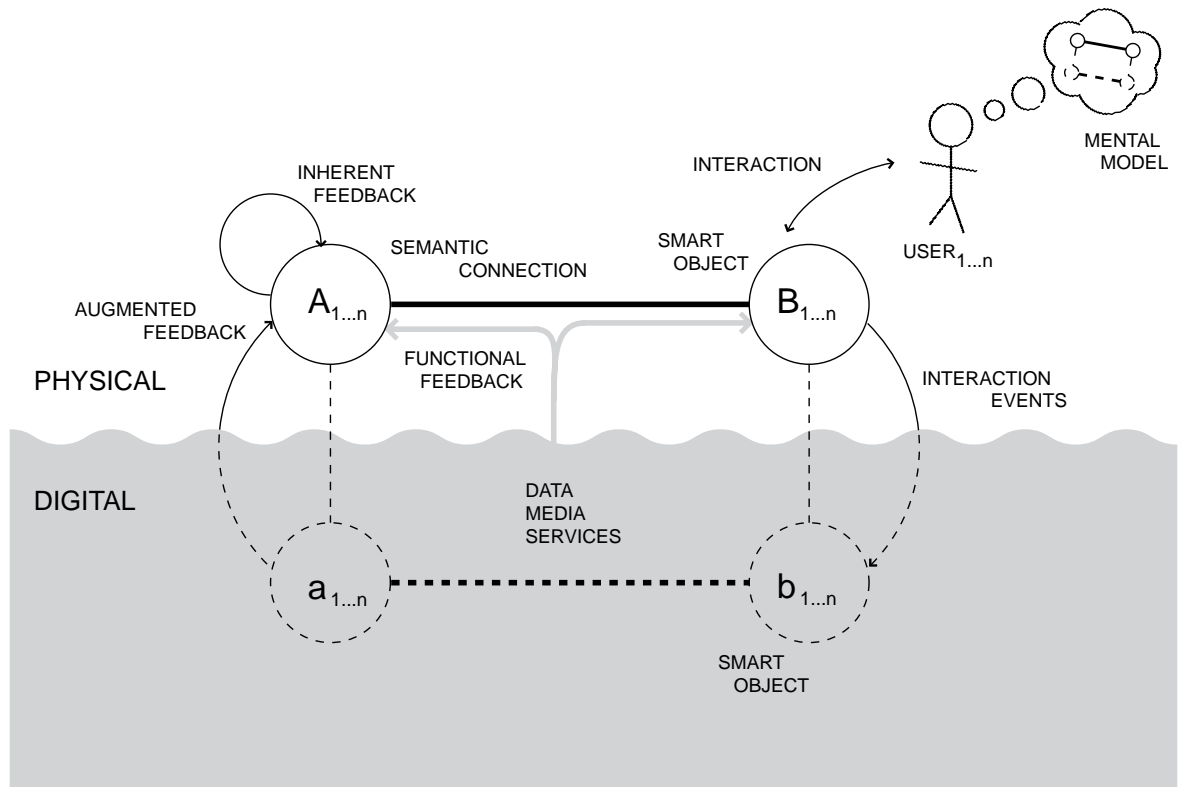
**Fig.** 1. **Semantic Connections user interaction model.**

## 3  Design Semantics Theory

### 3.1 Direct Approach – Interaction Frogger Framework

The Frogger framework, as was introduced by Wensveen [18], describes user interaction in terms of the information a user perceives, (like feedback and feedforward) and the nature of this information. It distinguishes between inherent, augmented and functional information. These types of information can serve as couplings between user actions and the products' functions in time, location, direction, modality, dynamics and expression. Although the framework was designed to describe the interaction with electronic devices and their interfaces, many of the concepts in the framework are applicable to our semantic connections concept as well.

When a user performs an action and the device responds with information that is directly related to the function of that product (lighting switching on when a light switch is operated), we speak of functional feedback. When a device has more than one functionality, functional feedback should be viewed with respect to the users' intentions and goals when performing the action. If there is no direct link between a user's action and the direct function of the product, or when there is a delay, augmented feedback can be considered to confirm a user's action. This feedback is usually presented in the form of lights, sounds or labels. Inherent feedback is directly coupled (inherently) to the action itself, like the feeling of displacement, or the sound of a button that is pressed.

While feedback is information that occurs after or during the interaction, feedforward is the information provided to the user before any action has taken place. Inherent feedforward communicates what kind of action is possible, and how one is able to carry out this action. Inherent feedforward is in many ways similar to the concept of affordances, revealing the action possibilities of the product or its controls [18]. When an additional source of information communicates what kind of action is possible it is considered augmented feedforward. Functional feedforward communicates the more general purpose of a product. This type of information often relies on association, metaphors and the sign function

of products, which are described by theories such as product semantics [8] and product language. Good practice in creating inherent feedforward is making the functional parts of a product visible, informing users about the functionality of the product [11].

**Implications for Semantic Connections.**

If we view semantic connections in terms of the Interaction Frogger framework, the following interesting insights emerge:

Feedback: When we consider multiple interconnected devices and the functionalities and services they provide, information like feedback and feedforward gets spatially distributed. A user may operate a device, receiving inherent feedback locally, but receiving augmented and/ or functional feedback remotely. In figure 1, the several types of feedback are indicated. As inherent feedback is inherent to the operational controls of the device, these reside only in the physical world and are local to the device. Augmented feedback is feedback that is augmented from the digital domain onto the physical world. This type of feedback is subject to change when devices get connected to other devices. In the domain of networked digital artefacts, functional feedback is of a digital nature. Data, media and services that exist in the digital domain become available in the physical world, through the various devices and their connections. Although many functionalities of digital devices can be regarded as (displaying) media, data or services, for some simple functionalities this seems problematic. If we, for example, look at functional lighting, it seems that the presence of light as the functionality of a lighting device is not a very digital concept. However, if we view a lighting device as a networked smart device, the presence of lighting, based on some sensor data, can be considered the functionality of a digital service.

But what about the semantic connections themselves, do they have these types of feedback as well? When we approach the connections as if they were physical entities with which one can interact, be it through an interaction device, they do provide these types of information as well. However, how this happens and what kind of information it is, is slightly more complicated. Inherent feedback is feedback that is mediated through an interaction device, as one cannot manipulate a connection directly. This inherent feedback

may however be closely related to the action of making or breaking a physical connection, like a snap or click when the connection is made or broken. Augmented feedback to indicate a connection may be in the form of lights, or in the form of projected or displayed lines. Functional feedback is information about the actual function of the connection, like the sound from a speaker that was just connected to a media player. This type of feedback always reaches the user through the devices being connected. Figure 2 shows examples of these types of feedback in designs that were created for this research.

Feedforward: Inherent feedforward, conceptually similar to the notion of affordances, provides information about the action possibilities with the devices or the individual controls of an interface. Similar to this are also informatives [8, p. 117] and partially also indication or marking functions as defined in the theory of product language [15]. Inherent feedforward is always physical and locally on the device. However, when devices or objects are part of a larger system, feedforward also emerges where interaction possibilities between objects exist (e.g. a key that fits a lock, a connector of one device or cable that fits another). The same holds for augmented feedforward, lights, icons, symbols and labels that provide additional information about the action possibilities. These may concern the action possibilities locally at the device, as well as action possibilities that concern the interaction with other devices in the environment. While inherent and augmented information are primarily concerned with "the how", functional feedforward communicates "the what", the general function of the device or the function of a control. This type of information often relies on association, metaphors and the sign function of products, and is described in theories such as product semantics and product language. With multifunctional digital artefacts, and even more with networked artefacts, this becomes increasingly difficult. Introducing the concept of semantic connections tries to address these problems; therefore the functional feedforward is the main challenge when designing semantic connections. Functional feedforward should give information about the function of the semantic connection before the interaction takes place. Properly designing functional feedforward is therefore the crucial part of understanding semantic connections, smart services and smart environments.
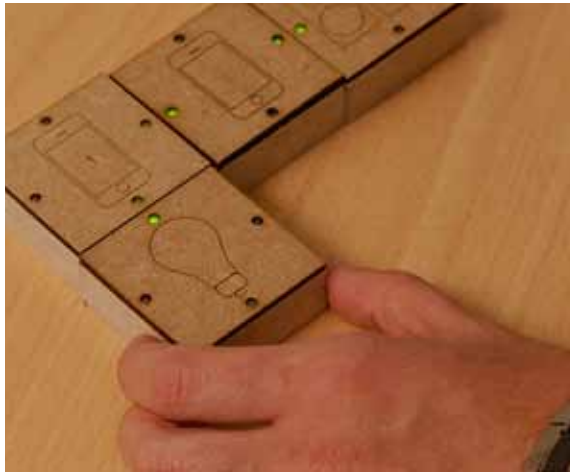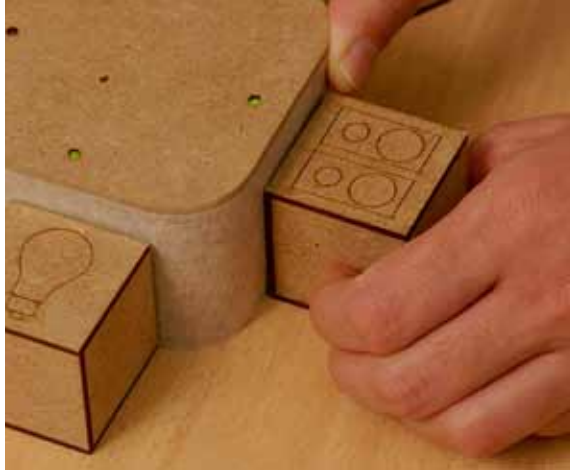
**Fig. 2. Examples of the different types of feedback:
(a) Augmented feedback; (green) lights showing a
connection currently exists. (b) Inherent feedback;
the feeling of a "snap" when two tiles are aligned. (c)
Functional feedback; a light rendering the mood of the
music when a music player is connected to it.**

Wensveen [14] further proposes that in interaction,
these types of information can link action and function
together in time, location, direction, modality, dynamics
and expression. Strengthening these couplings between
action and function will lead to richer and more
intuitive interactions [18]. We can also view semantic
connections in the Frogger framework in more general
terms. Although semantic connections are not a physical
device or product, but rather describe the structure
or configuration of a system of devices, the Frogger
framework can teach us important lessons. When
we look at the link between action and functional
information in time or location, a strong link would
mean they coincide in time and location. For location
this would mean that the connection that is made
between devices corresponds to the location of the
actual devices in physical space. Additionally, the
direction of the action of connecting/disconnecting
devices, being moving devices towards or away from
each other, would strengthen the coupling in terms of
direction. Also, the direction of the action could have a
link to the directionality of the semantic connection that
is made. This is similar to the couplings in dynamics.

### 3.2 Product Semantics

As discussed previously (to some extent), the theory
of product semantics describes and analyzes the
meaning of products in terms of what a product is and
to a certain extent how it can be operated. Product
semantics is a theory about how products acquire
meaning. Krippendorff states in his work The Semantic
Turn [8]: "Humans do not see and act on the physical
qualities of things but on what they mean to them"
[8, p. 47] and "One always acts according to the
meaning of whatever one faces. [...] It always concerns
sets of possibilities and presupposes human agency"
[8, p. 58].

Krippendorff [8] thus differentiates between the
intended meaning of the designer, leading to the
design, and the meaning it eventually acquires after
interpretation and reinterpretation by the user during
use. These two meanings are different things and the
meaning that a design has for its user may be a different
one than the meaning the designer intended. This
concept of meaning is in accordance with information
theory, where the designer is viewed as a communicator
of a message in the form of a product and the user as
a receiver of that message [19].

Krippendorff's semantic theory has, as briefly discussed before, a very human-centered approach; as he states: "meanings are always someone's construction [...] meanings are always embodied in their beholder" [8, p. 56]. He also argues for conceptual openness, as meaning emerges in the process of human interaction with artefacts. "Meanings are neither intrinsic to the physical or material qualities of things, nor can they be located within the human mind. [...] Meanings are constructed from previous experiences, expanded on them and drift, much like imagination does" [11, p. 56]. All meanings are context-dependent as usually many meanings are possible, but only few of them make practical sense. Artifacts may mean different things in different contexts and may mean different things to different people. Contexts limit the number of meanings as "artifacts mean what their contexts permit" [8, p. 59]. Contexts work in two directions, in the sense that one thing provides the context for the other and vice versa. For artefacts this means that "the meaning of an artefact's parts depends on the meaning of their arrangements, just as the meaning of its arrangements depends on that of its parts" [8, p. 61]. Krippendorff compares understanding complex artefacts with reading texts, with the distinction that one can interact physically with an artefact, in contrast with only visually perceiving a text.

Krippendorff [8] speaks of four main mechanisms of how artefacts acquire meaning: meaning of artefacts in use, meaning of artefacts in language, meaning in the lives of artefacts, and meaning in an ecology of artefacts. For our semantic connections, both the first and the last of these mechanisms invite a closer look.

Meanings of artefacts in use: Norman distinguishes between surface artefacts (what you see is all you get) and internal artefacts, of which the latter needs interfaces to represent and allow control over its internals. The majority of problems with usability and the constructions of meaning occur with internal artefacts. Krippendorff describes interfaces and states that: "Humans always act so as to preserve the meaningfulness of their interfaces" [8, p. 84]. When using a well-designed interface users go through the stages of:

**Recognition:** correctly identifying what something is and what it can be used for;
**Exploration:** figuring out how to face something, how

it works, what to do to achieve particular effects, and **Reliance:** handling something so naturally that attention can be on the sensed consequences of its use.

For recognition, (product) categories, (visual) metaphors and attractiveness play an important role. By finding resemblances in form and finding closeness to ideal types of a product category, people can recognise artefacts for what they are. Artefacts deviate from ideal types in dimensions, varying within certain boundaries of dimensions that define an artefact. They may also vary in features, dispensable additions to an artefact that do not alter its identity. As an example consider a smart phone. With or without many of its features it would still be a phone, as long as its core function is preserved. When we have to recognise new artefacts we can rely on the meaning of existing artefacts by using metaphors. Central to the stage of exploration are User Conceptual Models (UCMs), which are mental models of how artefacts could work, when to do what, and what to expect as a consequence of one's actions. Affordances and (physical) constraints are important mechanisms to invite users into actions and guide users in an artefact's possible use. Other conceptual handles for designing interfaces are informatives and semantic layering. Informatives are similar to the concept of "indication functions" in the theory of product language and essentially guide and inform users about the flow of the interaction. Informatives include: signals, state indicators, progress reports, confirmings, affordings, discontinuities, correlates, maps of possibilities, error messages and instructions.

Meanings in an ecology of artefacts: Looking at artefacts as a species, that are part of an ecology of things, is an interesting viewpoint. There is a crucial difference between ecologies of things and biological species however, as is pointed out by Krippendorff "biological species interact on their own terms; artefacts interact on human terms" [8, p. 195]. Technological artefacts do not know of each other but "interact with each other on account of the designer's specifications and/or users' desire to connect them" [8, p. 195]. Krippendorff [8] distinguishes between diachronic accounts and synchronic accounts to analyse ecologies of artefacts. While for a diachronic account artefacts are being traced according to their evolutions, a synchronic account "describes the network of concurrent

connections between artefacts that co-determine their use" [8, p. 197]. Important here are: causal connections (actual physical connections); family resemblances (belonging to the same product family, part-whole relationships); metaphorical connections (carry meaning between one, more familiar species of artefacts to another species) and institutional liaisons (different institutions are depending on the same species of artefacts).

Within the context of smart environments, an increasing amount of automation and increasing interconnectedness may have a negative impact on the meaningfulness of products. Artefacts can no longer be considered in isolation, as they are part of a larger ecosystem of technologies that we interact with.





**Fig. 3. Example from our research; using a spotlight metaphor to project connections into the physical world.**
**The Spotlight Navigation device (top); and projecting the wireless connections between devices (bottom).**

Therefore, designers need to provide users with handles and clues to make them understand and enable them to be effective in such an ecosystem of technologies, to understand what is happening and allow them to be and feel in control.

**Implications for Semantic Connections.**
Considering the theory of product semantics, and in particular Krippendorff's view on semantics, we can start defining what implications this has for our concept of semantic connections.

Building on Krippendorff's user-centred approach to meaning, we should be careful when indicating that a certain connection has a certain meaning. Although it might have a certain predefined functionality, what it will come to mean for its users is not entirely for the designer to control. By taking a second-order viewpoint, and using principles such as metaphor, affordances and informatives to support the phases of recognition, exploration and reliance, designers can, however, provide circumstances that increase the probability of the intended meaning to come across. For semantic connections this might mean that we have to look for reliable metaphors like physical cables and the interactions with them. Or like using a spotlight metaphor to explore connections that are invisible without using it (figure 3).

Physical constraints and informatives like signals, state indicators, affordances or discontinuities in form might help to indicate where and how to act; how to make or break connections, and which devices allow (and which do not allow) to be connected. Additionally, the notion of causal connections that link artefacts together, like wired or wireless networks, that is known and understood, provide helpful clues. Also the notion of family resemblances, where portable media players, stereo sets and speakers belonging to the same product families, might provide practical understanding of what a connection, connecting products of this family (with music playing capabilities) together, might mean and what the emerging functionality will be. Looking from an ecological perspective the following should be considered:

- The meaning of a semantic connection depends on the meaning of the artefacts it connects.
- Semantic connections work in mutual cooperation. They depend on other species (smart objects) and also support them.
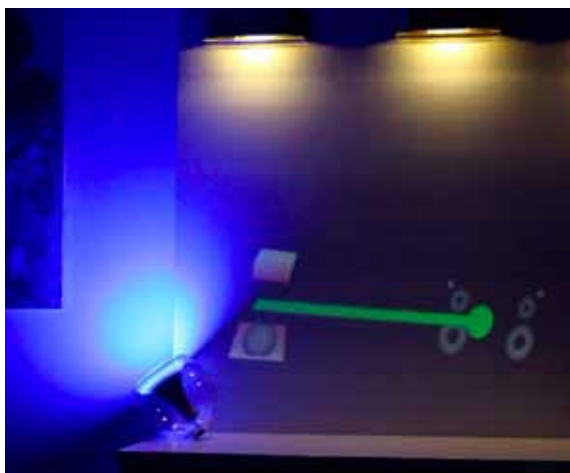
- Semantic connections might also have competitive interactions with other artefacts. Emergent functionalities through interoperability between artefacts could eventually lead to less objects around us. By combining the functionality of several artefacts, others might become obsolete (e.g. combining a printer and a scanner gives copying functionality).
- Semantic connections may also have a cooperative relationship with other artefacts, because more smart objects might result in more semantic connections being made.

## 3.3 Ecological Perception

Although the theory of ecological perception and the concept of affordance has been briefly discussed in some of the previous sections, we would like to discuss the theory and its implications a bit further. While many of the semantic theories discussed depart from a semiotic/linguistic and communication perspective, the ecological approach to perception has an entirely different theoretical foundation. Despite these differences, it will also become clear that on a practical level, the resulting designs might rely on similar perceptual qualities. Affordance, which is a central concept of ecological perception theory, is the property of an object that appeals to our sensory-motor skills, like a door-handle that "affords" to be grabbed and a chair that "affords" to be sat upon. When the insights of ecological perception were introduced into design by Norman [11], it fuelled the design community to try and solve many usability problems. Whereas on a practical and application level not necessarily relevant, Norman's view of affordances is slightly different from the original thoughts of Gibson and many like-minded psychologists [11, p. 219]. Central to the notion of affordances is the inseparability of humans and their environments, as humans have always dealt with their environments going through evolution. Affordances can thus neither be seen independently from humans, nor can they be viewed independently from the environment. For affordances to be detected, they need to be available as information that can be perceived by the human perceptive system. Secondly, they need to be viewed in relation to the bodily properties of every individual. While chairs may afford seating for adults, it may afford something else for children that might play underneath it [20]. Furthermore, when designing complex products and interfaces, affordances often work well for inviting users

to perform certain actions that the controls allow for. This does not necessarily indicate what the results of such an action will be. This is acknowledged by Djajadiningrat [21]; however, he also successfully shows that the notion of affordances can be used as a framework for design.

**Implications for Semantic Connections.**
Because connections/relationships between networked artefacts are not physical, and perhaps only mental constructions, affordances are a difficult concept in this context. We can create affordances for the control over these connections, but they will most likely only reveal how to manipulate the connections/relations, and not be very informative about the nature of these connections. Here, associations and meanings of the artefacts and their capabilities are important, which are learnt and rooted in convention and previous encounters with products. However, affordances can be used to invite users to perform certain actions, and these actions can carry meaning. To give a few examples of possibilities - the affordance of a control to make a connection can be shaped in such a way that it invites an action that may associate it with permanent or non-permanent connections, like a locking action after inserting a connector into a socket. Furthermore, there can be the affordance that invites the movement of a control in a certain direction (e.g. a sliding switch). This direction may in turn translate into the directionality of a connection. Some of these ideas have been implemented in the design of a digital camera and a VCR controller as described in [21].

## 4 Discussion

In this article we have discussed various theories of design and sense making. Much of the design theory described is, however, about the meaning of objects (or sometimes language) and originates from the era of non-interactive, mechanical and electric products and machines. With the introduction of microelectronics and digital electronics, many of these theories have been reconsidered to accommodate for interfaces and interactivity, and some have evolved into new ones. Now that we have entered the era of digital networked artefacts, which introduces additional concepts and complexity, these theories may need to be reconsidered; especially when considering that the networking technologies that connect these devices are

wireless and thus invisible. Even if we find ways to shape objects in such a way that they reveal their connectivity, how will they inform users about the possible connection types and the emerging functionality? Today networked objects are often recognised by their LCD screens, as part of a product category of "smart objects", or desktop, portable or wearable computers. Developing a form language and interaction paradigms for such products is a challenge that a large part of the (interaction) design community is and has been working on. Despite these efforts, today's products remain mainly GUI-based and these GUI's are the most important means for controlling connectivity.

The semantic connections interaction model and underlying theory proposes to reveal these invisible connections and allow direct physical control over them, like we have control over many physical wired connections. To support this, part of our semantic connections interaction model also proposes a software architecture to solve the current interoperability problems to a certain extent. This software architecture enables networked devices to exchange information and share device capabilities. Together this is expected to enable users to interact with the various devices in the system on a higher, more goal-oriented level, moving away from the current device-oriented way of interaction. Even though our approach still has to prove itself in practice, our experimental prototypes and setups show potential.

Wensveen et al. [14] propose an approach they refer to as the direct approach, which departs from the idea that not only the physical appearance of a product, but also the actions it invites users to perform, are carriers of meaning. They argue for a strong link between the qualities of an action and the result of that action, as is described in the Frogger framework [18]. The notion of feed-forward is pivotal in this direct approach, especially functional feedforward (as described in section 3.1). For our notion of semantic connections, we rely on several mechanisms to provide this (functional) feedforward. First of all we rely on natural mappings [11]. The connections or associative links are created between devices, places, persons or interactive parts of devices, that all exist in the physical reality. Instead of relying on identifying networked devices by name or other types of representation, we identify them by their physical location, where users can perceive them, point at them and touch them. Secondly, we rely on the meaning

of the devices that are being connected, in particular the resemblances in meaning of the devices being connected. Important here is the change in meaning that might occur, when users view the device no longer in isolation, but as part of a larger system. Krippendorff [8] discusses these part-whole relationships (as is described in section 3.2). Thirdly we rely on feedback and feedforward being provided by a mediating device or service, which has the special purpose to enable exploring and manipulating the – otherwise invisible – connections. We not only consider which things are connected, but also how these connections are made. This is where we have the freedom to carefully craft the way we discover and manipulate these connections, to provide additional information about what the connection will mean once it is made. Once the connection is active, in many cases the functional result in the physical environment will give additional feedback on the success and functionality of the connection that was made.

Although we believe that our approach will contribute to the necessary paradigm shift in user interaction, needed to accommodate interaction with systems of devices in contrast with single-device interactions, we realise our contribution is only a start. However, we are convinced that sharing this viewpoint and its theoretical foundation with the design community can be beneficial for starting the discussion amongst a larger audience than primarily the ubiquitous computing research communities and interaction designers working in that area.

## Acknowledgments

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# Table manners: The influence of context on gestural meaning

## Abstract

We investigated the activation of gesture control for a dining room table lamp. Using video scenarios which show a user interacting with the lamp during a dinner with friends, we carried out an online user test comparing the existing activation through hand gesture with three new alternatives: clapping, finger snapping and voice. Though we had expected users to prefer these alternatives for being more fluid, easier and faster than the existing initiation through hand gesture, the opposite turned out to be true. They were considered intrusive since they disturb through sound, through their connotations and by violating the personal space of others. We argue that the appropriateness of gestures is strongly dependent upon socio-cultural context and should be evaluated in the final use context.

## 1  Introduction

In this project, we focused on an interaction style called deviceless gesture control. Deviceless gesture control allows users to operate devices from a distance without the need for physical remote controls, body-worn electronics or markers [1], [2].

One of the challenges with deviceless gesture control from a distance is that it is difficult to distinguish between gestures which are intended to control the product and gestures which are not. That is, if gesture control were continuously enabled, users may unintentionally trigger a function. For example,

if the brightness of a dining room table lamp were continuously controllable through an up-down gesture, any vertical movement such as picking up a pan would influence the lighting. To prevent such frustrating, unintentional triggering, gesture control should only become active after users have explicitly activated gesture recognition. This activation is called the initiation action.

## 2  Use Case: A Dining Room Table Lamp

One of our business divisions developed a gesture-controlled prototype version of a Philips Arcitone dining room table fixture (Figure 1). With this suspension light, brightness can be controlled through a vertical hand gesture. Moving the hand upwards increases the fixture's brightness, moving the hand downwards dims it. The advantages of using gesture control for this type of pendant light is that the user need not walk to a wall dimmer, use a remote control nor touch the fixture which would lead to it to sway. This Arcitone pendant was first publicly shown to critical acclaim at Light + Building 2010, a trade fair on architectural lighting [3].

The gesture initiation movement for this pendant requires the user to move a hand horizontally from either end of the lamp to just below the middle, then move this hand downwards vertically, to finally stop and wait for two seconds for the luminaire to confirm its initiation through blinking (Figure 2).

**Fig.** 1. **The Arcitone gesture-controlled pendant.**

## 2.1 The Gesture Control Paradox: The Unnatural Initiation Gesture

The difficulty in deciding upon an initiation procedure based on movement only, is that the movement should not occur in daily ritual as gesture control may then be activated unintentionally, thereby defeating the point of having an initiation gesture.

The paradox then is that while gesture control is often described – as is voice control – as a form of natural interaction, the required initiation is unnatural by definition.

Indeed a user test conducted by the business division concluded that, although the initiation was easily learnable, it was not intuitive. Our team was asked to investigate alternative ways of initiating gesture control.

## 2.2 Project Scope

When we started our project, the product design and gesture sensor technology for the dining room table fixture had already been frozen. Therefore it was not possible to change the form factor. This blocked the possibility to add use cues to the existing form or to incorporate additional visual guidance through LEDs or displays. Alternative initiation actions would have to work in combination with the existing product design and sensors.

## 3 Critiquing the Existing Initiation Action

In its strictest definition, intuitive interaction implies that it is immediately clear to the user how to act in order to achieve a certain goal. In other words, users should not need to learn the right action by trial and error, by instruction, or by having to read

the manual. This is difficult to achieve with deviceless gesture control, especially if no changes can be made to the product design. We therefore focused on three aspects in which the initiation gesture clearly fell short: naturalness, repeatability and speed.

## 3.1 Naturalness

The original, movement-only initiation gesture has a rather mechanical, even robotic expression, as there is no flow to the movement. Due to cost-driven technological choices, the user is required to move orthogonally (first horizontally, then vertically) and then pause (Figure 2). As a result, the initiation action felt like an unlocking procedure and rather contrived.



**Fig. 2. Diagram showing the dining room table fixture suspended above a table. The original initiation gesture required users to: (1) move their hand horizontally from the side to just below the middle of the lamp, (2) move it vertically downwards, (3) hold it still for two seconds.**

## 3.2 Repeatability

Even experienced users did not always manage to initiate gesture control successfully every time. Initiation would fail if the user moved too quickly or too close to the sensors. So, even though the gesture is easy to remember in broad terms, it can be difficult to execute it exactly correctly. The main reason for this is that users only get feedback after they have completed the initiation movement, not during the movement. Since the interaction lacks real-time feedback, users cannot correct their actions mid-movement. Their only option is to carry out the movement and hope that it will turn out to be correct. If not, they have to start all over again which causes frustration.

## 3.3 Speed

Because of the change of direction and the pause, the initiation gesture feels long-winded, even though the initiation may only take seconds in absolute terms. The emphasis is more on the initiation gesture than on the functional gesture which changes the brightness.

## 3.4 Design Brief

Ideally, an initiation action should be accompanied by continuous feedforward and feedback, which makes users understand what is going wrong in case of errors and which allows them to correct their actions [4], [5]. However, with the product design already finished, our options to provide such continuous guidance were limited. We therefore aimed for an initiation action which was short, so that in case of a false negative users could try again without becoming too annoyed. The initiation action should:

- Feel fluid and not be discontinuous in either space or time. The user should be able to continue immediately with the up-down gesture to control the brightness.
- Be sufficiently unusual to score low on false positive (i.e. the product mistakenly flagging an event as an initiation action), yet be simple enough not to result in many false negatives.
- Be easy to get right every time without many false negatives (i.e. the product mistakenly ignoring an intentional initiation action) and without requiring additional guidance.
- Feel instantaneous.

## 4 Initiation Alternatives

Through bodystorming we explored three initiation alternatives: finger snap, double hand clap and voice. Finger snapping and clapping were already suggested repeatedly by test participants during earlier evaluations of gesture-controlled lamps. All three alternatives are multi-modal, require the recognition of both sound and movement, and allow more fluid, simpler and quicker initiation whilst managing the risk of false positives. Simpler initiation is also interesting from a communication perspective. As it is not self-evident that a product can be controlled through gestures, marketing gesture-controlled products is likely to require an explanation of this new technology and how to interact with these products. There are many touch points at which both brand and user benefit from a simple initiation gesture which can be explained in a split second: in advertising, at point of sale, on the packaging, in the manual etc.

## 4.1 Finger Snap, Double Clap and Voice

With finger snap initiation, after users have snapped their fingers underneath the luminaire they can immediately change the brightness by moving their hand up-down. The initiation procedure through double clapping is similar, with the only difference being that instead of having to snap their fingers, users have to clap their hands twice underneath the luminaire. With voice initiation, users first say the name of the luminaire to activate gesture control. This is similar to human-human interaction in which we first attract a person by saying their name to get his or her attention before we enter into conversation. The risk of false positives with voice initiation is increased if the word which is used as the voice command does not occur in everyday conversation. As the concept was to be tested in Holland, we chose the name 'Linea', meaning 'line' in Italian, as the name befits the minimalist rectilinear form factor and because the word 'Linea' is not part of the Dutch language. Clearly, this name would not be a good choice in Italy since the word 'linea' occurs commonly in Italian conversation.

## 4.2 Robustness

The term robustness refers to the ability of the product to withstand adverse, confusing conditions. With sound recognition, various noises may be mistaken for the initiation sound. Though finger snapping has the

Fig. 3a. Initiation by hand movement.


Fig. 3b. Initiation by finger snapping.


Fig. 3c. Initiation by double clapping.


Fig. 3d. Initiation by voice.

advantage that it can be done one-handedly, double clapping is likely to be more robust than a single finger snap. A single sound spike can result from all sorts of actions (e.g. putting the lid on a pan, throwing a magazine on the table), possibly resulting in false positives, whilst two loud noises in succession are far more unlikely to occur. Whilst clearly it would be possible to analyse the waveform of the sound to determine its origin, this puts higher demands on the processing power of the embedded microcontroller and thus raises the product's complexity and bill of materials.

The robustness of all three initiation methods can be increased by requiring that sound and movement have to be detected simultaneously. That is, the luminaire only initiates if it 'hears' finger snapping, double clapping or voice whilst detecting movement in the active zone. If people make an initiation sound anywhere in the room without movement being detected underneath the lamp, gesture control will not be activated.

## 5 Online, Video-Based User Tests

To obtain user feedback we shot video scenarios of the initiation options being used during a dinner party (Figures 3a-3d). The resulting video clips were evaluated in an online user test. The original, movement-based initiation was the only method which was technically operational. The other three (finger snap, double clap and voice) were executed using a Wizard-of-Oz set-up. As the actor carried out the gestures, the brightness of the lamp was controlled from behind the scenes.

### 5.1 Hypothesis
Our hypothesis was that the alternative initiation procedures would be preferred over the original movement-only initiation, as the alternatives were less contrived, less convoluted and faster.

### 5.2 Experimental Design
Twelve participants (5F, 7M) took part in the evaluation. For the user evaluation AttrakDiff was used [6]. First, the participants watched the four movie clips in randomized, counter-balanced order. Then they watched them one by one, completing a questionnaire after each viewing. They also sent us their comments and critique.

## Movement



## Finger snap



## Double hand clap



## Voice
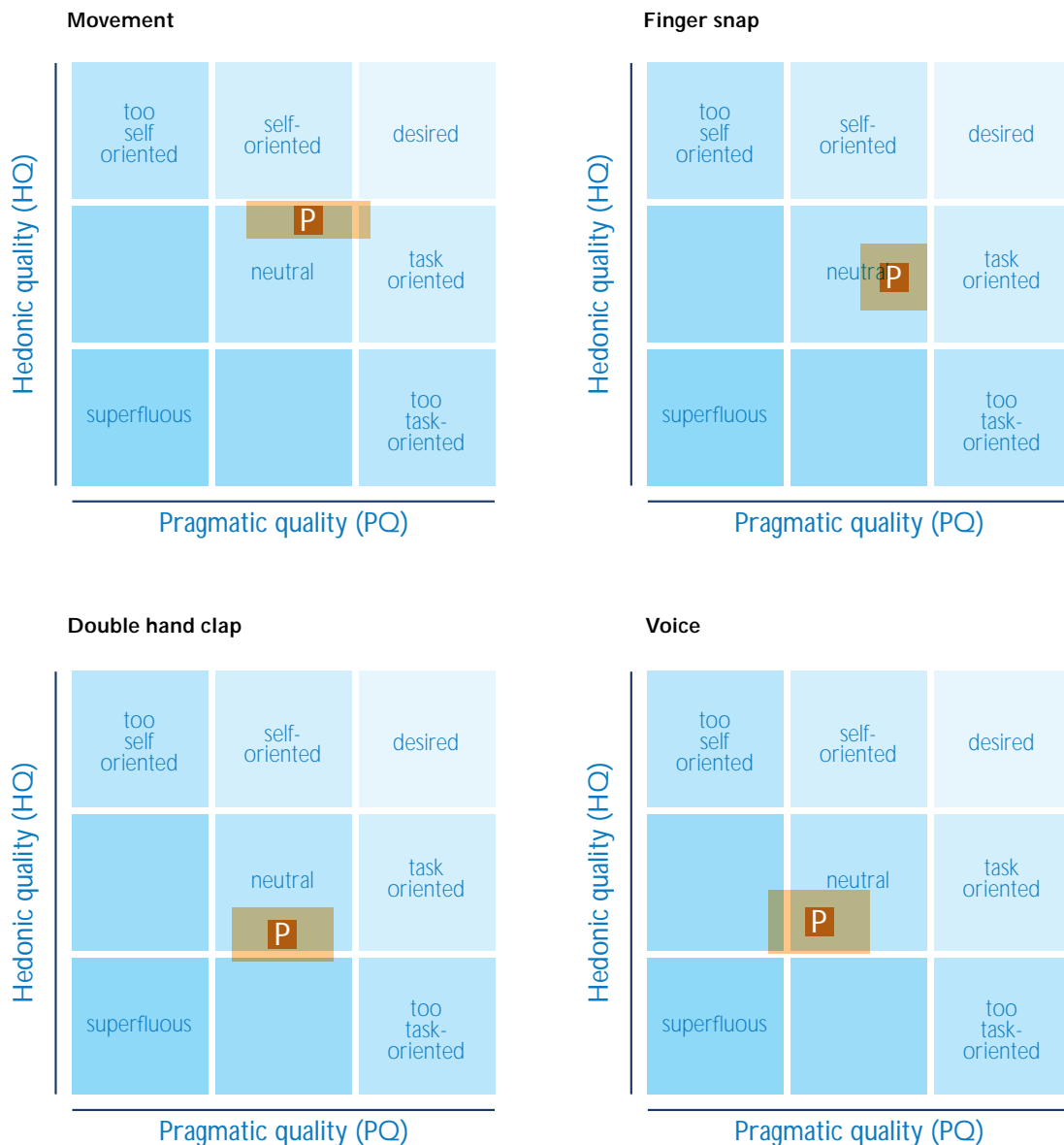


**Fig. 4. AttrakDiff test results for the four initiation actions.**

### 5.3 Results

The results are shown in Figure 4. Since the comparison was based on video rather than on interaction with working prototypes, all initiation methods offered apparently perfect recognition: in all four videos the user makes the correct gesture and the product initiates correctly. Once implemented, some methods will have a higher recognition rate than others. Such recognition errors were not taken into account in this test. The pragmatic quality scores are therefore not a realistic reflection of real-world usability, but rather an indication of perceived usability. On the hedonic axis we see that finger snapping, double clapping and voice all score significantly lower than the original movement-based initiation. Hedonically, only finger snapping approaches movement-based initiation.

### 5.4 Discussion

For an explanation of these results, consider some of the comments provided by our participants.
Finger snap. It's considered impolite to attract attention by snapping your fingers, but may be acceptable to a device. Still, guests at the table may be disturbed.
Voice. Too loud and noisy.
Movement. In my opinion this is the friendliest way to control the lamp, with the least hindrance on what is going on around the table.
Double clap. This is too loud and noisy (e.g. when you're in a conversation), people will be shaken up, conversations might stop and all attention will go to controlling a lamp. / I don't want to clap my hands in front of my guests' noses nor make some funny noises just to activate a dining lamp. / Gesture-controlled

activation seems most logical to me (…once you know how to use it and get used to it). In the movie it still comes over a bit unnatural and complicated to me. The recurring critique appears to be that the alternative initiation methods are too intrusive for three reasons. First, in a dining setting double clapping and finger snapping both have the connotation of attracting attention with an air of superiority (e.g. calling a waiter, reproving children). Second, suddenly speaking to the lamp, the sound of finger snapping and double clapping may interrupt conversation. Third, by making these gestures close to other people's faces, the user is intruding upon their personal space. Considering that a table may only be 100cm wide and that the lamp is suspended above the middle of the table, the user may be finger snapping or double clapping as close a 50cm from the face of a table companion.

In terms of hedonic quality, only finger snapping comes close to movement-based initiation. However, not everyone can snap their fingers sufficiently loudly, resulting in consumers being locked out from using the product.

In this particular use context, the original movement-based initiation therefore remains – at least from a hedonic point of view – the preferred initiation method. The only way we may achieve a simpler initiation is by reconsidering the product design and concurrently designing the product's form and required gestures.

## 6 Conclusions

Our experiences with the dining room table fixture resulted in the following recommendations for the design of gesture-controlled products:

• Use a holistic approach: product form, interaction and gestures should be designed concurrently as they are strongly interdependent. Premature decisions on form without considering interaction and gestures can result in 'digging yourself a hole' and the loss of design opportunities.

• Provide continuous guidance: the product should guide users during, rather than after, a gesture through feedforward and feedback, thereby allowing users to correct their actions.

• Evaluate in context: gestures should be evaluated with a product's final form factor and in the intended socio-cultural context.

Gestures carry not only functional information but also socio-cultural and even emotional connotations. Therefore, gestures which are simple to execute may still be inappropriate in particular contexts. The three multi-modal initiation actions were both simpler and more robust than the initiation by movement only. Yet users disliked them, as they were considered to be in violation of good table manners.

This case study shows that we need to consider the connotations or feelings that gestures might invoke, something which can only be judged in combination with the use context. Looking back, we did act out the alternative multi-modal initiation actions in the early stages of the project, but only in a meeting room setting with a single user operating a task light. It was not until we tried these initiation actions in a setting with dinner guests and the fixture above the dining room table, that we discovered the negative associations of the gestures.

## Acknowledgments

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# Persuasive design for energy saving behavior through social gaming

## Abstract

This paper proposes to use social network gaming as a persuasive tool to adapt energy saving practices amongst the Millennial Generation while using connected devices or appliances. The proposed solution leverages the power of connected devices and social networking principles to bring behavioral changes for efficient energy consumption among users aged 18-25 years. The paper is based on the insights gained through the research we conducted to understand the motivations of users regarding energy saving in devices, capabilities of connected devices and the role of future web. Insights from our research revealed that a solution that is an extension of user's daily energy consumption behavior, could lead to sustained behavioral changes for energy conservation. We suggest a system that captures the energy consumption of users, analyses and provides recommendations for efficient consumption on a social networking game. This paper reports on the work in progress of a gaming solution called 'Wattever'. Wattever is a social networking game which maps users' devices in the real world to a game in the virtual world.

## Keywords

Connected devices, social networking and gaming, energy conservation, millennials, virtual worlds.

## 1 Introduction

Connected and smart environments make it possible for users to be always 'ON' their devices. The inventory of devices and appliances we use in our everyday life continues to grow: Smartphones, Tablets, microwave, smart TVs, washing machines, electric vehicles, etc [1]. A lot of these appliances consume a significant amount of energy. There is a high demand for energy and the supply is not meeting the equivalent to this demand [2]. Therefore it is essential to enable users to take steps that support energy conservation in connected devices. We adopted a three-pronged approach to propose an energy conservation method for connected devices. We studied the following factors
• **Motivations of Millennials regarding energy conservation**
• **Capabilities of connected devices**
• **Future web and its impact on users.**
Using emergent technologies; Governments, Energy providers, Device Manufacturers and other Energy sector players are able to track and communicate about energy consumption to users [3]. Although these players are able to monitor, and analyze the energy consumption information to the users, moderate success has been achieved for the intended outcome of changing the energy consumption behavior among users. We conducted a user study to understand the inherent motivations and issues in Millennials about adopting existing energy conservation solutions.

## 2 Millennials and Energy Saving

The target audience for this solution is aged 18-25 years. They are also known as "Millennials" or the Net Generation. Millennials have been chosen for this study since they are characterized by heightened use and familiarity with Communications, Media and Digital technology [4]. The term "Digital Native" is used to refer to the Millennials. In addition, their constant exposure to the Internet and other digital media has shaped how they receive information and how they learn. To develop a thorough understanding of Millennials behaviors and attitudes towards energy saving, we conducted user research. Our research included an online survey of 30 participants, one-on-one interviews with ten participants and an extensive literature study. The focus of this study was to understand lifestyle, energy consumption awareness, energy saving practices followed and issues faced, and energy saving information needs required by them.

### 2.1 Insights

Based on our research user study and literature study, we identified some key issues in existing energy saving solutions. Figure 1 shows some existing energy management solution interfaces that indicate consumption of energy.



**Fig.** 1. **Use of complex graphs in existing energy management systems.**

Complex graphs and visuals make energy information dull and difficult to comprehend. We learnt that frequent addressing of Energy issues as a crisis situation has made it routine information and the alarming nature of this propagation desensitizes the users to act on the issue. Although there is a heightened awareness among users about energy wastage, they are little affected by the repeated energy recommendations proposed to them [5]. Studies reveal that [6] Millennials find routine boring and unchallenging and are driven by a need for novelty. Their preferences tend towards new experimental actions, use of new technology and group activities. Millennials believe that it is cool to be smart, are tech savvy and goal oriented. This goal constitutes major focus of their attention. For any other practice or behavior to be adopted, they need a non-serious, tangential motivation which does not divert them from their main goal. We have identified this attribute, of not developing a tangential approach for addressing energy issues, as one of the reasons for the failure of some existing energy saving behavior models. We also found that energy cost saving is not the key motivating factor for Millennials. Most users felt that the electricity prices were reasonable and not significantly expensive to motivate them to save energy. People generally were unaware of the electricity costs and value for money it provides [7]. Our research further indicated that real-time feedback of energy consumption is effective in promoting a sustained response and users feel accountable for their actions. Therefore real-time feedback can lead to reduced energy consumption [8], [9]. We observed some personas enthusiastic about saving energy were keen to know what to do 'now' rather than getting a delayed feedback about their overall energy consumption.

## 3 Capabilities of Connected Devices and Future Web

Trends indicate that devices and appliances will have a unique way of identification in future as more and more machines and people will get connected through the internet. Future devices, like Smartphones, tablets, electrical appliances, vehicles, etc. will be equipped with an IP, hence capable of communicating with each other and the user. Internet connected appliances will empower users and energy service providers with more access and control [10]. As new technologies like Cloud computing enhance the addressability of appliances and advanced computing capability will bring in ubiquity of devices. The scope of future web also includes networking within environment; hence the smart grid, energy service providers, home environment and users' devices, users' social networks will be connected [11]. The omnipresence of the internet across systems can

be leveraged to bring together variable systems like social networking, online gaming and connected devices. The connectedness of devices will not only provide information to users about energy consumption in their devices, but also that of other users in their networks. Moreover, when the users' environment along with the appliances will be connected to user's social network, they will have an involvement in the user's decision making. This reach of the internet through connected devices, can be used to bring about a change in user behavior, leveraging on its power of persuasion.

An important aspect of future web is social networking. Insights from our user research indicate that social media has been an important factor among users to communicate and share information. Users choose social networking sites to express themselves and to reflect their personality. B.J. Fogg mentions that social networks have an ability to trigger an inherent motivation within users and hence persuade them to take action [12]. Millennials have a notable presence in social networks and social networking games. Currently online social gaming is rapidly growing as a main form of digital entertainment among Millennials. Online social games like Sims Online, Cityville and Second Life are good examples of the power of social games to engage Millennials [13]. Studies show that the target audience spends an average of 10.6 hours a day accessing social networking [14]. Online multiplayer games add a social dimension to the game, which manifests in changes in existing behavior and/or emergence of new behaviors. Users choose these games to reflect their personality or aspirations through avatars. The word avatar originated from Sanskrit and means 'a form of self'. An avatar is used for self-representation or the alter ego of users [15], [16]. The behavior of a user's redirection of their feelings and desires through an avatar in a game is referred to as 'Transference' [17]. An example of this phenomenon is explained using the popular online game Sims Social. Sims Social gives an opportunity for players to interact with their friends in new ways. In addition to taking care of the basic needs of one's avatar, a user can also enrich relationships with other online friends. This game leverages on the existing relationship of friends on Facebook to climb up in the game hierarchy. In order to reach a relationship milestone within the game, the user has to involve approval of the real Facebook friends. Instead of choosing from predefined interactions with an

AI-controlled character, the user has to ponder about the nature of the relationship to be established with the online friend. These relationships range from being friends, lovers, flirting, making out and even making enemies. The avatars visit each other's home and use the objects in the home to explore new interactions, like playing a guitar, looking at stars through a telescope, etc. In order to customize and decorate the avatar's home, the user has to send requests to friends or spend money to buy virtual merchandise. The eagerness of the user to send many gift requests to each other and spend real money to buy virtual merchandise in these games is notable.

The entropy of parameters like the psychological effects of Social Gaming, the capability of Connected Devices and Web and principles of Sustainability can result in a new learning leading to new behaviors. The understanding of this learning can be used to develop new approaches for promoting sustainable behaviors among Millennials [18]. Our solution is therefore built on social network gaming which is an already established platform for communication and interaction among Millennials.

### 3.1 Related Work: Energy Saving
We studied existing efforts to promote energy saving behavior. An interesting solution is 'Power House' by Stanford University which gives users the task of managing the power usage in a game world home and incorporates their actual home's utility data using a smart meter [19]. Nissan's Leaf line of electric vehicles have "Eco Mode" software that keeps track of variables like speed and power usage and provides feedback to the drivers to improve driving efficiency. It also provides online profiles to these drivers, so people can compete with other drivers.
 Another solution from OPOWER, a smart grid software firm for energy conservation, provides reports for users with monthly household energy consumption. It also has a feature to compare individual energy consumption over a period and also with other households in the neighborhood. A successful case study of OPOWER is in a California municipal utility where they managed up to 4.1% energy saving during peak season, using this solution [20].
The competition aspect of these solutions is a major motivating factor for customers to consistently consume less energy than those that do not.

## 4  Design Proposal: A Social Gaming Solution for Energy Saving

As established through the above studies the internet makes it possible to monitor, control, regulate and inform about the Energy supplied and consumed. Leveraging this device capability and future web capabilities, a solution is proposed to encourage energy conservation behavior among users while using electrical appliances and smart devices in connected environments. Our proposed solution is called 'Wattever'. This is a multiplayer online social game that enlists players worldwide to save energy in using their connected devices and appliances. Users' real world connected devices are mapped to a Green Plot in the virtual world. The game world reflects the energy consumption of the devices in the real world.

The virtual equivalent of users and their devices in the game are the avatars and a green plot respectively. The health of the plot of a user is directly proportional to efficient energy consumption by devices in the real world. The objective of the game is to efficiently consume energy in connected devices in the real world in order to maintain a flourishing green plot in their virtual world equivalents. This real-virtual mapping system is illustrated in Figure 2.



**Fig. 2. A system where users' real world entities like connected appliances, law making bodies, friends and social circle are metaphorically mapped into a virtual gaming world with their virtual surrogates.**

Lower energy consumption by a user in the real world yields a higher game score in the virtual world. Since this is a multiplayer social game, players can collaborate and compete with other players to obtain the highest-scoring (lowest-energy using) models.

### 4.1 Game Play as a Single Player and a Multiplayer

The energy consumed by a player in the real world is translated to the health of user's green plot in the game. Over-consumption or misuse of energy leads to deterioration and efficient consumption results in higher scores resulting in a flourishing green plot. The challenge in the game is for the players to plan and consume energy in real life effectively so as to score higher and maintain the health of their plots. In case of surplus energy consumption, there is an energy loss which leads to negative scoring and the corresponding wilting of plants in the player's plot. Users are motivated to decrease their surplus energy consumption by noticing a corresponding weakening of health in the game. Apart from this, in order to inculcate new energy saving practices among users, they are given tasks in the game interface. Tasks are activities to be undertaken by the players which will result in energy saving. The tasks are devised based on multiple factors such as: Energy standards, device capabilities, information on energy from the Smart Grid and the user's profile information. These tasks are either to be achieved as an individual or as a group. Table 1 describes the type of tasks that can be undertaken by players in this game, the challenge posed to the user and their examples.

| Task | Challenge | Example |
|------|-----------|---------|
| General Tasks | To decrease over-consumption of energy in daily usage of connected devices | Turning the switch of electrical appliances off, even when they have been switched off |
| Task as a single player | To decrease over-consumption of energy by adopting new practices in individual usage of devices | Washing clothes in washing machine during non-peak hours based on Demand Response cycles |
| Task as a multi-player | To decrease over-consumption of energy as a community | Organized carpooling in an internet connected Electric vehicle |

**Table 1. Tasks and challenges based on single and multiplayer options.**

**Fig. 3. Wattever interface with player's avatar and green plot.**



**Fig. 4. Recommendations for energy conservation.**

Each task will have corresponding recommendations for saving energy. A user can choose a suitable energy saving recommendation and complete the task. Since learning of energy efficient practices is paramount to the success of the game, an increasing learning curve will be maintained in these tasks, as users proceed to subsequent levels. Some tasks will be easy and lead to marginal energy saving, whereas completion of tougher tasks will result in higher scores and therefore more energy saving. Upon completion of these tasks players are rewarded with scores, collectables or titles. These rewards are an incentive for players to keep saving energy (see Player engagement mechanism: Section 4.4). Apart from earning scores and rewards, players will also be able to publish their energy saving achievements on their social networking sites.

## 4.2 Game Interface
Wattever provides a playful interface through which users can monitor and control the energy consumption of their devices. Figure 3 illustrates the basic screen of this game. The interface primarily has a plot with green plants. Other interface elements on the screen are tasks, scores and user's energy consumption data. In Figure 3 the user has been given a task to restore a wilting plant. There is an avatar of the player who tends this plot, restores the wilting plants and maintains its health. The greenery of a player's plot is a visual indicator of how efficiently the player is consuming energy. Since Wattever is accessible from multiple user devices, like PC, Smartphone or tablet, a common interface is proposed. This interface provides a unique feature, where users will be able to see their devices as part of a feedback loop of the game (see Recommendation and Feedback mechanism: section 4.3, 4.4).

## 4.3 Recommendations in Wattever
Wattever provides energy saving recommendations to the users to regulate their energy consumption. These recommendations are based on tasks undertaken by players. The recommendations are contextual to users. These recommendations are formed taking into account the following factors:
• The energy to be saved for the task chosen by users/players

• Users' devices that are consuming surplus energy
• Recommended Energy Standards for devices by Energy Saving Bodies and Government policies
• Comparative energy consumption of other players in the game network.

These recommendations are real time by default but can be based on timings set by users. The real time recommendation appears as notifications on users' device screens. Users can interact with these notifications to take energy saving actions. Users will get multiple choices of recommendations to save energy and complete a task. Users can choose to act on a suitable recommendation. These actions need not be taken only when users are actively playing the game. The ubiquity of devices facilitates users to act on given recommendations from any of their devices. These recommendations are given in game vocabulary. For example, in Figure 4 the user has a task to restore a wilting plant. The reason for a plant to wilt is due to surplus energy consumption amongst the user's devices. Figure 4 shows a recommendation pop up in the game interface. This recommendation consists of choices like:
• Switching off a gaming console
• Following recommended device settings of a steaming iron
• Turning off a porch light.

The details of the recommendations mention the devices that are consuming extra energy, their individual energy consumption in kilowatts and the energy cost of each device. Users can implement the suggested recommendations via the game interface. Interactions with the game interface will enable users to control their devices any time and anywhere. Users are prompted to switch a device off through the game, using the visual cues. A wilting plant will prompt a user to take action, and the user will follow the suggested recommendation through the game. For example in figure 4, the user switches off the gaming console while not using it.

## 4.4 Feedback, Scores and Rewards in Wattever
Once players have taken the recommended action, they are provided with feedback. Feedback loops are employed by many social games to give compelling information to the users about the tasks they have

undertaken. These can be positive or negative feedback based on the consequence of a player's action. The positive feedback is in the form of scores and rewards. The scores help to maintain the point system in the game. Higher scores lead to better rewards and lower scores lead to a deterioration of health of the green plot. Hence players are motivated to earn high scores in order to unlock new rewards in forthcoming game levels and maintain the plot's health.

The calculation of scores is made based on the recommended energy consumption levels of users' devices. The average energy consumption level is not just based on energy consumed by devices but also various external parameters. Energy requirement per devices, time of day, age of the device and efficiency standards of a device are all taken into consideration while evaluating a device's energy consumption. Earning a particular total of scores corresponds to rewards in Wattever. These rewards provide incentives to players in the real and virtual worlds. The real world incentives can include cash discounts while buying energy efficient devices from device manufacturers, tax incentives from government, Wattever game badges, goodies and so on. Virtual rewards, as the name suggests are not tangible. These rewards can be used by the players to enhance their existing game experience. These rewards include Game Titles, collectibles, virtual gifts and more. The rewards are not only meant for a single player but involve multiple players in a user's network. For example rewarding a player with an ability to challenge other players, game tokens that help players to buy collectibles in the game that help through difficult challenges. These reward systems offer various forms of addictive gaming. Negative feedback is given when a user fails to perform the given task. Examples of negative feedback include negative scoring, loss or turn. Wattever will employ a feedback loop that encourages its players to perform energy saving actions. The priority will be given to positive feedback, so that players are encouraged by rewards of playing the game. Players can earn 'in game' tokens which will enable them to decorate their game environment. Negative feedback will be subtle unlike many social games. Since the primary goal of this game is Energy Saving and not entertainment, player's inability to complete the task should not be dealt as a punishment. Failure to complete a task will result in a lower score and affect the health of elements in a player's game plot.

Feedback also provides an opportunity for players to brag about their achievements in a social networking platform. Users can use this to project their green facet on a social network. Wattever uses player engagement mechanisms to engage the users to undertake new energy saving tasks, without losing the excitement of performing the task. The playful interaction and the inbuilt sociability of this game will be used to develop a closer bond between users and their appliances. Figure 5 displays feedback to the player about earning a high score for switching off an unused gaming console.



**Fig. 5. Positive feedback saving energy saving.**

## 4.5 Social Gameplay of Wattever

Wattever reflects the energy consumption in devices of an individual and a social community who are part of the game. A user is not only motivated as an individual but as a social being to save energy. The social nature of this game gives a platform to users to take up activities together. Many online social games involve the users and their network to cooperate within a game.

For example in the popular social game Cityville, if a player has cultivated some crops and is unable to harvest them in the right time, player's friends can come and harvest it for them, saving them from withering. The player who has been helped by a friend feels obligated to help the other friend in an hour of need. This causes the effect of reciprocity [21], that is, when people give you something, you feel the need to give something back. Reciprocity is employed in Wattever to enable users to help each other save energy. Wattever proposes the following method by which a community can play together in the game to save energy:

• User's friends can reduce their regular consumption in order to gain game scores and share it to maintain the health of user's game plot

• Users can be given a task, completion of which depends upon actions of multiple players

- Users can give device control rights to other trusted players, and manage energy consumption of each other's devices.

If the user is consuming surplus energy due to an unavoidable reason, the user's social network can come to the rescue by choosing from the above mentioned options. Users can make individual contributions to saving energy, in order to achieve a community goal in the game. Figure 6 displays how different players adapt energy saving practices to complete a group task in the game.



**Fig. 6. Multiple players acting together to complete a task.**

In fig. 6 users adapt sustainable practices like car pooling, using solar power and washing in water saving mode, in order to unlock a community park in the game. A community park adds to the visual appeal of the neighborhood. A neighborhood is formed by a network of friends in Wattever. Therefore networks of friends can compete against each other to have a better virtual neighborhood. The multiplayer nature of Wattever encourages cooperation and healthy competition thus leading to gamification of energy saving practices. The intent of gamification is to inculcate competition in an otherwise mundane task. At the end of completing a task in the game, the users are given positive feedback and also reminded of how their other friends are faring in the game. When users of similar lifestyle and life stage compare each other's progress the sense of competition is invoked where each player tries to outscore one another. The scores of players are displayed in scoreboards. Wattever will display the scores of users along with their corresponding game title and rank. In this game, players are encouraged to compare their appliance usage statistics with other users who are faring better using a similar appliance.

**4.6 Player Engagement Mechanisms**
Popular social networking games imperatively focus on Player Engagement Mechanisms. These mechanisms are used to retain the interest of players for a sustained period through powerful player engagement strategies. Few examples of these mechanisms include enhancing entertainment value, encouraging cooperation and competition between players, giving bragging rights for achievements and rewarding completion of tasks. Many games have employed these tactics to keep the existing players tied to the game and also to entice the less active players back to the game. A notable mechanism developed by the online games is that of gifting. These gift announcements are made on the user's social networking profile and the user's network is notified about this. These gifts usually are useful to their recipients to complete some game task. Figure 7 indicates the player engagement features employed in a social game design to make lasting behavioral changes in Millennials.



**Fig. 7. Player engagement features employed in a social game design.**

**4.6 Wattever: The Game's Integration with Connected Devices**
Wattever players leverage addressability of devices to use and control them. The real time device usage information of a user's connected devices is pushed to the internet. Increasing the number of sensors in the devices, device to device communication and DLNA capabilities are additional enablers of connected devices to collect energy information. The ease of access of energy information facilitates enhances the monitoring and tracking of energy consumption by appliances of different users. A system where the web encompasses energy information from different entities like legal bodies, smart homes, smart grid, external services providers and users on social networks is shown in Figure 8.

A system like this works on the participation of multiple stakeholders for energy saving. Device providers can enable the device with sensors so that energy consumed by the devices is pushed via the internet to information providers. Sustainability Service providers like AMEE [22] can aggregate this energy data and distill this into meaningful information. Smart energy standards

**Fig. 8. A system that analyzes energy consumption based on inputs from various information providers.**

bodies like ZigBee alliance [23] can share protocols for interoperable products that monitor, control, inform and automate the delivery and use of energy. Smart grid can predict and intelligently respond to the behavior and actions of all electric power users connected to it in order to efficiently deliver sustainable electricity services. Social networks can provide data about individual users and help in the profiling of energy consumption data. The aggregated data is analyzed by our proposed system and mapped to its virtual equivalent in the game world. For example, if the user has consumed an amount of surplus energy, then a corresponding amount of damage will be incurred to an element in the game world. The devices are not mapped one to one in the virtual world whereas the health of the virtual elements in the game corresponds to the total energy consumption by real world devices. This damage can be rectified by adopting energy efficient practices while using devices and appliances and gaining game scores. These scores are considered to restore the health of the game world element.

### 4.7 Why Will this Work?

Wattever presents an informal environment to learn energy saving practices. This energy saving Social Game can result in a system that subtly assists users to consume energy efficiently. Online Social games already have an established popularity among Millennials. Hence this approach will provide a lower learning barrier to users than adopting a complex energy saving practice. The multisensory experiences that games can provide increase the attention span on energy conservation of Millennials [24].

The key differentiator of this approach is that a user is adopting energy saving practices through other users instead of an impersonal third party recommendation. The metaphorical representation of one's own devices in a game world establishes closer relation between users and their devices. Studies show that users perform better in the presence of others [25] and follow people with lifestyle similarities and for information [26].

Therefore players can learn the best energy saving practices from each other to prosper in the game. The internet provides a 'Never off/always on' experience. Wattever can leverage this to engage players in energy saving games through time zones. This capability also provides for the possibility of people from different cultures and countries coming together under the cause of energy saving through the game. Because of this 'Never off/always on' nature of the internet, multiplayer online games can have players across the globe engaged in heated competition with teams comprising of players across time zones and geographies.

### 4.8 Future Direction of Using a Social Gaming Approach for Inculcating Desired Behaviors

Changes in technology provide creative ways to reach the target population. The proposed solution harnesses the ability of future web and connected devices to create a virtual world for the user. This solution caters to core motivation and inner needs among the target age group. A role playing game gives a user the freedom of choice; this is exercised when users strategize about survival and the success of their avatars in the game world. By addressing inherent needs of Millennials like the need for power, affiliation and a sense of achievement though an energy saving online game; a new approach is created to communicate about the seriousness of the energy issue. An online social game removes the alarming nature of this situation and makes the learning more enjoyable and active. The learning curve in a simulated virtual environment is lesser than other traditional methods of addressing the energy crisis. Wattever can cater to a broader audience who are already playing a variety of online social games and provide a complement and supplement to other traditional methods of energy saving.

### 5 Conclusion

We have proposed the social gaming approach for energy saving based on our insights from research aimed at Millennials. Wattever's game design principles and scoring algorithms have to be further articulated.

However, this research helped us develop a new approach of a tangential and casual motivation for encouraging desired behavior in Millennials. The learning from this project can be employed for causes other than sustainability like, education, healthcare, driving behavior, abstinence from anti-social practices and so on. Social games provide a rich learning platform which can be embraced by device manufacturers, energy solution providers and governments to keep up with today's and future generations' thinking and behaviors.

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# Four installations inviting playful interaction

## Abstract

The course Embodiment, Tangible Interaction and Games was offered as an elective in the Bachelor of Creative Technologies (BCT) programme at Auckland University of Technology, New Zealand in semester 1/2011. It was open to year two and three students. We discussed ideas of phenomenology and attempted to apply them to the design of interactive installations. The installations integrated space, movement and artefacts in collaborative and competitive settings and in playful ways. A number of the installations appear suited for exhibition and are presented here. The Eight-Bit Mirror, Deimous and [sol] are student works[1], Box Me Dumb Human was developed by the author while preparing the course. The installations focus on different sides of the bodily experience, and on different aspects of playful interaction.

## Keywords

Student works, phenomenology, tangible interaction, play.

## 1 Introduction

The course Embodiment, Tangible Interaction and Games was offered as an elective in the Bachelor of Creative Technologies (BCT) programme at Auckland University of Technology, New Zealand, in semester 1/2011. The programme was only established a few years ago in 2008 and is located within the Interdisciplinary Unit which was formed to develop new experimental alliances, research collaborations and student-centred learning experiences across the overlapping disciplines of Art & Design, Computing & Mathematical Sciences, Communications & Media Studies, and Engineering. The research-led BCT is seen as a key component of this interdisciplinary project. The course was open to year two and three students. We discussed ideas of phenomenology in relation to software systems (e.g. [1], [2]) and attempted to develop holistic concepts for interactive, playable installations. The student works were conceived and created in a process that attempted to include and connect theory and practice, writing and building, reflection and action. Lectures were accompanied by technical tutorials and exercises. Students were asked to research theory, implement a classic computer game, create several designs for their project, build mock-ups and prototypes, and present, discuss and critique their works.

The installations incorporated the arrangement of physical objects in space, and bodily action and movement in a collaborative or competitive setting of multiple users as outlined in [3]. The students came up with very different ideas for their projects which varied considerably in the ways they established connections to phenomenology. Some works were open-ended and invited free exploration, some had explicitly defined and formulated goals and were organised in levels or rounds; some had background stories, some incorporated

[1] The Eight-Bit Mirror was developed by Felicity Powell, Nick Redwood and Dylan Turney; Deimous by Anneke Crouse, Brandon Dawson and Sahil Vallabh; [sol] by Tarei King, Zak Henry and Thorsten Ziller.

[2] This quote and the following quotes are taken from design documents written by the students.
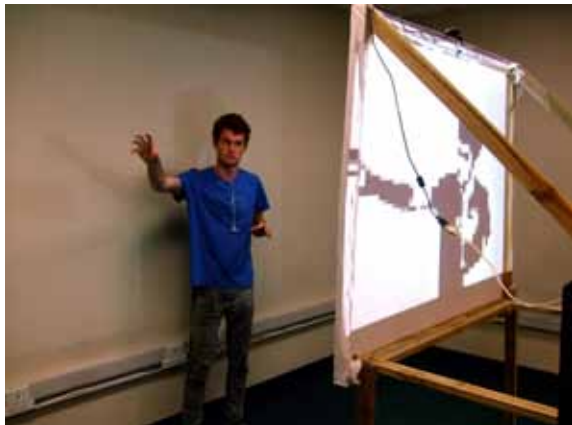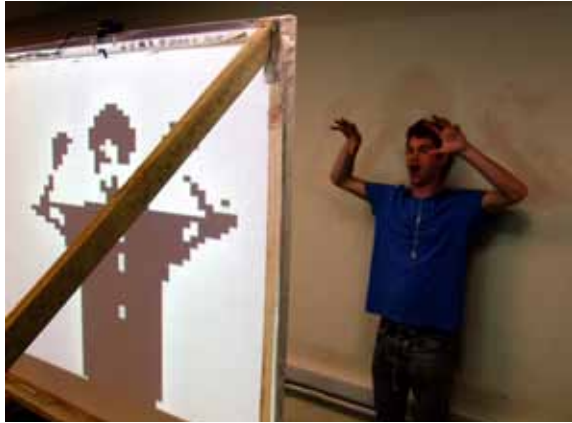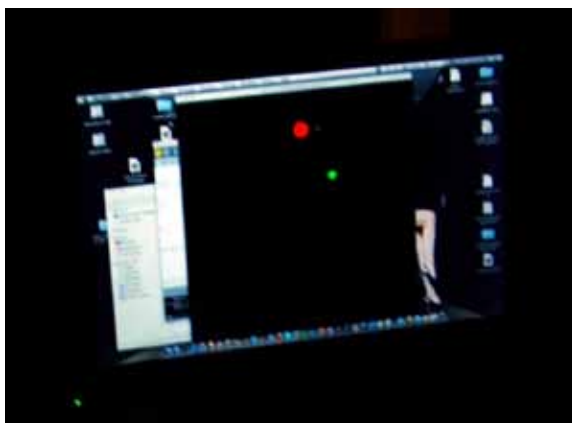
Fig. 1. **Eight-Bit Mirror (top) and Deimous (bottom).**

abstract entities; some took the notion of playful interaction in the direction of action games, some moved towards artistic reflection.

## 2 Eight-Bit Mirror

The Eight-Bit Mirror installation (Fig. 1) is an interactive mirror, inviting passing people to interact playfully with its representation. It mixes recordings and live view, and it shows a roughly pixelated image in black and white, similar to [4], [5] and [6].

The installation was inspired by J.J. Gibson's studies in the field of visual perception and aims at creating a visual instigator to prompt moments of instinctual reaction in the visitor. 'The original idea came from observing both animals and infants' reactions to mirrors. [...] Reflections and mirrors are often met with a raw curiosity, and perhaps in some cases a mild alarm.'2 The Eight-Bit Mirror attempts to create a visual anomaly 'to examine, experiment, or provide insight into overall visual behaviours'. It is something like a magic mirror, that augments or diminishes what it sees and reflects. It creates 'a sort of alternate universe in which the projection is still a mirror image of the person[s] interacting with the installation, but it does not behave as an everyday mirror image is expected to'. The software reads the visitors' silhouettes for a few seconds and makes 'the projection behave in anomalous ways by rewinding, fast-forwarding, and flipping it in the vertical plane'. The distortions are comprehensible enough that the visitors recognise their silhouettes but are piqued in their curiosity as to just what the mirror image is doing next.

## 3 Deimous

The Deimous installation (Fig. 1) was conceived to induce fear and manage an interactive experience through sound alone. It is about fighting creepy creatures in a dark room. The creatures make noise as they approach the player, and the player slashes them by waving a plastic meat cleaver at their position in space. Having only sound as a means to perceive the environment around him, the player is made acutely aware of this sense and transforms his or her reception of the surroundings during and even after the experience. A 5.1 surround sound system is used to play sounds triggered by MaxMSP on different speakers/at different locations around the player. Constant background noises create an ambient sound environment 'that
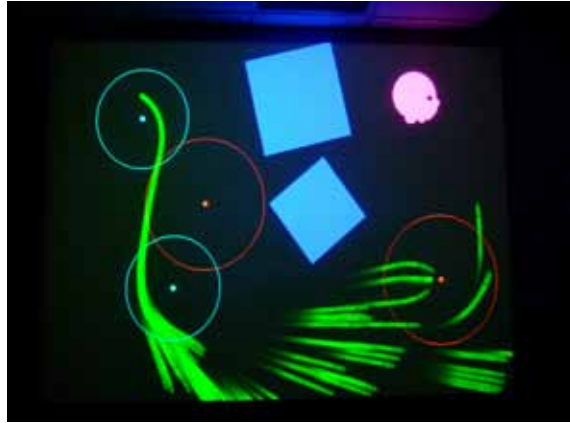
stimulates emotional reactions of fear'. The enemies have no definite entity, although the sounds draw on conventions of horror movies. By not knowing what or who exactly the enemy is, a sense of the unknown is established – a key concept in creating fear. To make the experience more challenging and interesting, the player needs to learn to differentiate between bad and good sounds. While the creatures sound "bad", health packs emit 'good' sounds, which the player needs to locate and collect.

## 4 [sol]

The [sol] installation (Fig. 2) invites collaboration between strangers who share a space. A stream of virtual particles is to be directed from emitters around obstacles to receivers. People attract particles and deflect their course by their bodily presence and movement. This work is intended as a large top-down projection.

It was inspired by the Beacon installation [7] and by the AntiVJ installations [8] which both use technology to build interactive live performances. Patterns of struggle for leadership and collaborative teamwork are erupting. [sol] focuses 'less on the relationship between the player and the game world, but more on the inter-relationship between the players'. The interaction in the virtual space is influenced by and influences the real-world interaction of the actual people. To provide for an easy entry and smooth immersion of the players, the installation is not using any physical interaction devices, 'save for the bodily interaction of being in the space'. A Microsoft Kinect is used to scan the space for participants' locations.

## 5 Box Me Dumb Human

In the Box Me Dumb Human installation (Fig. 2), a large leather bunny puppet with red glowing eyes (a boxing bag for now) is boxed by the player, while insulting/motivating him with arguments taken from the AI debate. The player is in a way fighting for all that is good about humanity, what distinguishes it from abstract mechanism, and he is fighting against the machine or system.
The puppet announces to the player the next boxing hit (i.e. jab, straight, hook) to be executed to a specific position, and the player has to react as fast as possible. The order is fixed and makes sense boxing-wise. Each round is 60 seconds long. If the player stops hitting the puppet or is too slow, it will start to insult him (e.g. 'Humans are slow', 'Humans are irrational', 'Fight like a man', 'The machines will win'). After each hit the puppet reacts (e.g. 'Uff', 'Ahh', 'That wouldn't stop me from telling what I know') and then announces the next hit (e.g. 'Right cross to face'). The computer voice is recorded with the Amiga's standard speech tool, which has the classic monotone pronunciation that marked computer speech for a long time. After the match is over, a photograph is taken for the high score list. Instead of pushing an OK button the player hits (i.e. boxes) the robot rabbit on the nose.
The installation is intended as a contribution to the debate that is coming to the front every few years about being able to construct intelligent machines. It draws on Norman White's Helpless Robot [9], being a playful comment on the often uneasy relationships between machines and people, taking the everyday struggles with e.g. telephone answering systems, ticket machines, network connections or computer applications to a visible, tangible level. Paradoxically, the conflict unfolds at the same time as the player/user/human is trying to do exactly what the machine is telling him.
In playing the game, the player takes sides, and fights

Fig. 2. [sol] (left and middle) and Box Me Dumb Human (right).

against the machine. This action can spark participants' reflection on what makes us human, and on the question if we are losing out to the system. The installation attempts to point out that living is not about abstract existence, reasoning, problem solving and sensory perception; but about bodily existence and lived experience; activities which are always connected to location and situation, and appropriating these (J. J. Gibson, e.g. [10]). Living is neither pre-planned [1] nor clear-cut, but creatively, associatively, initiatively moving on and creating meaning along the way. Being, experiencing, acting, reasoning, learning, understanding and making belongs together, naturally – how could we imagine otherwise? The dynamic process of having a world is intimately connected to concrete, direct and immediate practice. Acting in and experiencing the world (Debray, e.g. [11]), changing it, change oneself, being changed, experiencing time and space (Heidegger, e.g. [12]), living and dying, is making us human. Our bodies do not limit our being, but enable us to be. They are not only our vehicle or tool in the world, but we are our bodies (Merleau-Ponty, e.g. [13]), we are our actions, we are what we do, we are our opinions and emotions. Don't we feel so alive when we do certain things, or when we experience certain situations? When we are fully in-tune with our surroundings, with what is happening [14], with other people? Our being is movement, rhythm, tone, tension, relaxation, ambivalence, play, success, failure, trying, texture, material, images, dreams, love, chaos and structure. This is what we as humans are concerned with, what we thoroughly enjoy (and despise), and it's called life.

## 6  Conclusion

This article described installations that were produced in a course on tangible interaction. The aim of the course was to motivate students to connect pheno-menological ideas with their own work. While developing their practical projects, students were invited to uncover the underlying theories, to explore them on their own and to (re-) connect their findings to their practice. We attempted to establish a feedback loop of practical work and theoretical reasoning, in a natural way, a holistic approach.

The approach led to some strong results, although it appeared to be a common trend to avoid (artistic) risks, conflicts and controversial topics, and to default to quite conservative messages or meanings.

Little exploration into the unknown was conducted. In this respect, many works were interesting, while not being very provocative or experimental.

The course appears to have worked to get basic ideas of phenomenology across to students and awaken their interest. It identified the main protagonists, made them and their theories accessible, and showed the relevance of concepts of embodiment for students' practice. This led to a new perspective on the relationship of reasoning and action with relevance and consequences for interactive system design. Of course, the full potential of the approach has not been realised yet, but it was exciting to see the initial results in students' creative work.

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# Fluenci: The expression of expressing

## Abstract

In this paper, we discuss the design process of a breast pump which celebrates expressing as a natural, intimate and emotional experience. Through interviews with mothers and breastfeeding experts, the psychological and physiological factors which may inhibit or stimulate the milk let-down reflex were identified. Based on this information, a concept called Fluenci was developed which, in its interaction and behavior, mimics many of the stimulating triggers provided by a baby. In an evaluation of an experience prototype of this concept, users preferred Fluenci over a conventional breast pump both on a pragmatic and a hedonic level. We discuss our design rationale in which the product's functionality benefits from anthropomorphic interaction and behavior yet does not result in a potentially disturbing anthropomorphic product appearance. Lastly we propose an additional form of anthropomorphism, Embodied Anthropomorphic Form, which invites the user to engage with a product as if it were human. Keywords. Expressing, anthropomorphism, product behavior, prototyping, interaction design, product design.

## 1  Introduction

Especially in Western culture, an increasing number of mothers start to combine employment and parenting within months after birth. The World Health Organization promotes mother milk as having benefits for both baby and mother [1]. However, breastfeeding during working hours is often not possible. Also, the mother and baby might not be physically able to breast feed. An alternative is expressing mother milk at work using a breast pump and feeding the baby the expressed milk. There is much room for improvement in the design of breast pumps, especially regarding the unpleasant experience mothers have while expressing. This paper describes the design process for a breast pump, in which we focused on the aesthetics of interaction and took the intimate experiential dimensions of normal breastfeeding as point of departure.

## 2  Inhibitors and Stimulants in Expressing

Seven mothers were interviewed on their experiences with expressing. The interviewees were asked to act out their expressing ritual and show the location and breast pump used. In addition, two lactation consultants provided expert knowledge on expressing. The interviews showed that the let-down reflex, which causes the ejection of milk, is influenced by a number of interdependent physiological and psychological factors.

### 2.1 Inhibitors

Oxytocine, the hormone that triggers the let-down reflex, and adrenaline, the hormone associated with fear and pain, are antagonists [2]. Discomfort and anxiety therefore inhibit lactation. Sources of discomfort can include work-related stress and suboptimal expressing tools. Most mothers indicated that they 'feel like a

cow' during expressing and described the experience as a very 'mechanical', even degrading ritual (figure 1). Sources of anxiety include a lack of privacy: many work places lack a breastfeeding room and mothers fear that colleagues will see them partially unclothed and expressing. Secondly, fear of not being able to express can lead to a vicious circle.



**Fig. 1. Illustration of mother using a breast pump at work.**

### 2.2 Stimulants

Whilst the primary stimulant for the let-down reflex is the suckling on the nipple and areola, the mother seeing, hearing and smelling the baby and feeling its warmth and trampling also contribute to the reflex. To mimic these stimuli during expressing, mothers use warm compresses, massage their breasts and rely on simulated 'triggers' from their baby. For example, mothers may look at photos or videos of their baby, listen to recordings of its sounds or bring pieces of clothing that carry its smell. These stimuli help to mentally visualize the baby and provide a conditioned trigger for the let-down reflex [3], [4].

### 3  Benchmarking Existing Expressing Methods

There are several ways to express milk. The simplest way is through massaging the breast with the hands. This method requires quite some practice and can be physically heavy. Therefore mechanical devices were developed: manual breast pumps. Breast pumps are designed to imitate the physical suckling of the baby on the nipple. Such manual breast pumps (figure 2a) are usually powered by squeezing a handle. Though manual pumps are quiet and relatively cheap, their use can be

tiring. Electric breast pumps (figures 2b & 2c) provide suction using a (separate) motor. The efficacy of electric pumps is higher than that of the manually operated ones, but the electric pumps are more expensive, larger, noisier and require a connection to a power socket or regular charging.

Current pumps address expressing on physical level but do not provide additional emotional or physiological triggers. On the contrary, the interviews revealed that the users related both product appearance and sound to cow milking equipment. The interaction is strongly machine-like in feel, with controls that are difficult to operate or even out of reach when holding the pump.



**Fig. 2a. Hand pump.**　　**Fig. 2b. Electric pump.**



**Fig. 2c. Double electric pump.**

### 4  Concept Design

Based on interviews with mothers and experts, a breast pump concept called Fluenci was developed and built (figure 3). The interaction with Fluenci was designed to be evocative of breastfeeding a baby and to avoid the machine-like connotations of traditional breast pumps. Fluenci features automated, baby-like behavior which eliminates the need for physical controls, contributing to a calm, object-like appearance.

**Fig. 3. The handheld part of the breast pump. Note the thermofoil wires in the breastshield and the circular tapping area.**

## 4.1 Baby-like Interaction

The interaction with Fluenci mimics many of the sensorial triggers provided by a baby. When the user holds Fluenci's soft, organic shape, her posture and gesture resemble the cradling of the back of a baby's head. The product's form contributes to reducing anxiety by hiding the nipple and most of the breast from view, thus providing privacy from incidental glances. Through electric thermofoils, the breast-shield is heated to body temperature, which widens the mammary ducts – thus stimulating the let-down reflex [5]. Similarly the back of the unit is heated to simulate the warmth of a baby's head. A digital sound recorder allows mothers to record and playback their baby's sounds or listen to music that they also listened to during breastfeeding, thus triggering conditioned reflexes. The baby's sounds are played back from the handheld pump, nearby and directed solely to the mother. Since the music supports creating a more ambient atmosphere, it is played from the base unit which houses the pump motor, which is more distant, both physically as well as psychologically.
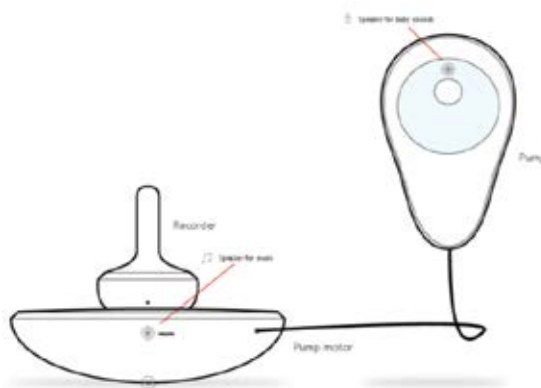


**Fig. 4. System overview: recorder, pump motor and breast pump.**

## 4.2 Baby-Like Behavior

Fluenci starts pumping when the breast shield is placed correctly on the breast and stops when it is moved away. This behavior resembles that of the baby (figure 5). Fluenci's milk flow sensor allows it to mimic a baby's changes in suckling frequency. A baby starts with suckling quickly and superficially to stimulate the let-down reflex. Once the milk starts flowing, the baby's suckling slows down as it drinks the milk. Similarly, Fluenci starts pumping stronger and at a lower frequency once it detects the flow of milk (figure 6). This optimizes the milk production and minimizes the chance of sore nipples. In case the mother wishes to override this automated process, a touch sensor on the product allows the mother to determine the pumping speed through three taps in the desired frequency, without having to reach over to the pump unit.



**Fig. 5a. Pump switches on when placed on breast.**
**Fig. 5b. Pump switches off when removed from breast.**



**Fig. 6. The frequency and amplitude of the pump automatically change after the let down reflex has been detected.**

## 5 Experience Prototyping

Experience prototyping was an essential element during the iterative design process. Initially, low-fi wooden prototypes with an integrated speaker were made, which could play sounds from an mp3 player. These were used to get feedback from the users in the first concepts.



**Fig. 7. User with one of the low-fi prototypes combining basic electronics and Phidgets within a housing of laser cut MDF.**
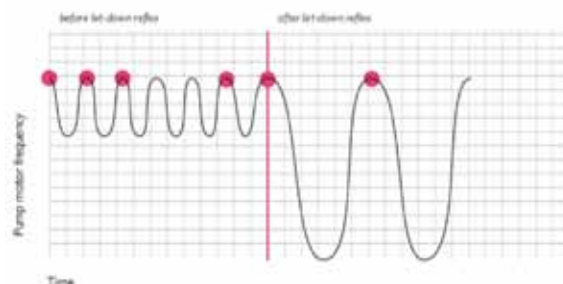
The final prototype was fully functional, including an Arduino prototyping board, speakers, sensors, heating elements and a 'hacked' Avent breast pump, all programmed in Cycling74's MaxMSP software. The final model was 3D printed. For hygiene reasons, the prototype could not be used to express milk.



**Fig. 8. Making the final prototype, using McNeel's Rhino 3D modelling software, 3D printing, an Arduino microcontroller board and Cycling74's MaxMSP programming environment.**

## 6 Concept Evaluation

Six mothers were asked to compare the final Fluenci experience prototype against a traditional, high-end electric breast pump (figure 10). Both pumps were preassembled and accompanied by custom-made quick-starting guides. The participants were asked to



**Fig. 9. Part of the final prototype.**

act out the expressing ritual – evoking a 'let-down reflex', adjusting the pump frequency, and so on, after which they ranked the pumps using AttrakDiff semantic differential scales [6]. The results (figure 11) indicate that Fluenci is rated higher than a traditional electric pump, both in terms of pragmatic and hedonic quality. On a side note, the Fluenci concept is rated as more isolating (as opposed to connected), which influences the hedonic identity dimension negatively, though actually 'isolation' can be a positive attribute since it might indicate that Fluenci provides privacy.
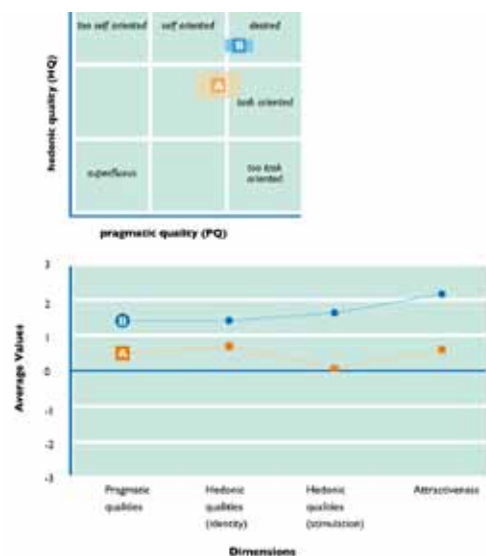


**Fig. 11. AttrakDiff results, A is the Avent pump, B is the Fluenci pump.**

**Fig.** 10. **Concept evaluation with end users and prototype.**

Semi-structured interviews confirmed the positive outcome of the AttrakDiff test. The way of holding Fluenci, the warmth and the optional playback of sounds were much appreciated. Aspects which received criticism were the dimensions of the milk bottle which should be increased to allow capturing more milk and the control of the pump frequency which should be more precise and direct.

## 7  Discussion of Semantic Considerations

A breast pump is an intimate product of which the functionality is strongly influenced by its look and feel. How the user feels she is perceived by the outside world and the feel of the product's interaction and behavior have a direct psychological and physiological influence on its core functionality: the stimulation of the let-down reflex. Here semantics are not limited to the product's appearance in isolation but include the user-product interaction.

The central semantic question in the design of Fluenci was to which extent the product should be anthropomorphic. Anthropomorphism is defined as the attribution of human-like qualities to inanimate objects or animals [7]. They focus on a part of anthropomorphism, which they call 'Anthropomorphic Form': the imitation of human form by designers as manifested in the objects they create – be it static or dynamic. DiSalvo et al. define four kinds of anthropomorphic forms:

1. Structural (imitating the appearance or functioning of the human body with a focus on its materiality)

2. Gestural (imitating the ways people communicate with and through the human body with a focus on human behavior)

3. Aware (imitating the traits, roles or functions of people as a social role)

4. Anthropomorphic Form of Character (imitating the common human capacity for thought, intentionality, or inquiry).

Due to Fluenci's multi-sensorial nature, it is interesting to see how it can be positioned in their framework. In general, Fluenci can be seen as an Anthropomorphic Form of Character. The playback of baby sounds, the suckling behavior and responsiveness to the user are expressive of a 'needing-role'. Fluenci's size, human-like warmth and organic 'neck-like' curvature invite it to be cradled. The pump hereby not only defines its own role, but potentially also changes the (self) image of the mother in her social context.

The suckling of Fluenci would be Gestural Anthropomorphic Form – the suckling can be seen as motions that suggest human action. The suckling behavior contains elements of Aware Anthropomorphic Forms as well – Fluenci seems to be aware of being held to the breast and attentively adapts the suckling rhythm to the milk supply from the mother, memorizing the favorite settings. This behaviour suggests intelligence and thereby minimizes the feeling of operating a machine. The warmth Fluenci gives can be seen as an example of Structural Anthropomorphic Form; it imitates the warmth of a human body, resulting from its 'operation'.

The warmth relaxes the milk ducts and provides comfort when holding it against unclothed skin, hereby stimulating the let-down reflex.

It is difficult to position Fluenci in DiSalvo's framework when focusing on its form. Fluenci's form is not Aware Anthropomorphic, since it does not express consciousness or awareness. It is not an Anthropomorphic Form of Character, because it does not per se display qualities or habits that define a role like a baby. Fluenci's form is not recognizable as an imitation of the appearance of a baby's head (structural anthropomorphism). A breast pump with the looks of a real baby would project a bizarre, possibly even disturbing image, the so-called uncanny valley effect [8]. Similarly, a breast pump with a video screen showing the baby's face would turn the product into a robotic piece of machinery. Gestural Anthropomorphic Form is using motions or poses that suggest human action to express meaning, but the emphasis is on actions performed by the anthropomorphic object – not on the actions from the user of the object.

Therefore we suggest a fifth kind: Embodied Anthropomorphic Form. Though the product itself does not visually resemble (parts of) a human body, its design invites the user to interact with it as if it were human. Hereby the meaning arises from the (inter)action with the product, both in physical and in social terms. In the case of Fluenci, its shape affords to be held by the mother in a particular, cradling manner. Once the mother holds Fluenci in this way, the similarity to feeding a baby can be experienced.

## 8  Conclusion

We set out to design a breast pump that would make expressing a more enjoyable experience for the mother, by restoring the mother's intimate multi-sensorial engagement during expressing and triggering her instinctive milk reflex. Our evaluation of Fluenci shows that we made considerable improvements compared to existing breast pumps. Instrumental for the final result was the iterative, hands-on design process and focus on the interaction experience, making use of anthropomorphic form that goes beyond simple product appearance, entering the realm of embodied interaction.

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# Fictional emotions within emotion driven design

## Abstract

The aim of this paper is to address imaginative experiences of emotions by drawing Kendall Walton's theory of make-believe. Moreover, we use a design case as means for investigating how a child's felt emotions towards a hospital situation relates to his or her imaginative experiences of emotions towards a fictive character in a computer game simulating the real-world situation. In so doing, we contribute with new insights to existing theories of emotions in design, which tend to focus narrowly on felt and measurable emotions.

## Keywords

Fictional Emotion, Emotion Driven Design, Interaction design

## 1  Introduction

Theories of emotion's role in design have been successful in explaining many new levels of product meaning and product experience that until a few years ago were hardly understood [1], [2], [3]. However, a number of knowledge gaps inherent in these theories become evident when working with new modes of interaction and time-based experiences in game design. While theories of emotions offer exhaustive frameworks for describing how emotion driven design is able to elicit emotions, the questions as to how such emotions may change and evolve over time has only received little attention.

Secondly, theories of emotions in design have a tendency to focus too narrowly on the user's felt and sensed emotions, while the question of how imaginative experiences of emotion relates to an emotional state is left largely unaddressed.

The aim of this paper is to address imaginative experiences of emotions by drawing upon Kendall Walton's theory of make-believe [4]. More specifically, we will use a design case to investigate how a child's felt emotion (towards a hospital situation) relates to a child's imaginative experiences of emotion towards a fictive character in a computer game.

In this paper we will first introduce the notion of 'fictional emotions' as a new key concept in design research that accounts for how a persons felt emotions relate to a persons response to a fictional world. Secondly we will introduce our design case, which is using the design of an experimental computer game (called the Child Patient Game) designed especially for hospitalized children as research artefact. The purpose of the Child Patient game is to design a computer game environment that can map the subjective feelings felt by children being in hospital. Here we will look especially into the relation between Character Experience (that of the fictive character in the game) and Player experience (that of a Patient).

Thirdly we will explain the method of inquiry; the overall method of this project, which is built up from a research through design method [5], [6] as well as

the specific method of testing the Child Patient Game in a hospital environment. A part of this method has been to organize the data by using "visual mapping". Visual mapping is a way of structuring and organizing information to see patterns and relationships. Fourthly, we will take a deep look into the data that this inquiry has produced; how does a child's felt emotion (towards a real hospital situation) relate to persons imaginary experiences with a fictive character? How are these make-believe states of mind charged with emotions? Which ones are not charged with emotions? Can we get a more fine-grained understanding of how mental states of fictional emotions, imaginary experiences and make-believe states are expressed? Kendall Walton's make-believe theory will be used as a framework for analyzing the relation between an actual, felt emotion (referred to as "Real Emotion") and the emotions we have towards fictional characters (referred to as "Fictional Emotion").

Finally we will discuss the outcome of our findings and where this outcome will lead us. Here a position will be taken in the favour of narratives and gaming to be used as a communicative practice that might give us valuable knowledge and new insight about the emotional lives of paediatric patients. In doing so we will widen the perspective on emotion elicitation by adding fictional emotions to the prevailing emotion measurement paradigm.

## 2  Key Concept: Fictional Emotion

Within emotion research (theories on emotion) there is general agreement on that emotion implicates Feelings, Actions and Thought [7]. This means that emotions are body related (somatic) as well as rational, meaningful and logic (involves cognition).

Fictional emotion also implicates Feelings, Actions and Thought - but the stimuli is to be found within the fictional world: we can cry when we experience a sad movie wherein the character we sympathize with will die. Such an experiences belong to the game of make-believe according to Kendall Walton [4] and must be distinguished from emotions exposed during a real situation that we actually cannot escape, for instance a situation that involves the death of a real friend. Walton's make-believe theory is interesting because it deals with the question how "remote" are fictional worlds are from the real world? What is the role of imagination?

Kendall Walton presents the following well-known experiment in his article Fearing Fictions from 1978 [8, p.1]: Charles is watching a horror movie about a terrible green slime. He cringes in his seat as the slime oozes slowly but relentlessly over the earth destroying everything in its path.

Soon a greasy head emerges from the undulating mass, and two beady eyes roll around, finally fixing on the camera. The slime, picking up speed, oozes on a new course straight toward the viewers. Charles emits a shriek and clutches desperately at his chair. Afterwards, still shaken, Charles confesses that he was "terrified" of the slime. Was he?

According to Walton the answer is "No". To Walton, it is only "make-believe-kind-of" true - that we have feelings for certain characters in films, books or games. He agrees on that these characters can have a great affect upon us - and that fictional worlds and fictional characters move us both physically and psychologically and that the similarities to real fear, real sadness or real happiness are close – but regardless of what our body responses are or what we might say, think, or believe we are feeling towards a fictional character it is not a real emotion. It is a fictional emotion we are experiencing - also referred to as "quasi-emotions" [9].

Quasi-emotions are very similar to real emotions but still different because they are generated by "second-order" believes about what is fictionally true. Walton explains: "Charles believes (he knows) that make-believably the green slime is bearing down on him and he is in danger of being destroyed by it. His quasi-fear results from this belief" [8, p.14].

Proponents of the Theory of Make-believe suggest that our (quasi) emotional attitude towards the fictional are strong related to our real (genuine) emotional states, except that the make-belief overrides the role that would otherwise be occupied by belief. So Charles doesn't believe that the green slime is dangerous: He imagines or makes-believe that it is.

It is not our aim establish weather fictional emotions (and imaginary experiences) are equal to real emotions (and real experiences) since this depends on how we understand emotions. The aim of this paper is to investigate - through game design - how persons felt emotion (towards a specific situation) relates to the persons imaginary experiences with a fictive character (going through a similar situation).

## 2.1 Player Experience and Character Experience

When Children involve them selves in a game like for instance playing "mum and dad" they involve them selves in a game of make-believe (using Waltons expression). They decide the rules for their game; who is playing who, what kind of "mum" is in their game and what objects must act as props. They are pretending that a cartoon-box is their "house", that stones are "food "and they acts as players in a fictional world, playing out "mum" and "dad" in various imaginary scenarios - imitating the real world, seen from their perspective. It's "just" a game. We think.

In the design case presented in this paper, we also deal with children's responses to fiction and how they interact with that. It's both similar and very different from the example presented above. It's similar because we are inviting children to take part (as players) in a game of make-believe. And it's similar because it's a game that includes a fictional world and has certain rules. Its different because in our case they cannot make their own rules, the story is narrated in a way that the main character (an animated character) must undergo a fixed number of experiences. Its different because the children must play the game under certain circumstances, when they are not well at all; when they have just been undergoing and uncomfortable (emotional) medical examination. So we are asking them to take part in a game of make believe that involves a situation that they have just experienced them selves. That's why it makes sense to talk about what the character (a fictive child patient) is experiencing in the fictive world - and what the player (who's a patient in the real world) is experiencing while playing the game.

## 3  Design Case: The Child Patient Game (CPgame)

The Child Patient Game (CPgame) is an experimental computer game for hospitalized children (age 4 to 6). The purpose of the game is to design a computer game environment for young patients that can map emotional experiences - and hereby allow hospitalized children to inform staff and researchers about their emotional lives. The concept of the game is developed by designer / researcher Eva Knutz in cooperation with the children ward and research unit at Kolding Hospital. The design of the CPgame is strongly shaped by emotion theory, as described in an earlier paper [10].

## 3.1 The Design of the CPgame

The CPgame is about a young child's journey through a healthcare system. This child figure is the main character that the player (the patient) will follow and must control in the game. The player can attach certain Emotions to the child figure (fig.1) or give the child figure certain Secret Powers (fig.2) that can help him through unpleasant things, such as the blood test.



**Fig. 1. Screenshot from the CPgame: the player is applying the emotion "afraid" to the main figure. © Knutz 20**10.

The player must attach one out of five emotions: three negative, one positive and one less articulated (Angry, Afraid, Happy, Sad or Uncertain) that the player thinks fits to the child figure in the game. The emotions are visualized as five animated characters, with five different colours (fig. 1). This action of game play results in the continuation of the story. For instance, if the player attaches the emotion "anger" to the child figure in a particular situation, the child figure will act angry. If the player thinks that "sadness" is more appropriate, the player can change emotion. When the player has arrived at the "right" emotion, the game can continue.
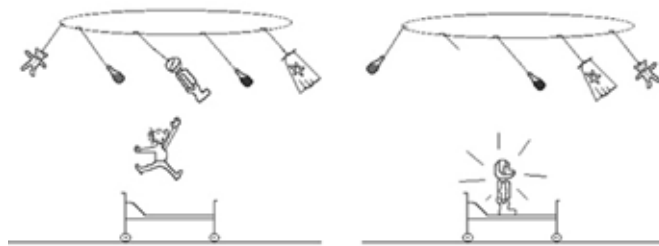


**Fig. 2. Screenshot from the CPgame: Catching a "Secret Power" © Knutz 20**10.

The "Secret Powers" consist of five different objects that the player can catch (fig.2) before going into the fictitious blood test. If an object is caught, the "Power" becomes visible: A teddy bear that the child figure can hug; an iron armour that the child figure can wear; a magic cape that makes the child figure invisible; a bottle of light liquid that makes the child figure shrink when he drinks it; and a bottle of dark liquid that makes the child figure grow up when he drinks it.

When the player has caught the Secret Power, that he or she think will help the child figure the best, the game can continue with that particular power attached to the game story. So the child figure keeps the secret power in the narrative sequence that follows. All choices of the player are stored in a database, fixing the players pattern of choices (of emotions and secret powers) throughout the game.

## 3.2 Game World, Game Story, Rules and Players

Fictional Worlds (in books, films or games) are by definition incomplete because it is not possible to specify all the details about any world [11]. This is where the player comes in; the player transmits his or her intentions into the game world. The sequence of action that unfolds in a game occurs as a result of the player's interaction with the game. Since it is a game - and not just a story - the fictional world represented in a game cannot function without the rules [11].

The way the player transmits her intentions into the game world is through gameplay. The gameplay lays down the rules for the player's interaction with the game world and the game story. Understanding the gameplay, is understanding the pattern you need to play with in order to perceive the fictional world of the game as a whole. A fictional world that can be described through the concepts of:

• Game World: An imagined world, inhabited with fictive characters (objects, sound);
• Game Story: A sequence of events within the game world containing beginning, middle, end;
• Rules: What the player "must do" in the Game world, constituted through gameplay;
• Players: Who are imagining the fictional world, interacts with game, make choices.

If we drop these concepts upon our case - the CPgame - we have a fictional world that (schematic) can been described as:

• Game World: The universe of a hospital, experienced by the main character: a child patient;
• Game Story: The journey of a child patient (a fictive costumer) going through a fictive healthcare system, with several events taking place over time: the child is sick (begin of game)    the child (now a patient) gets treatment (middle)    the child becomes well again (end of game);
• Rules: The player must control the child character, lead him through the hospital and must attach "emotions" and "secret powers" to the child patient (during his journey) that the player feels must be the right ones;
• Players: Hospitalized children who are in the middle of a similar "journey".

## 3.3 Player Experience and Character Experience in relation to CPgame

The game is build up that way that the main character (the child figure) must go through certain experiences; he will become sick, he must overnight at the hospital, he will be treated and he will become well again (Character Experience). But it is also a game that allows the player to interact with the game world, through gameplay (Player Experience). Table 3 explains the Character Experience and the Player Experience in relation to the CPgame.

| Character Experience | Player Experience |
| --- | --- |
| The main character (a child figure) is at home; he becomes ill and is brought to the hospital by his parents. Here different things are happening to him; he is being treated (examined, measured, having a blood test) and he has to spend the night in the hospital (where he falls into a strange dream). When he wakes up, he feels well again and can be brought back home. It's like a 24-hour circle story, where the end is connected to the beginning. | During this journey (the stay at the hospital) the player must attach "emotions" and "secret powers" to the child figure, that the player feels must be the right ones (the emotions) or the ones that can help the child figure the best way (the secret powers). The game is build up so that that it increasingly becomes more difficult and challenging and that the player slowly gets more control over the main character. What the player does in the game and the way he interacts with the game (the choices he makes in the game, the movement of his play pattern) will form his Player Experience. |

**Table** 1. **Character Experience and Player Experience in relation to the CPgame.**

In the next section of this paper, we will take a closer look at how the players (children patients) interact with the Child Patient game. We are investigating how persons felt emotion (towards a real hospital situation) relates to the persons imaginary experiences with a fictive character (experiencing a fictive hospital situation). For the sake of clarity, let us define all experiences, before we move on:

- Character Experience: What the character (a fictive child patient) is experiencing in the fictional world (of the CPgame)
- Player Experience: What the player (a child patient) is experiencing while playing (the CPgame)
- Real Emotion: Emotional Experience towards a real situation.
- Fictional Emotion: Emotional Experience towards a fictional situation.

## 4 The Method: Using Game Design as a Method for Exploring the Relation between Real Emotion and Fictional Emotion

In this section we will explain the method of inquiry; how the CPgame has been tested and how real emotion and fictional emotions are mapped into so-called "CPcards". But since the argument of the paper is built up from a research through design method [5], [6], [12] this need to be explained briefly.

### 4.1 Overall method: Research Through Design
This research project has been undergoing two Experiments: First of all a computer game has been designed that allow hospitalized children to inform staff and researchers about their emotional experience (Experiment 1) as explained in the previous chapter. Secondly, the computer game has been tested upon a group of patients and non-patients, using the game as an alternative method of inquiry (Experiment 2). In the next section we will focus on the second experiment.

### 4.2 Specific method: Using the CPgame as an alternative method of inquiry
The CPgame was tested at the children's ward of Kolding Hospital from February 2011 until October 2011. The overall scope of Experiment 2 was to account for relation between Real Emotions (expressed by

the child during hospitalization) and Fictional Emotion (expressed by the child during gaming). This is done by letting a group of 12 patients (aged four to six) play the CPgame, right after having had a blood test. During the blood test, the emotional states of the patients were observed by staff, parents and researcher. The staff were asked to observe the bodily states of the patients, the parents were asked to judge the emotional state (of their own children) and the researcher observed more general issues, such as moods and attitudes. Immediately after the blood test the game session took place. During the game session the patients had a "game-dialog" with the researcher while playing the CPgame. In these dialogs the researcher would ask about the choices that the patients made in the game. For instance if a child attached "sadness" to the child-figure in the game, the researcher would ask "Why is the child figure sad?". In the game dialogs, child and researcher stayed within imaginary world of the game and the researcher was observing as well as asking questions. During the game session, the play pattern of the players were obtained within the database of the CPgame. The table below shows how the different sources of data, collected during the experiment, addresses particular aspects of emotion - or aspects of the imaginative experiences of emotions.

| Observations forms, filled in by staff | Emotional state / body evoked feelings. The staff's observation of body states and behaviour during blood test. How do the children feel during blood test? Which emotions are involved? | Real Emotions |
|---|---|---|
| Ratings systems, filled in by parents | Emotional state / appraisals. The parent's judgement of their children's emotional state during blood test. How do the children feel during blood test? Which emotions are involved? | Real Emotions |
| Database of CPgame | Play pattern. Which secret powers do they choose in the CPgame? Do they choose emotions and secret powers directly or play around for long? | Fictional emotion or Imaginative Experiences expressed through play |
| Game-Dialogs, between researcher and child | Motivation and play behaviour How do the children play? What do they say about their choices in the CPgame. | Fictional emotion or Imaginative Experiences expressed through verbal or non-verbal accounts. |

**Table 2. Shows how different sources of data address particular aspects of emotion.**

### 4.3 Control Group of Non-patients

The experiment involved a control group of non-patients. Here a group of children (aged four to six) were chosen from a kindergarten, matching age and gender. These children all played the CPgame in a separate office of a kindergarten. Obviously, the control group did not undergo any medical procedures they simply just played the CPgame and were involved in a game-dialog under same conditions as the patients.

### 4.4 Discussion of Inquiry (Experiment 2)

Experiment 2 was aiming at collecting knowledge from different sources at the same time; sources that supported the emotional aspects as well as the narrative and imaginary aspects of a hospital experience. This is not an easy task. An hospital experience involves many sorts of experiences; the children must be away from home, they must sleep in strange place, eat at certain hours, they are being examined and tested and must undergo treatment in various forms (medicine, scanning, operations etc.). In consultation with the research group at Kolding Hospital, we chose from the beginning to deal with a specific experience that all children patients must go through; the blood test. So we chose to put emphasis on the blood test in the CPgame - and let the blood test play a particular role in the testing of the CPgame.

It is a non-linear method that makes it easier to see patterns, relationships, hierarchies and dependencies that might otherwise remain hidden.

The data was filtered before it was mapped: the ratings from the parents and the observations from the staff was colour-coded to show if there was a relation between the real (actual, felt) emotion and play-pattern (the children's choices of emotion obtained in the game database). Furthermore the recordings and notations from the game-dialogs were transcribed to include only verbal expressions and catch words, representing each respondent's imaginative experiences or play behaviour. After organizing all data from both groups the data was mapped into so called CPcards, representing each player of the CPgame.

Figure 9 represents the visual mapping of information of a patient into a CPcard:

The cards are divided into a left side, representing the real emotions - and a right side representing the fictional emotions. In the middle of the card we have the player of the CPgame. The colour indicates if there is a link between the emotions observed and rated by staff/parents (left side) and the emotions chosen by the player in the game (right side).



Fig. 5. The Child Patient during testing © Knutz 2011.

### 4.5 Organizing the Data through Visual Mapping

After the testing of the CPgame all information, from rating system (made by parents), from observation (made by staff), from game dialogs (between researcher and children), and from the database (of CPgame) - were organized into a large visual map. Visual mapping is a way of structuring, organizing, arranging information.
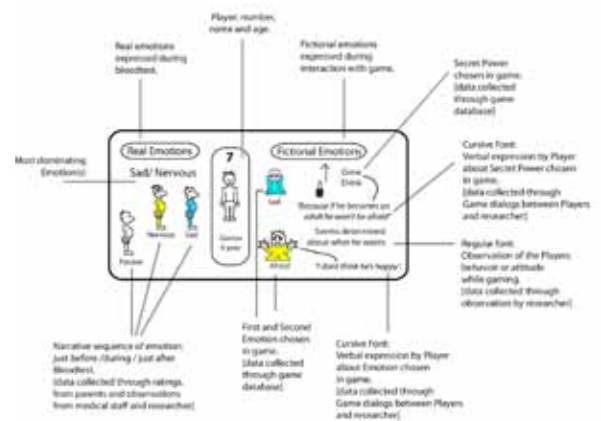


Fig. 9. Visual mapping of information into CP card. © Knutz 2011.

The CPcard above gives us information about the patient "Gustav". The card tells us that Gustav's emotional state during the blood test (left side of card) evolved in sequence that can be described as Passive (just before blood test) to Nervous (during blood test) and to Sad (right after blood test). The right side of the

card tells us that Gustav first gave the child figure the emotion "Sad" when the child figure (in the game) was hospitalized. Later in the game (when the child figure, had to have a blood test) Gustav attached the emotion "Afraid". In order to give the child figure a "secret power" before the blood test, Gustav gave the figure a "grow-drink" and Gustav explained that the reason for giving the figure such a power was: "because if he becomes an adult he wont be afraid" (quote Gustav, CPcard right side, fig. 9).

Gustav also verbally expressed the reason for choosing "afraid" as fitting for the child figure in the CPgame: "I don't think he is happy" (quote Gustav, CPcard right corner below, fig.9).

For every player a CPcard has been made. This gives us a visual framework of how persons felt emotion (towards a real hospital situation) relates to the persons imaginary experiences with a fictive character (experiencing a fictive hospital situation). The CPcards also gives us information about how emotions may change and evolve over time.

## 5 Outcome and Discussion: Exploring the Relation between Real Emotion and Fictional Emotion

Figures 10 and 11 gives us a picture of how patients and non-patients (the control group) chose emotions and secret powers within the CPgame.

### 5.1 Explaining Player Choices

Figure 10 tells us that not a single non-patient chose a positive emotion, where as the positive emotions were chosen several times by the patients.

Figure 11 tells us that eight out of the twelve non-patients chose the teddy bear, where as only four of the patients chose the bear. This is interesting since it is only the (teddy) bear that actually belongs to the real world (some of the patients do actually bring their teddies) whereas the other powers (becoming invisible, wearing an amour or growing big or small) truly belong to the world of fiction. We will speculate on that in the discussion section. For now we can just conclude that the 12 patients played the CPgame rather differently than the 12 non-patients, who functioned as a control group.

Figure 12 gives an overview of all the CPcards drawn from each patient playing the CPgame during the
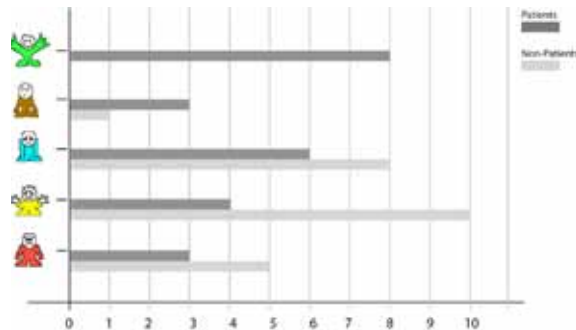


Fig. 10. Relation between choice of "Emotion" (Angry, Afraid, Sad, Uncertain and Happy) chosen by Patients and Non-Patients in the CPgame. © Knutz 2011.
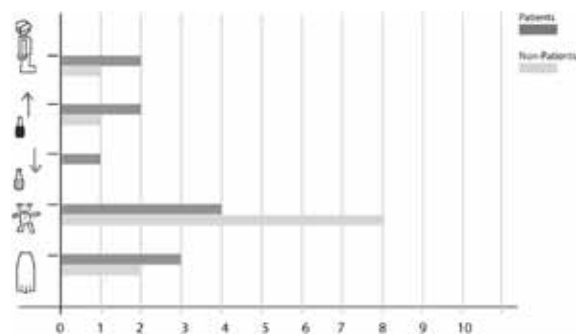


Fig. 11. Relation between choice of "Secret Power" (Cape, Bear, Shrink-Drink, Grow-Drink, and Armour) chosen by Patients and Non-Patients in the CPgame. © Knutz 2011.

experimental game test. The 12 cards are organized in such way that the children who felt most anxious, insecure or uncomfortable during the blood test are placed at first (number 1) and the patients feeling at least anxious are placed at last (number 12).

The CPcards (Fig. 12) reveals several insights in relation to the "the real" and "the fictional" world making. First of all, if we look at the second emotion (below, at the right side if the card) which is the emotion that the player attach to the fictitious child patient during the fictitious blood test - we can see that 7 of the 12 players (player no. 2, 3, 7 8, 9, 11, 12) chose an emotion very similar to the real emotion (left side of the card). That will say, in most cases the children's own (real) emotion is close to the emotion the children think the fictional child patient "must feel". This is particularly the case when we look at the two (only) players, Player 11 and 12, who exposed a mainly positive sequence of real emotions during the blood test session; they expressed
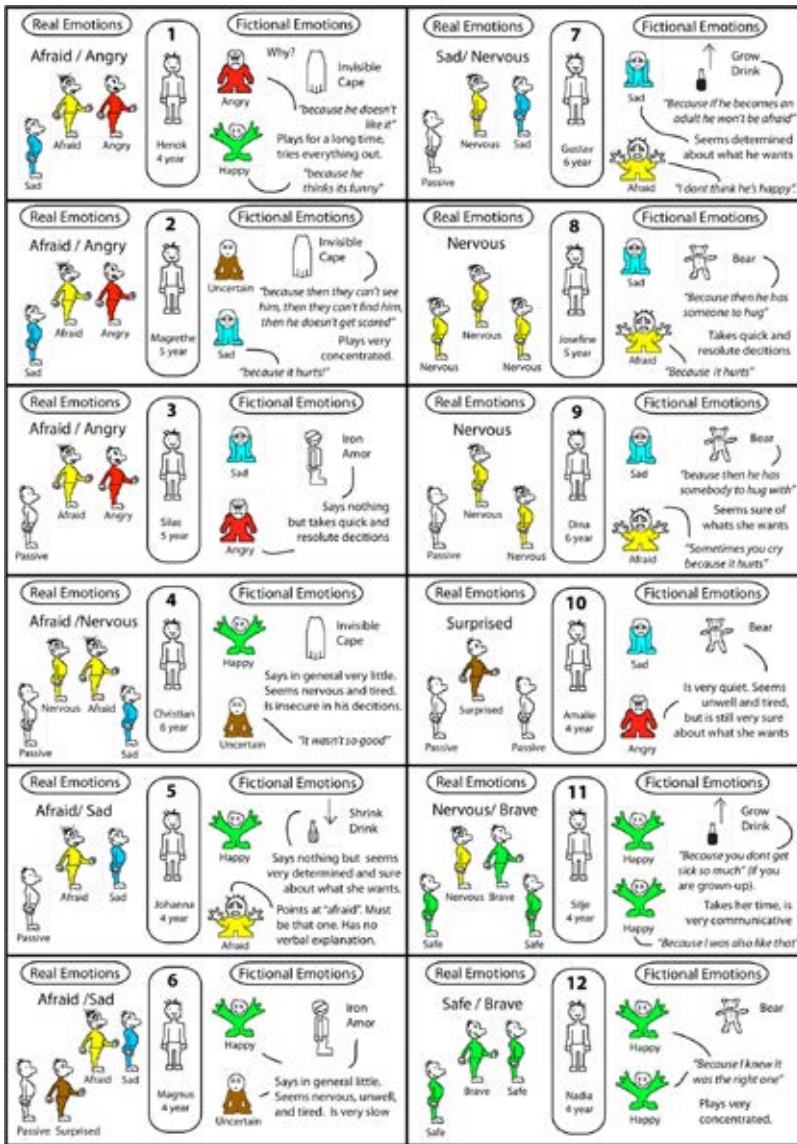
Fig. 12. CPcards of all patients (seven girls, five boys) playing the CPgame. © Knutz 2011.

both positive emotions within the real world and choose only positive emotions as fitting to the fictional character in the game world.

What is significant, is that 6 of these 7 players (player: 2, 7, 8, 9, 11 and 12) were able to verbalize and motivate their imaginative experiences of why the child figure in the game needed a specific Secret Power; Like player 8 and 9 (who both seemed very self assured about there choices) - both chose the bear "because then he has someone to hug". Player 2 (who choose Invisible Cape) motivates her choice with saying; "because then they can't see him, then they can't find him, then he doesn't get scared". Player 7 chose Grow-Drink "because if he becomes an adult he wont be afraid". Player 11 also chose the Grow-Drink, but here the imaginative experience is different. Player 11 chose the Grow-drink because "then you don't get sick so much" (if you are an adult). These experiences says clearly something about the children's emotions on a narrative and imaginative level; thinking that in the future, when you grow up, you won't be afraid anymore, or get sick.

If we look at the remaining five players that chose fictional emotions, a bit more remote to their real

emotions (player: 1, 4, 5, 6, and 10) then it is as if we have a different set of players: These Players have in general very little to say. They were very willing to play the game, but were difficult to get in contact with during the game dialogs. Player 4, 5 and 6 had a similar pattern - both in having the same narrative sequence of real emotions (Passive-Afraid-Sad), and they all choose the positive emotion as the first emotion: so they believed that fictional child patient felt happy in the beginning of the game (arriving at the hospital and being hospitalized)

When it comes to the second emotion (the emotion related to the fictional blood test), this group of children all chose an emotion in the game, close to their real emotion: Player 5 choose (in a self assured manner) the emotion "afraid"; an emotion identical to the real emotion he felt during the blood test. Player 4 and 6 chose "uncertain"; an emotion a bit remote from their real emotion during the blood test but similar to their play behaviour (being uncertain and insecure about playing the game).

Player 1 and 10 both chose fictional emotions, very remote to their real emotions. Player 1 expressed a high degree of anger and fear during the real blood test, but still chose "happy" as the emotion fitting best to the character in the game, when he had to go the through the fictitious blood test. When I asked him why, he said, "Because he thinks its funny". Player 1 played the CPgame for the longest time of all. He tried all emotions and secret powers out many times - and kept on choosing the positive emotion in relation to the fictional blood test. Did he want the animation figure to be happy? We will discuss that in the next section.

Player 10 seemed calm about the blood test and had no objection towards medical procedures. Player 10's narrative sequence of real emotions is described as: Passive in the beginning then surprised during the blood test, and hereafter passive again. But the play-pattern at the left side of the card reveals some quite different emotions towards the fictional situation of the hospitalization and the blood test: Sadness, Anger and a Secret Power in the form of a teddy bear. Also this we will discuss in the next section

We can - on the basis of the CPcards - sketch out a more detailed picture of how a young person's felt emotion (towards a real hospital situation) relates to the persons imaginary experiences with a fictive character (experiencing a fictive hospital situation).

Player type A:
Fictional emotion relates to Real emotion
(player no. 2, 3, 7, 8, 9, 11 and 12)
Characteristics: Fictional emotion relates strongly
to Real emotion. The players can express their
imaginative experiences verbally.

Player type B:
Fictional emotion partly relates to Real emotion
(player no. 4, 5 and 6)
Characteristics: Fictional emotions are different
from their real emotions, but not entirely remote.
The players can't (or won't) express their imaginative
experiences verbally. Only through gaming.

Player type C:
Fictional emotion is very remote to Real emotion
(player no. 1 and 10).
Characteristics: Fictional emotions are completely
different from their real emotions. The players can't
(or won't) express their imaginative experiences
verbally. Only through gaming.

## 5.2 Discussions of Findings

Why does only the patients (and not the control group)
choose positive emotions in the game world?? Why
does some patients, who are clearly very distressed
about the blood test insist on giving the animation figure
a positive emotion? Why do the CPcards sometimes
reveals two different emotional worlds, as was the case
with Player type C?
To understand this we have to return to the central idea
of seeing "emotions" and "secret powers" in the game
world, as a set of reactions that the player can apply to
the animation figure "as if they where him". This might
explain, why its only the patients who wants the little
figure in the game "to be happy" - and not the children
who are not hospitalized; the CPgame may offer the
patient opportunities for communicating and modulating
its emotions by playing with fictional characters, finding
themselves in a "as-if scenario" similar to that of the
patients own situation.
So even though a child, who feels insecure about the
hospital treatment, chooses positive emotions in the
CPgame, they are just as important because it indicates
that the Player Experience may act as a (positive)
modulation process to the actual (negative) situation.

This is where the CPgame distinguish itself from
other products or tools that seeks to measure or
communicate emotion, such as the Product Emotion
Measurement Instrument "PrEmo" [1], the hospital
game "SiSom" [13] or the Self-Assessment Manikin
"SAM" [14]. This, because the CPgame contextualizes
the emotional experience it is meant to measure and
brings in the notion of Fictional Emotion.

Temporality and modulation play an important role
at both sides of the CPcard; on the left side ("Real
Emotion") integrated in the narrative sequence of
emotion - and on the right side of the card ("Fictional
Emotion") as an emotion-modulation process, taking
place during the interaction with the fictional characters
in the game ("in making the animation figures feel
certain ways"). This narrative and visual form of sense-
making is our main argument for developing a narrative
framework for emotion driven design that is actually
capable of providing us with valuable knowledge
and new insights about the emotional lives of
paediatric patients.

## 6 Conclusion

In this paper we have demonstrated that by drawing
upon Walton's theories of make-believe it is possible
to address two unexplored areas within emotion
driven design; a possible framework for describing how
emotions may change and evolve over time, as well as
addressing imaginative experiences of emotion. In doing
so we seek to merge existing emotion theories with a
narrative approach that accepts imaginary experiences
and fictional emotions, as meaningful activities (or
perceptions) that contributes to our emotional
experience of the real world.
Furthermore this paper will contribute to the field
of interaction design and emotion driven design with
a visual and playful method for communicating with
paediatric patients that can increase the understanding
of children's unique emotional experiences during
hospitalization.

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# Co-authored narrative experience: Affective, embodied interaction through combining the diachronic with the synchronistic

## Abstract

Examination of perception tends to look at senses in isolation, but Neuroaesthetics and Gestalt design principles treat perception as an embodied synaesthetic experience. The Diasynchronoscope project takes time-based techniques from animation and converts them to spatiality, animating static objects through projected light and creating transient visual cues that, when combined with sound, demand selective attention. The work challenges the use of passive nouns to describe participants such as 'user' or 'audience' or 'viewer' and instead asks participants to recognise their true position to be that of 'exegete', reading and interpreting the gaps in space and time. Their interaction with the work provides narrative meaning transcending the static and hidden, to create a Gestalt systemic whole, making each participant a truly immersed co-creator. Using audience analysis, the paper evaluates the work against more traditional media such as screen-based visuals and makes the case for further research into somatic perception of dynamics.

## Keywords

Gestalt, animation, attention, projection, audience, perception.

## 1 Introduction

By removing the mediation of a screen, and suppressing image recognition factors to create a narrative based primarily on movement, the Diasynchronoscope is designed to test the hypothesis that change is a key signifier in perception [1] and that all change can only be perceived through attention. In visual terms, this last has been demonstrated in a number of reproducible psychological tests such as studies in 'change blindness' [2]. The creators of the project are from audiovisual industry backgrounds, and felt that ideas on continuity of perception and how to 'direct' the eye had not moved on greatly from psychologist Richard Gregory's observation that perceptions can be seen as predictive hypotheses [3]. Indeed the powerful influence of the 'just seen/heard/perceived' is an essential tool for all screen media. Marchant et al of Leeds University, UK, showed through a three-year eye-tracking experiment in attention mapping of audiences watching scenes from Hitchcock's Vertigo [4] that attention can be directed about a screen with a surprising commonality [5]. This commonality of viewing could be attributable to a number of factors (perhaps not least to Hitchcock's skill in directing an audience's attention and that Vertigo is generally regarded as the best film made by a virtuoso film director), but also appears to be physiologically attributable to the way our visual cortex divides and processes four separate parallel pathways of perception: form, color, movement and depth. This paper looks

at the first phase of the Diasynchronoscope project where experimental media designed by the authors to explore notions of directed attention in an audience unmediated by screen, and with suppressed cultural and contextual content, is documented. It is the intention that this first phase should be scaled up to a larger space and to incorporate longer narrative elements, where some current restraints such as audience number and restricted viewpoints will be removed.

## 1.1 **What is a Diasynchronoscope?**

The name Diasynchronoscope comes from combining Diachronic, (the study of a phenomenon as it changes through time) with synchronous and scope (view). In being so named, it evokes the early animation simulators such as the phenakistoscope and the zoetrope which we regarded as direct ancestors of the piece acting both as art object and experimental media.

Used in a performance environment, the Diasynchronoscope is a real architectural space where prepared 3D objects are arranged in a way that they change incrementally in shape and/or position (figure 1). Although nothing in the room actually moves, the objects are revealed through serial illumination in a dark room, sequenced using the technique of projection mapping. This technique enables creation of a dramatization over time, encouraging the common perceptual shortcuts of a participant to create sequences and a narrative from static abstract objects.



**Fig.** 1. **A range of objects in the Diasynchronoscope.**

The closest practical examples for the Diasynchronoscope are the 3D zoetropes created by Pixar and studio Ghibli. Here a rotating turntable is lit by strobe lighting to give the illusion of 3D characters as real objects performing in loops in a real space. Because the illusion relies on a turntable, there is no narrative just looped action. Nonetheless, the 3D zoetropes are objects that

create great wonder in modern spectators. It appears that medium does impact significantly on the qualia of experiencing movement and that there is something special about seeing 3D unmediated by screen or camera [6]. Because the Diasynchronoscope uses masks to create specifically applied, sequenced projected illumination, a narrative is possible, as is synchronization of the effect with audio. In this first phase we showed a restricted chunk of narrative to an audience of ten participants from various backgrounds and ages and recorded their perceptual responses.

## 1.2 **Physiology Versus Personal Schemas**

Although today's audiences may not share the same geographical or cultural space, they do share the same cognitive neural architecture and perceptual shortcuts. The interesting question is if they would create the same narrative from abstract movement in an embodied experience [7]. This introduces two main, at first sight competing, areas for investigation: physiological, universal shared cognition; and individual responses drawn from personal schemas of movement.

The four separate parallel pathways of perception in our visual cortex transmit signals devoted to form, color, movement and depth. Of these four the least explored appears to be movement, perhaps because it is so hard to separate from other attributable contexts. The first experiments in phi phenomenon were made by Gestalt founder Max Wertheimer in 1912, where he observed that rows of flashing lights created the illusion of motion even when there was none [8]. The discoveries of Wertheimer are credited with launching a perceptual revolution giving designers the Gestalt laws of similarity, pragnanz, proximity, continuity and closure. Although as Filip Pizlo of Purdue University points out, the literature on the phi phenomena or 'pure' movement and Beta movement, or 'apparent' movement is very confused indeed [9], both require attention in order for cognition to take place. Further, although Beta movement has been divided into short-range and long-range apparent motion the definitions of what these terms actually constitute when translated to cognitive perception is still opaque in most literature with, as Joseph and Barbara Anderson remark in their seminal paper The Myth of Persistence of Vision Revisited, little consensus on the perceptual differences between Phi and Beta [10]. The Diasynchronoscope explores the two physiological functions (Phi and Beta) in a new way,

by including synchronization with audio and embodied phenomenological observation. The experiment exploits Gestalt laws and human cognition shortcuts to achieve an illusion of movement through selected attention.

Put simply, a personal schema is what makes us all respond differently, eg. One man's famine is another's feast. Each person's upbringing and experience means we cannot help but bring our 'personal baggage' along with us when we encounter any phenomena. Personal schemas are shaped by 'relevance' [11], and relevance can be defined in terms of a cost-benefit analysis weighting effort against effect. The more information processing effort it would take to bear x in mind in the context of y, the more costly it would be, giving an equation of High cost = Low relevance. It is not that we pre-compute just what effort and effect would be involved in considering this or that connection/belief before picking the most economical one, but that we have evolved unconscious psychological mechanisms that have much the same result [12]. Salience is what makes us apply attention to a stimulus, and salience can be either personal, or an evolutionary imperative. For any set of sensory data, there are generally multiple interpretations possible, but we need to rapidly come to a perceptual conclusion if we are to spot an aggressor or potential food source: Better to duck a fleeting shadow than be hit by a rock. If a common narrative were to be interpreted from an abstract movement it would indicate salience taking precedence over personal schema, but this could only be tested in an embodied way. By combining Gestalt principles with media theory and cognitive neuropsychology we have developed a new form of kinetic perception, with novel implementations of sequenced images in time unmediated by the camera or screen. It is the first step in a new way of looking at attention in perception, communication and action that poses the question: Does the unconscious perception of movement provoke a stronger emotional response than image recognition, particularly if synchronized with sound?

## 2 Methodology

Because the Diasynchronoscope used projected light, it was essential that the sculpture took place in a blacked out space. The creators achieved this by erecting a 2200 sq mm gazebo indoors and covering the frame with heavy black velvet. After some experimentation it was decided that the optimum material for creating the objects was white medium density polystyrene cut to shape. The polystyrene had to be painted black so that it would not be visible to the viewer in the blacked-out space. The lit result was pleasingly hard to register as material, imbuing the finished artifact with a level of ambiguity (figure 2).
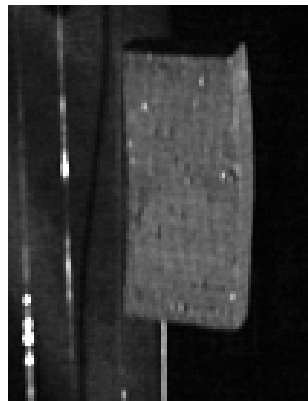


**Fig. 2. A single polystyrene object from the sequence.**

As no object can really be construed and labeled as 'abstract', an early challenge was to design objects that deliberately emphasized movement and were less likely to be culturally loaded than recognizable. This led to considerable debate about the character/object. We finally settled on a basic 'hero' object/block measuring 60 x 100 x 30mm. Aside from practical considerations, we were very clear that we did not want anything that resembled either a ball or a 3D pixel, i.e. cube. As when we developed the movement in virtual 3D, we decided we wanted to include a level of animated squash and stretch.

Because the artwork required the dimension of time to be translated into spatial dimensions, the work could not have been made without using 3D visualization (figure 3). In fact, all animation requires the animator to translate the dimension of time to that of space but this phenomenon is rarely made visible to the consumer, who only receives the data when it is translated back into time. Animators automatically switch between time/space when animating, always aware of how, for instance, higher speeds translate to greater gaps between objects in space. Because the objects were solid and the movement was so rapid, it would have been very difficult to have accomplished a reasonable animation without testing and adjusting it in 3D first.
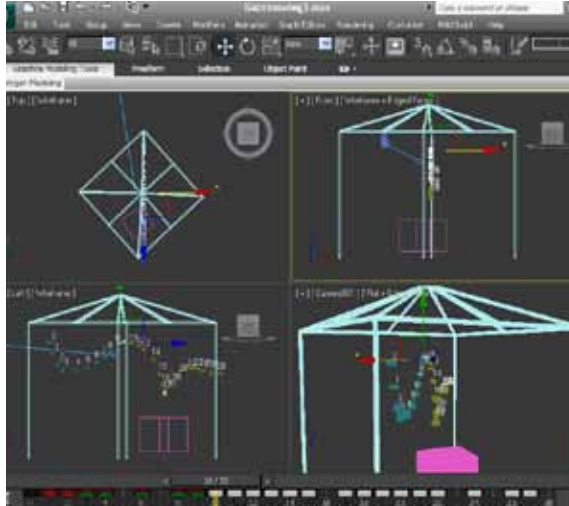
**Fig. 3. 3DS Max mock-up.**
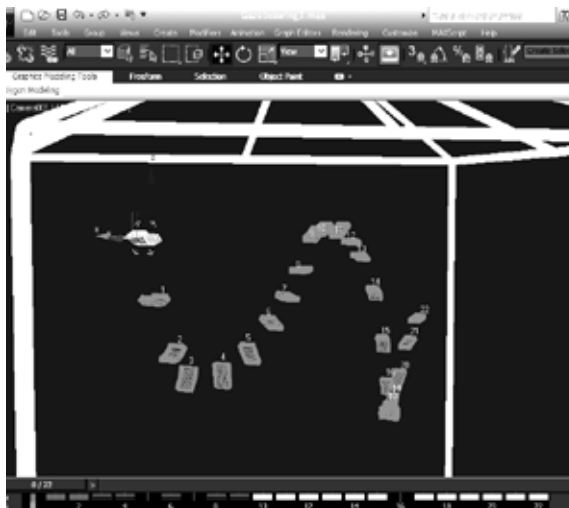


**Fig. 4. Viewer's perspective in virtual 3D.**



**Fig. 5. Objects 'floated' in space on fishing line and suspended on black sticks.**

The creators first worked out the sequence in Autodesk's 3DS Max at 12 frames per second (fps). The normal rate of film in the UK is 25 fps, but there is a long tradition in model animation and claymation of animating on 12 fps and holding each frame for two frames to make up a second's worth of animation. This is clearly less labor intensive and we trusted it not to look too jerky if the animation held an optimum path. We also could not 'overlap' action frames, so we knew that the animation would have to consist of fast movement and that we could not stay on one plane but wanted to explore all axes of the 3D space. Because of space restrictions, the animation was kept very simple and short using just 23 objects that translated into exactly two seconds of animation (objects 10 and 17 were held for 3 frames) (figure 4).

The virtual objects were recreated in polystyrene and hung in place using fishing line. This was fiddly and required each block to be tethered to the top, bottom and side of the gazebo to achieve stability (figure 5).

It was necessary to avoid hanging the three dimensional objects perpendicular to the projection as only one side would be illuminated. The optimal positioning was where three sides are illuminated, emphasizing the 3d effect, but this was not possible for every block. If we could have accommodated two projectors, we could have used one as a 'key' light and the other to act as a 'fill' light. When we were happy with the block positions, we mapped the light projection using a sequence of mattes animated in Adobe After FX. This had to be done with much precision as each pixel became crucial; too few and the definition of the object was lost, too many and the light spilled off the object and bled onto the black backcloth dividing attention. Sound effects were added to the movement and relayed via stereo speakers. The sound was designed to draw attention and synchronize but not to provide a solid identification for the objects as objects or characters.

The restrictive space meant we could only accommodate one viewer at a time, and that viewer was placed on a particular spot so that they might best view the work's 3D form. Each viewer was shown the sequence three times, interviewed, and then asked to turn around so they might experience the whole art object at once (figure 6).
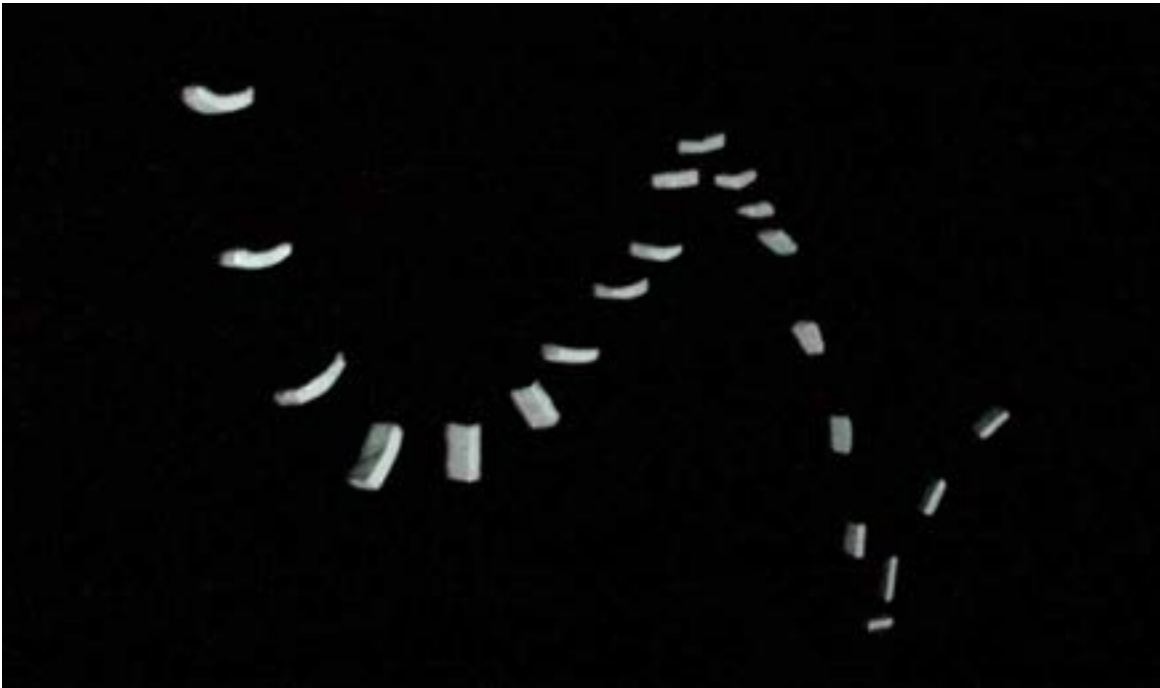
**Fig. 6. Picture of the whole artwork.**

For this first phase of the project, the participants were drawn via open invitation to friends and colleagues. The participants (whose ages ranged from 25 - 81) were: Juliet - a Jazz singer (and tennis player), Janet - a tennis player, Ruth - a retired doctor, Clem - a graphic designer, Peter - a web designer, Rob T - an actor and writer, Rob M - a film director, Livia - a music therapy teacher, Joseph - a painter (and tennis player), Lucie - a lecturer in digital media. Individual responses to the artwork were recorded on film at the time of viewing, then the participants were asked some deliberately open questions such as: 'What are your first impressions?' and 'What was going on?' This was followed by a filmed plenary discussion.

## 3  Findings

Generally the findings of audience response could be divided into three areas: response to the animation; response to the holistic artwork; and influence of personal schema. This last proved particularly interesting as it yielded the strongest sense of co-authored narrative, and was most satisfying for both artists and participant. It also shed interesting indications on the way personal schemas or memories are laid down, offering a rich seam for further research.

### 3.1 Response to the Animation

The two-second animation was played three times (http://vimeo.com/32451411gestalt/diasynchronoscope-animation). Participant responses were recorded as they watched the animation and they were then asked a number of questions. The animation evoked a variety of responses from 'Is that it?' to 'wonderful!' to laughter. All participants read the movement as movement and

were content that it felt 'natural'. The majority felt that the action was that of a ball bouncing. The animation had been designed to give the impression of a swing and bounce, with sound that served both character and object, so this was what we expected. Where participants did not agree was whether the object was an object or a character, i.e. what it was or whether it was a single object or a multiple one. However this did not seem to cause confusion in most. To some it felt very like a digital animated experience and to others it felt very different and 'real'. This could be attributed to the nature of the embodied experience as some moved their heads more than others and so would have achieved a sense of depth and a level of parallax. The people who moved most were non-digital artists and those who played tennis.

### 3.2 Response to the Holistic Artwork

Participant responses to the revealed whole artwork were also recorded (figure 6). Responses to this were extremely positive, eliciting comments such as: 'Like a dream', 'Tactile, I want to touch it', 'Magical!', 'Looks larger than life', 'Fabulous!', 'Oh yeah!'. The unlikelihood of the objects hanging in space without visible support, and the new knowledge of the previous movement made the holistic artwork a satisfying experience for all of the participants. One question we asked everyone while they viewed the holistic artwork was: 'Would you describe what you are seeing as a single object or multiple objects?'. Responses were evenly divided with four of the participants choosing it as clearly representing a single entity, and four being equally emphatic that the piece consisted of multiple objects. Two participants were happy to conclude that it was both multiple and single at the same time without seeming to find this paradoxical.

### 3.3 Influence of Personal Schemas

The artwork was a sincere attempt to isolate movement by suppressing the contexts of shape, mass and color. Thus the shape was a block constructed of no immediate contextual dimensions, and of no indicative material. Although the mass had continuity, the size was indeterminate as there was no reference point to gauge size against. The color was suppressed, deliberately neutral in context and consistent. However it became rapidly obvious that all participants imbued the experience with interpretations drawn from their personal schemas; often holding contradictory beliefs at the same time with apparent ease.

Juliet and Livia, both from musical backgrounds were primarily drawn to the audio, using their interpretations of the sound as a springboard for their interpretation of the whole artwork. Peter and Lucie, both working in the digital domain, drew digital interpretations first of all, before expanding their experience to other areas. Joseph, Janet and Juliet who were all regular tennis players interpreted the object clearly as a tennis ball despite the contradictions of it being a) a block and b) having the sound of a scrabbling creature. The movement of the objects elicited a number of ball responses from the participants, with Ruth (aged 81) interpreting the movement as being 'just like the Dambusters' film. The synchronous nature of the sound and the 'cartoon' quality of squash and stretch elicited laughter from Rob T and Rob M (both used to performance). The designer Clem was much drawn to the holistic art object rather than the movement. Several of the participants described the object as bringing to mind a 'kitchen sponge'. This could be because of the 'squashy' nature of its mass or be indicative of the prevalence of domestic associations in their lives. Many described the final holistic object as resembling a dinosaur spine, and there seemed to be no problem for four participants to interpret the whole artwork as ball, sponge and dinosaur spine within the same contextual description.

These interpretations proved revealing of how varied personal schemas are in individuals when they approach stimuli and led to a deeper understanding of the real nature of narrative co-authorship. Because of the abstract nature of the artwork, it also shed some interesting light on how memories may be laid down to create our personal schemas. What is highly salient and suggestive to one person may well be of no interest to another, but what triggers saliency when the stimuli is abstract?

## 4  Discussion

### 4.1 Animation: Gestalt, Phi, Beta and Apparent Motion

The four separate parallel pathways of perception in our visual cortex transmit signals devoted to form, color, movement and depth and the animation was designed to use Gestalt laws and animation principles (such as arcs, and squash and stretch) to achieve continuity of movement in all of these pathways. Animators, magicians and film makers all exploit how an audience will endow continuity of perception to objects that displace within corresponding graded constraints of shape, color, motion and mass, particularly if they move in arcs and have verifying synchronous sound.

The Gestalt laws grew from experiments showing that we group visual objects (in space) according to similarity, pragnanz, proximity, continuity and closure. It also demonstrated that auditory stimuli are grouped (in time) according to similarity, proximity and closure. A closer look at the Gestalt laws reveals how important they were to underpinning the artwork in all of its forms in time and space:

- **The law of simplicity suggests that similar things** tend to appear grouped together, the objects within the artwork were of sufficiently similar nature.
- **The law of pragnanz is sometimes referred to as** the law of simplicity. This law holds that objects in the environment are seen in a way that makes them appear as simple as possible.
- **The law of proximity holds that things that are** near each other seem to be grouped together.
- **The law of continuity holds that points that are** connected by straight or curving lines are seen in a way that follows the smoothest path.
- **The law of closure refers to the way our brains** often ignore contradictory information and fill in gaps in information to group things together if they seem to complete some entity. We do not find it easy to attribute randomness to stimuli; we cannot help but search for a pattern.

One question that occurred to the writers was: Could dynamics enable or disable a viewer's comprehension and assimilation of data? In an earlier experiment,

the creators of the project tested the idea of graded constraints by attributing varied colors to the objects, thus disrupting the law of simplicity (figure 7). It was immediately apparent that even though we were using objects of great similarity, the color changes were too great for their movement to be held as continuous. The objects lost their grouping and became separate, even though they held constant in terms of shape, motion and mass. It would be true to say that any large change in the constraints of each pathway would also break the idea of Gestalt grouping. For instance introducing random sizes would be similarly disruptive.
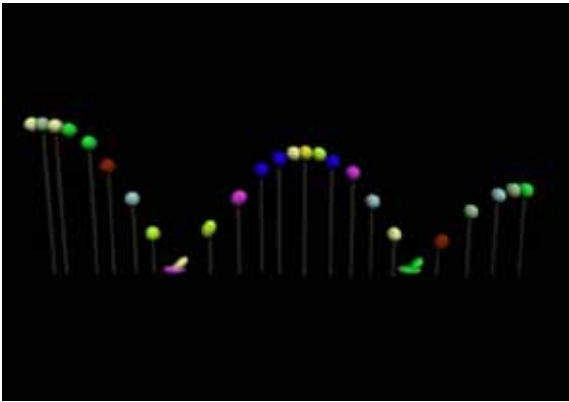


**Fig. 7. Random adjacent color changes across a wide range flouted the Gestalt law of simplicity so that the impression of continuous motion broke down.**

This suggests that all four perceptual pathways of form, color, movement and depth are equally important, and raises the idea of further experimentation that incorporates synchronized sound and vision. The phi movement of Wertheimer has been proved not to be a reasonable explanation for why we interpret film as motion [10], [13]. This leaves only Beta movement as a possible explanation. Beta movement is apparent movement caused by luminous stationary impulses. Multi-element or closely spaced displays may be mediated by the same mechanisms as real motion, while more widely spaced displays (such as the usual two-flash displays used to demonstrate apparent motion) involve a different type of processing. These two types of processing are termed short-range and long-range apparent motion, respectively. The four perceptual pathways are processed in parallel, but the movement pathway carries data more swiftly

to our visual cortex and according to the discoveries of neurologists such as Livingstone and Hubel and Zecki [13], [14] our visual systems employ two different computational strategies for processing closely spaced stimuli and widely spaced stimuli. This leads to Anderson and Anderson's intriguing conclusion: If we viewers process the motion in a motion picture the same way we process motion in the real world, then we must ask how we process motion in the real world. The short answer to this question is that we process movement in active meaning-seeking ways. We rapidly sample the world about us, noting the things that change and the things that do not change. We turn our heads for a better view; we move left or right to gain additional information provided by a different angle. We move closer or farther away. We actively seek more information about things that interest us. [10] It is for this reason that we regard the Diasynchronoscope project as scientifically worthwhile.

### 4.2 The Satisfaction of Art
Is the Diasynchronoscope project a work of art or a scientific experiment?
Margaret Boden defines creativity as 'the ability to come up with ideas or artefacts that are new, surprising and valuable' [15]. This clearly allows for scientific experiment to be both creative and interpretable as Art. Part of the fascination for participants in experiencing the Diasynchronoscope was that it was viewed as an embodied experience that allowed for individual opinion and interaction. Because the artwork had different points of access (as a time-based study and as a static art object that held the time-based object inherently within itself), the two forms informed each other. Paradoxically, the holistic artwork could be conceived as though the participant is a camera on a very slow shutter speed, receiving two seconds of data in a single moment. This, coupled with the embodied 3D element, is a new and surprising sensation. The artists would also like to stake modest claim for this sensation being potentially valuable in exploring dynamic cognitive perception.

### 4.3 Attention, Saliency and Personal Schemas
Change can only be perceived through attention, and attention can intrude on conscious perception because attention is drawn to an unexpected stimulus on an involuntary basis. Thus a person suffering from arachnophobia will spot a spider in a room before

anyone else, as their awareness antenna for such a stimulus is always near the surface, and it is most pertinent to them. It is obvious that personal schemas are highly influential in shaping our attention through salience. Salience brings a stimulus to consciousness, and immediately we set about selecting associations from our personal schema to interpret the stimulus. Because the stimulus was abstract and open to interpretation, it seems likely that we store memories dynamically with confirmatory sensory input increasing their likelihood of truth. This is at odds with the frequently used analogy of our minds as indexical filing cabinets; How likely is a static mental model of anything if we can associate so freely, riffing mentally between dinosaur bones, sponges, balls and bombs in consecutive moments? Memories are not stored indexically but dynamically, i.e. when movement is interpreted in an abstracted manner, we access mindful connotations that are not drawn upon through taxonomy, but through metaphor and metonym. Neurologically, we need to access events/ objects with a degree of intrinsic abstraction, so we store memories dynamically. Hence art, poetry and metaphor and metonym are simple manifestations of the way our brains work. This tallies with the thesis of Neuroaesthetics, namely that artistic models that echo the psychophysical architecture of the mind are best for depth of communication and qualia of experience [14]. For art and poetry, metaphor and metonym are not found in the concrete, but in the 'gaps between' the concrete, and these gaps are filled by audiences acting as exegetes. Exegetes who, despite being guided by artists and sharing cognitive neural architectures tend to take the same perceptual shortcuts, consulting our personal schemas immediately and unconsciously, and bringing forward contextual associations which have been stored dynamically in our minds.

## 4  Further Research

When principles of design replicate principles of thought, the act of arranging information becomes an act of insight. [16]
The first phase of the Diasynchronoscope project has yielded results that appear to confirm some theories of cognitive perception such as the design theory of neuroaesthetics and the importance of personal schemas in co-authored narratives. However in some ways it is clear that the project needs to expand if it is to answer other questions raised in this text.

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Because the work is performative yet entirely replicable despite being unmediated by screen, it offers a new and embodied way of exploring the physiological nuances of Gestalt law and perceptual cognition.
The intention is to use this experimental artwork as a springboard for a more ambitious artwork that removes some of the restrictions of time and space inherent in the piece.

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# Semantics of surprise: Strategies for eliciting surprise through design

## Abstract

This paper reports on the role of semantics in the strategies industrial designers use when attempting to elicit surprise. Surprise is the emotion people experience when they appraise a stimulus as "novel". While "novelty" is one of the main factors that designers can bring into a product, little has been reported about what strategies designers use when they intend to surprise.

Thirty senior representatives from influential design organisations were interviewed with the intention of uncovering strategies that designers use in their process. The analysis of the responses suggests the strategies are often connected to the semantics of the product, and that a common factor in order to elicit surprise is to challenge the expected semantics of an object on different levels: social, cultural and emotional. The suggested strategies are analysed in comparison with current literature. The research suggests that the strategies suggested in this paper represent explicit ways in which designers attempt to elicit surprise. The paper concludes suggesting that further research should be carried out in a research through design approach to uncover further strategies that designers use implicitly and did not explicitly mention during the interviews.

## Keywords

Industrial design, surprise, semantics.

## Relevance to Practice

The paper suggests a list of strategies that industrial designers use when addressing the semantics of products in order to elicit surprise. The strategies can in turn be used by students and practicing designers.

## 1 Introduction

Semantics has been investigated and used to offer meaning to complex to use objects: it helps designers indicate how objects should be used [1], [2]. This has been criticised [3] as producing objects that, while offering an interaction in which people easily understand what they need to do, it also produces objects that lack novelty, and therefore a sense of surprise. On the other hand, surprise breaks expectations, which implies that sometimes it may go against usability, as people cannot employ their expectations about how an object should be used.

Surprise has often been used in design as an element for eliciting an experience of amazement [4], to create a sense of novelty [5], "to increase interest or prolong the attention value of a product" [6], to "engage the user" [7], and to elicit curiosity and further exploration of the object [8]. Designers have often relied on their intuition and informed experience to produce objects that elicit experiences through the appearance and interaction that their designs offer. However, little has been reported about how designers approach projects
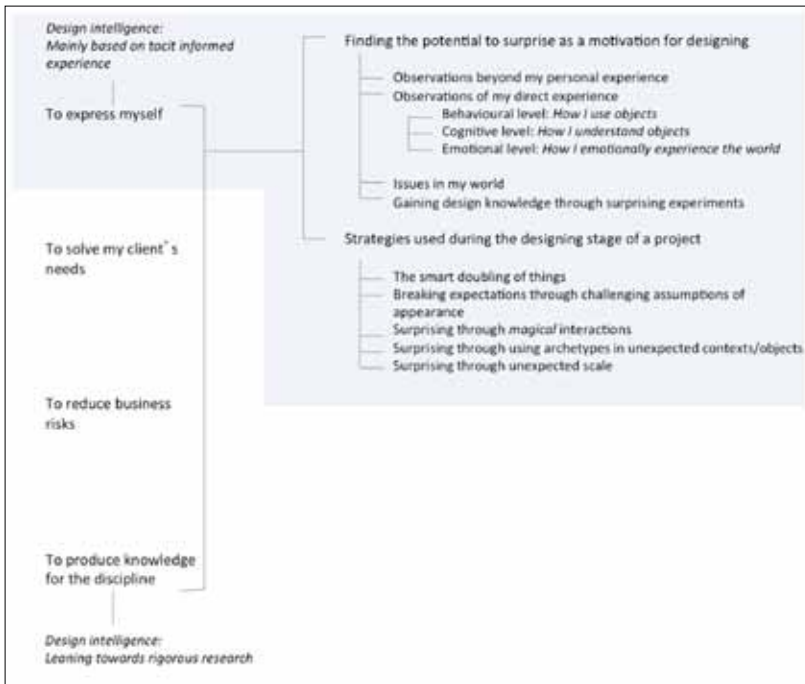
Table 1.
Situational map
constructed from
the analysis of
interviews showing
the constructed
strategies.

when they intend to surprise and what strategies they may follow and in particular, what the role of semantics is in eliciting surprise.

## 2 Methodology

There were 30 interviews with senior representatives from design organisations. All interviewees were senior designers, design managers or CEOs of design companies. The interviews were semi-structured and in-depth. The interviews were carried out according to Victoria University of Wellington's Ethics Committee Approval number 16059. All interviewees agreed to have their name published, as it would be impossible to present their projects and maintain anonymity. The interviews were semi-structured [9], in-depth [9], [10] and lasted between 40-60 minutes.

The analysis of the interviews followed a Grounded Theory approach with a postmodern turn, namely situational analysis [11], [12]. Firstly, the interviews were transcribed using a selective transcription approach [13], [14]. The transcriptions were printed and used for coding and memoing [12], [15]. There were several stages of interviews following theoretical sampling and opposite sampling approaches. The codes and memos were used as raw data to build situational maps. The questions necessary to build situational maps are: "Who and what are in this situation? Who and what matter in this situation? What elements make a difference in this situation?" [12]. Once the maps were constructed, they were used to find and describe relations between the important elements in the situation (Table 1). In particular, the analysis focused on creating "positional maps", which help develop "strategies for plotting positions articulated and not articulated in discourses" [12].

## 3 Results: Strategies to Elicit Surprise

The results from the situational analysis of the interviews suggest strategies that designers explicitly use when intending to surprise. They are divided into two main sections: strategies used as a motivation for designing; and strategies used during the act of designing. The paragraphs below indicate whether the projects address semantics at the cultural, social or emotional levels, or a combination of the three.

### 3.1 Strategies Used for Observing the World: Finding the Potential to Elicit Surprise as a Motivation for Designing

The strategies found in this category refer to the observations designers have of their world that inspire design projects. There were several ways in which designers found relevance in their worlds, and these could be seen as "observations beyond my personal experience", "observations of my direct experience", and "issues in my world". These observations have the common denominator of having such a strong impression on the designers that motivate them to start and carry out full design projects, from concept to manufacture, based on such observations alone.

Observations beyond my personal experience. This strategy refers to observations that designers have of how other people use objects, what they do in their daily activities, what they need. There seems to be a difference between observations of people close to the designers, such as family and friends, and strangers, which means that this strategy relates to semantics at the social level. Observations of family and friends seemed to be more meaningful for the designers. For instance, Matali Crasset mentions how she designed a range of furniture based on observations she had of her friends. The range is called Les Amis de Matali (Matali's friends). One of the projects develops from the observation that some of her friends often visit Paris, where apartments are small, and the friends they stay with often lack appropriate furniture for sleeping guests. In this case, Crasset designed furniture for her friend Jim who often visits her in Paris. Quand Jim monte à Paris (when Jim goes to Paris) is a structure of everyday furniture that could become a small private space and bed in a small apartment (Figure 1). It attempts to elicit surprise by normally being a piece of furniture for storage, and becoming bedroom furniture when Jim visits.

**Fig.** 1. Quand Jim monte à Paris by Crasset. Image courtesy of Matali Crasset.



**Fig. 2. Lamp On/Off by Santachiara, Meda and Raggi for Luceplan. Images courtesy of Denis Santachiara.**

Bill Webb mentions the example of designing an alarm clock for Barbie based on the observations he had of her nine year old daughter. He mentions:
I have a daughter, inevitably I start to see through her eyes and what she might want and understand. Kids' products or toys are challenging, trying to get into their mindsets does not come as naturally. You want to keep the energy alive. You want to be as passionate about you doing [sic] a Barbie box as you are when doing a Nike watch (B. Webb, personal communication, October 6, 2008).
Webb talks about seeing the world through his daughter's eyes in order to keep a high level of interest in the project as well as to better understand the potential users. In order to achieve this, he turns to people close to him, as Crasset turned to her friends. Observations of my direct experience. Designers also described finding relevance in their worlds through "personal experience". In this case, it is not an observation of something happening to someone else. It is something that happens directly to them. Personal experience can be at the behavioural level "how I use objects", at the cognitive level "how I understand objects" or at the emotional level "how I emotionally experience objects and the world".

Behavioural level: How I use objects. At the behavioural level, designers mention that how they use objects themselves is sometimes the deciding factor as to how to approach the design project. This category refers specifically to how they interact physically with objects. This strategy refers to semantics at the cultural level, as the designs attempt to elicit surprise by challenging the ways in which people have culturally learned that the physical interaction with objects should be like.
An example of "how I use objects" is the lamp On/

Off by Santachiara (Figure 2). The lamp is turned on or off by shifting its weight from one side to the other. The lamp attempts to surprise people by not having a standard switch. The design of the lamp originated as a response to accidentally knocking over the bedside lamp when falling asleep and trying to turn it off. The same kind of gesture can in this design turn the lamp on or off, without knocking it over.

Emotional level: How I emotionally experience the world. Bill Webb offers a description of "how I emotionally experience the world". He mentions that:
designers are pretty emotional people, there is a lot of passion in the work that we do that hopefully comes through the work that we do… Research can be very instinctual to us as designers being part of the culture, whether it's sports, consumer electronics, housing, gaming… Just because we live and breathe as much as we can every day, we have our point of view as consumers and designers (B. Webb, personal communication, October 6, 2008).
This strategy is obviously within semantics at the emotional level. Ingo Maurer offers a more specific example of how an emotional experience of the world can lead to a specific design. Back in 1975, Maurer was in Lake Constance in Germany. He saw a fisherman hauling in a net full of fish, and the drops of water falling from the net looked like tears. There was a strong light from the morning sun reflecting on the drops. He kept this observation for 35 years and designed the Lacrime del pescatore (Fisherman's tears) installation (Figure 3). The design consists of a series of layered nylon nets with 350 crystals illuminated by a halogen light bulb. The nets move slowly and give a sense of breathing. The illuminated crystals represent tears. Maurer admits that the installation was very close to his own emotions,

**Fig. 3. Lacrime del Pescatore by Ingo Maurer. Images courtesy of Ingo Maurer.**



**Fig. 4. The Euro Condom by Ingo Maurer. Image courtesy of Ingo Maurer.**

and his intention was to express those emotions. He even mentions that the design "was a bit on the edge, it may be seen as kitsch, but I am comfortable with it because the final result, including the movement and composition, express what I felt 35 years ago" (I. Maurer, personal communication, September 21, 2009).

Issues in my world. "Issues in my world" involves mainly current social issues that are important for the designers and subsequently sits at the social semantic level. Crasset mentions that she often develops ideas from reading newspaper articles (M. Crasset, personal communication, July 22, 2006). Maurer offers an interesting example of this category. Maurer says that for him the incandescent light bulb is "the most wonderful object made by human beings" (I. Maurer, personal communication, September 21, 2009). The law introduced in Europe in 2009, which banned frosted incandescent light bulbs, irritated Maurer. His team designed the Euro Condom (figure 4) in response. The design involves a silicon cover that diffuses light just as the frosted incandescent bulbs do. The design intends to make a statement about an important issue in the world according to the designer.

Gaining design knowledge through surprising experiments. A category beyond observations for intending to elicit surprise as a motivation for designing is through experimenting. The designers set up the experiments, but they do not know what may come out of them. The results of the experiments are then modified in order to make them final functional products. This strategy relates to semantics at the cultural level, in particular as the designers are surprised themselves by producing findings that challenge their cultural assumptions of how objects ought to be.

Examples of projects that are the result of experimenting and where the designers intend to elicit surprise come from Front Design. For instance, in the "Design by Animals" project, Front put different animals to the task of affecting their material environment. In one experiment, Front mapped the movement of a fly around a light bulb in order to design a lamp (figure 5).

The design process normally involves some degree of experimentation, where the designer sets up experiments with materials, textures, colours, interactions or other media and cannot fully anticipate the final result. For instance, the lamp Titania by Alberto Meda and Paolo Rizzato incorporates interchangeable coloured filters. The light from the lamp changes colour when the user changes a filter (figure 6). Meda mentions that the initial intention in designing Titania was to explore the form of a plane's wing (A. Meda, personal communication, September 15, 2006). They found the property of changing the colour of the light from experimenting with different materials attempting to decide which colours of plastic they should offer the lamp in. They found that including only one coloured sheet of plastic was enough to change the colour of the whole lamp, which was an unexpected finding. The difference with projects such as the ones described above by Front Design is that Meda did have an intention to design a lamp with particular characteristics and he found a particular feature – changing colour through changing filters– during the design process. On the other hand, Front Design did not know what the actual object or formal result would be at the start of setting up their experiments. The full result of the experiment becomes an object, rather than a feature of the object.

Fig. 5. Fly lamp by Front Design.
Image courtesy of Front Design.



Fig. 6. Titania lamp by Alberto Meda and Paolo Rizzato.
Images courtesy of Alberto Meda.

## 3.2 Strategies Used During the Designing Stage of a Project: Applying my Informed Experience

As opposed to "strategies at the observation stage of a design project", this category does not focus on observations by the designers; it represents the synthesis of their research into a designed object. It occurs during the design process, as opposed to being a motivation for starting a project. The process has been described as design synthesis [16] and the designers' spark [17], [18].

It is important to note that some designers seem unable to verbalise the properties of objects that will surprise. For instance, Laura Polinoro from Alessi states that what they look for in new projects is "to create a resonance, an affinity", and that "objects need a personality, an identity" as well as "a semantic value to create emotion" (L. Polinoro, personal communication, September 25, 2004). It is impossible to tell how to achieve this, as every object needs to be new, and therefore there are no recipes to achieve such goals. As creative director, Polinoro can only tell that such goals have been achieved when she sees the finished project, but she is unable to explicitly say what those characteristics are.

The smart doubling of things. Morenstein asserts that "it is 'the smart doubling of things' that I think people discover, are surprised by, and enjoy" (personal communication, November 10, 2008). For instance, Fuseproject was involved in the branding and product design for the Y water bottle (figure 7). Morenstein states that "it is a very emotional product, and that it had to appeal to children" (J. Morenstein, personal communication, November 10, 2008). The clients wanted to brand a healthy drink with special ingredients for bone and muscle growth. They wanted



Fig. 7. Y water bottle by Fuseproject.
Image courtesy of Fuseproject.



Fig. 8. The way in which the Y water bottle needs to be held implies a playful interaction. Image courtesy of Fuseproject.

to elicit surprise through the aesthetics of appearance reminiscent of the shape of bones through the form of the bottle.

In the same project, Fuseproject approached aesthetics of interaction through the form in which the bottle is held, which offers a playful interaction for children (figure 8). The design goes beyond an aesthetic
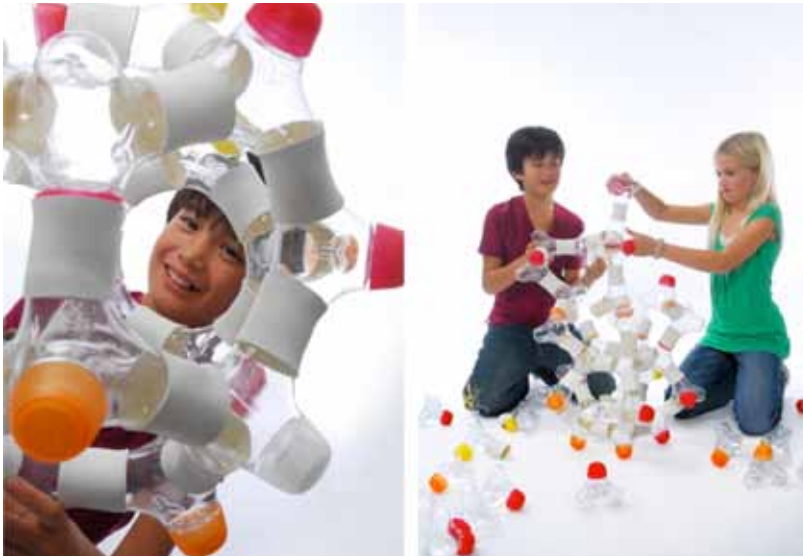
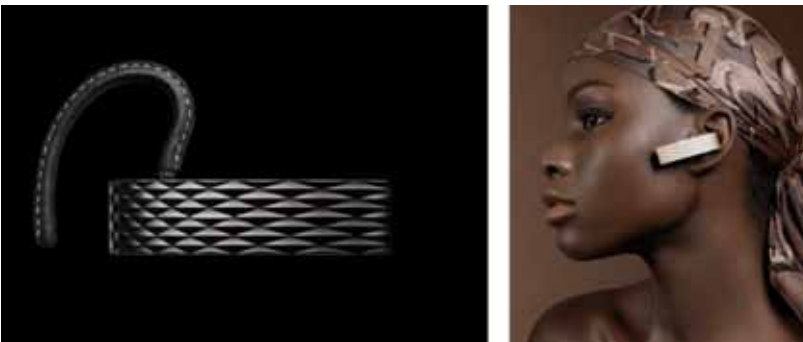**Fig. 9. The design of the Y water bottle becomes a toy after consumption. Images courtesy of Fuseproject.**



**Fig. 10. Jawbone Bluetooth headset by Fuseproject. Image courtesy of Fuseproject.**



**Fig. 11. Levitating lamp; Fig. 12. Separating drawers; Fig. 13. Disappearing drawer by Front Design. Images courtesy of Front Design.**

interaction during the consumption of the drink and includes literal playfulness by using a biodegradable rubber band that serves to join bottles together (figure 9). This feature incorporates an environmental factor that is achieved through creating an appealing use after consumption. Fuseproject claims that the use after consumption is only possible because the object produces an emotional connection with children.

Breaking expectations through challenging assumptions of appearance. This strategy refers to projects in which designers change what could be seen in the industry as an assumption of how a specific object should look, and refers to a culturally-learned visual-meaning. It seems that the more established an assumption of appearance, the more surprising a challenging design can be. Morenstein mentions the Jawbone Bluetooth headset (figure 10) as an example of a project attempting to challenge assumptions of appearance. He states that previous Bluetooth headsets looked like "blobs" as they were designed with the premise that "if we are going to design something for your face, let's make it organic, so that it'll blend in" (J. Morenstein, personal communication, November 10, 2008). Fuseproject's way to address this issue was to design beyond an expected assumption: that a Bluetooth set needs to look organic. By addressing such assumptions and expectations, the designers attempted to elicit surprise. Morenstein adds: "I don't put a chicken wing on my face, that's organic. We said: things people wear on their face are jewellery. They have to have details and materials selection… that was [sic] complementary to the way that I look".

Surprising through magical interactions. There were at least two studios that explicitly claimed to attempt to elicit surprise through magic and used cultural expectations of the objects' meaning in order to surprise. Front Design has incorporated magic in an attempt to elicit surprise. For instance, they developed a range of products in collaboration with magicians. The designs are created with what would seem "impossible characteristics that defy the laws of nature" [19]. The results include a lamp that levitates (figure 11); a chest of drawers that separates and floats away (figure 12); and another chest of drawers with fronts that disappear, revealing an empty inside (figure 13).

Surprising through using archetypes in unexpected contexts/objects. Under this category, designers used an archetype for an object and translated it into unexpected situations. Pezzini's design of the moving stool reflects the use of an archetype –a bucket– used in a different context: as a stool (figure 14).

Designers have often used this strategy in the design of lamps. The archetype used is the form of a trapezoid to signify a lamp. For instance, Santachiara's workstation

**Fig.** 14. **Moving Stool by Pezzini.**
**Image courtesy of Pezzini.**



**Fig.** 15. **Workstation/lamp Angel by Denis Santachiara**
**for Naos. Image courtesy of Denis Santachiara.**

desk "Angel" includes doors that when closed make
it look like a giant lamp (figure 15). This project also
connects to the strategy below "Surprising through
unexpected scale". The design includes another identical
but smaller lamp inside the bigger one, as a medium to
emphasise the changes in scale.

Sismo Design from Paris often uses archetypes in
different contexts. For instance, they used the form of
a wine glass to design the vase Verre ("glass", figure 16).
They also used the shape of a key as an element to turn
switches on and off (figure 17).

The use of an archetype in a different context can
sometimes allow only a very literal interpretation:
once the new connection is understood, there may be
very little more about the object that is interesting. As
mentioned in the introduction, the emotion of surprise
is very short lived and may be a single experience.
Fox-Derwin suggests that some projects are "one-
liners", which means that they hold an interesting
feature, but once that feature is experienced there is
not much more to the design (E. Fox-Derwin, personal
communication, May 26, 2010). To express the idea
of a "one-liner", Fox-Derwin refers to the "crushed"
ceramic cups by Rob Brandt that imitate what a crushed
plastic disposable cup would look like. In her research,
she explores the idea of incongruity and tries to find
ways to take designs beyond "one-liners" [20].

Surprising through unexpected scale. Designers referred
to the use of scale for intending to surprise people. For
instance, Santachiara's workstation/lamp Angel uses
the form of an archetypal bedside table lamp on a much
bigger scale (figure 15). Sismo Design uses unexpected
scale in the form of changing the proportions of an
object. The design of their Chaise longue (long chair)

plays with words to offer exactly that: a long chair
(figure 18). The design plays with the scale of the length
of the chair.

## 4  Conclusion

This paper serves as a snapshot of how designers use
semantics to intend to elicit surprise. This paper offers
specific strategies that are directly applicable to design
projects. The strategies are specific enough to be
workable, but general enough not to dictate recipes
that limit creativity.

### 4.1 Attempting to Elicit Surprise through Interaction as a Motivation for Designing or During the Design Process

The ways in which designers apply their informed
experience could be put into two categories: as a
motivation for designing or as strategies to use during
the design process. The first category refers to the
inspirational observations of the designers' world.
These could include observations of other people's
experiences, or observations of their own experience.
When the observations related to the designer's own
experience, projects were discussed that came from
a behavioural level: how the designer uses objects;
from a cognitive level: how the designer understands
objects; or from an emotional level: how the designer
emotionally experiences the world.
The second category refers to strategies through which
designers intend to elicit surprise through interaction.
This section reported on five specific strategies:
smart doubling of things; breaking expectations
through challenging assumptions of appearance; use
of archetypes in unexpected contexts/objects; use of
magical interactions and use of unexpected scale. It
should be remembered that these categories relate only
to the findings from the Grounded Theory analysis of

Fig. 16. Vase Verre; Fig. 17. Switches Les reférents; Fig. 18. Chaise longue (long chair) by Sismo Design. Images courtesy of Sismo Design.

the interviews. There are many more strategies that designers use. Ludden et al refer to at least six strategies to elicit surprise specifically through visual-tactual incongruity [21]. These include using a new material with unknown characteristics; a new material that looks like a familiar material; a new appearance for a known product or material; combination with transparent material; hidden material characteristics; and visual illusion. Ludden also reports other strategies to elicit surprise through visual-auditory and visual-olfactory incongruities [8].

Two of the visual-tactual strategies offered by Ludden et al [21] resemble strategies from this research. The first one is "a new appearance for a known product or material" [21]. It is similar to the strategy "breaking expectations through challenging assumptions of appearance" from this research. I specifically refer to it as "challenging assumptions" as this implies that an assumption has been formed about what the appearance of an object should be like. This is important, as it may seem that the more established the assumption of an appearance is, the more surprising a challenging appearance would be. Josh Morenstein reinforces this idea when he says "we found that people thought that all Bluetooth headsets needed to look organic… so we challenged that notion" (J. Morenstein, personal communication, November 10, 2008). Ludden refers to this characteristic by mentioning that the strategy refers to a "familiar" or "well-known" product [21]. The second strategy that resembles the findings from this research is "visual illusion" [21]. The strategy connects to "use of magical interactions" from this research. It also relates to and involves "visual illusions", but expands such a notion by allowing more than just visual illusions and allocating other potential ways to use magic. An example of this can be seen in the use of

technology and touch in the Leaf lamp by Fuseproject, which uses tactile sensors to turn on and off, dim the light, and change colour through an RGB controller, all without moving or visible switches.

The categories described above do not intend to be exclusive or exhaustive. As previously discussed, some designs served as an example for two or more categories. For instance, the project for the On/Off lamp started from a behavioural observation by the designer – knocking over bedside lamps with one's arm. The solution relates to the specific way in which the designer understood objects, and involved an intention to elicit surprise through magic and unexpected movement.

### 4.2 Further Research
The limitations of this research include that the suggested strategies are based solely on the responses from the interviews. Such an approach gives depth to the analysis and assures that the intentions of the designers are accounted for, which is the main goal of this research. However, it should be pointed out that there are other categories that could be found through analysis of existing designs without directly talking to the designers. Such categories were omitted in the analysis, as I had no further information about the original intention of the designers.
It was mentioned in the introduction of this paper that surprise has the characteristics of drawing people's interest towards stimuli and that it relates to familiarity. Designers either moved away from the familiar to elicit surprise, or used familiar elements in a different context to elicit surprise. However, further discussion about familiarity is necessary. For instance, how do we establish what, and for whom, something is familiar? How far away can designs step from familiarity and still

elicit a pleasant surprise? Using unexpected contexts seemed to be a common strategy for designers. Nevertheless, an unexpected context could be anything that is not the expected context. How do we know that an unexpected context may work in a favourable way for eliciting surprise? Such questions go beyond the answers from the interviewees and the scope of the research this paper draws on. The balance between eliciting pleasant surprise and moving away from familiarity should be further investigated.

The goal of this paper was to report on explicit ways that designers use to surprise. Further research should investigate implicit strategies designers use to surprise. The research could follow a participatory research approach, with researchers working as designers with design studios, attempting to uncover strategies that designers do use but were not able to verbalise through the interviews.

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# The role of designer expertise in source selection during product metaphor generation

## Abstract

Metaphors have a communicative role in design that entails a transfer of meaning from an entity (i.e. source) to the designed product (i.e. target). In this paper, we investigate the effect of the expertise of designer on the accessibility of the sources that they employ in metaphors. In the study conducted, novice and expert designers were asked to generate metaphors and the sources they selected were used for analysis. The results indicated that, (1) novices tended to select easily accessible sources whose similarity with the target were obvious, and (2) experts tended to use sources that were less similar with the target and more difficult-to-access in the first place. These results were then discussed in the light of metaphor theories and product design knowledge.

## 1 Introduction

The flyswatter of Atypyk nicely illustrates the power of metaphor use to tell stories through products (Fig. 1). By associating a flyswatter with a magic wand, the designer of this product wittily brings in a novel approach to get rid of the unwelcomed flies and insects in your house. Actually, killing flies is an activity that is not quite pleasant for the most, and to be able to kill them "magically" without the brutality is a tempting idea in itself. Although the product works as a regular flyswatter rather than with magic in this case, its form leads the users to use it in a creative manner. By means of this product, it is easy to picture people running around in the room and getting rid of flies with a magical "wave and flick". This gentle movement is also in contradiction with the harshness of the hitting that you would do with a regular flyswatter. For these reasons, the product has a strong humorous and playful dimension that associates the mundane activity of killing flies with the world of fairies and magic.

As a matter of fact, this is what the metaphors are used for. They have a communicative role that entails the transfer of meaning from one entity to another. This quality extends the limits of metaphors beyond language. Since metaphors associate two distinct entities in order to attain new meanings, various disciplines make use of them frequently (e.g., psychology, linguistics, art, advertising, architecture, music, mathematics, gesture studies, literature, film studies, religion, etc.). In the design domain, metaphors are used as tools to define the design problem, generate ideas and enhance creativity [1], and/or as a communication medium with the users to express meaning and achieve cognitive and affective effects [2], [3].

**Fig.** 1. **"Bzzzz... Vlan" flyswatter by Atypyk Design, 2005.**

To go back to Fig. 1, in technical terms, the flyswatter is referred to as the target of the metaphor, which is the product that is designed for conveying a particular meaning. The magic wand is called the source, namely the entity that is associated with the target to convey that meaning. The generation of product metaphors involves a transfer of attribute(s) from the source to the target. In a typical metaphor generation situation, there are tens, if not hundreds, of possible sources to associate with the target, yet the designer focuses on only one of these. This selection is a highly important decision that determines the comprehensibility and the quality of the metaphor, but little is known about the factors affecting this selection. Metaphor generation and source selection are mostly neglected even in the linguistics domain, where the wealth of research is directed towards metaphor comprehension and appreciation [4].

In the literature, it is widely accepted that target and source domains in a metaphor share some attributes, and this similarity is the reason why they are brought together [5], [6], [7], [8], [9]. This similarity may be rather obvious and easily accessible; or it can be based on "deeper" relations and thus more difficult to notice in the first place. In this paper, we address the ease of accessibility of a source based on target-source similarity. We argue that the expertise of designer has an effect on the ability to access sources that have different levels of similarity with the target. For this reason, our aim in this study is to investigate if novice and expert designers tend to use sources with a particular level of similarity with the target while generating metaphors.

In the sections that follow, we will first expand on what is currently known about target-source similarity, source accessibility and their relation to expertise in the literature, and then present the study we conducted together with the discussion of the results in the light of metaphor theories and product design knowledge.

## 2 Similarity of Target and Source

Similarity refers to the likeness or resemblance of two entities, and it increases as the number of common features between the entities increases and as the number of distinctive features decreases [10]. In metaphor literature, it is acknowledged that the target is seen through the lens of the source by construing attributes that apply to target as corresponding to those that apply to source [9]. This correspondence is on account of the similarity of target and source, which governs the association of these entities with each other. To go back to our example, we see that a flyswatter and a magic wand share many perceptual and conceptual attributes. They somehow look like each other since they have similar size, proportions and construction (i.e. flat surface attached to a stick), and they are held by the hand in the same way. They are also similar to each other if we abstract their function – they can both make things disappear. In that sense, we can state that the association of the flyswatter with the magic wand is considerably meaningful as they are both used similarly on an abstract level. Still, this association is not very obvious, which is why the connection is a clever one.

What the similarity between target and source entails is often investigated in analogy and metaphor literature. Although these descriptions are all given in relation to the semantic qualities of "words" or "concepts", we maintain that they are also applicable to target-source similarity in product metaphors because they are generic enough to cover all dimensions of an entity, whether it is abstract or tangible. For instance, some scholars argued that perceptual similarity between target and source is essential for metaphoric success [11], whereas some others maintained that good metaphors have targets and sources that are similar in their functional qualities; especially in the way they affect our emotional states. In another study, two terms, which are called taxonomical and thematic relations, were defined in order to explain the possible relations between two concepts [13]. The former is

a relation that represents the physical resemblance between two objects, and the latter represents the relation between two concepts through a thematic scene. Seitz [14] distinguished six types of metaphoric matches that originate from target-source similarity: color, shape, cross modal, physiognomic, psychological-physical and taxonomic. Color and shape matches refer to pairing off shape or color of an entity with another in a nonliteral way, like comparing an egg yolk to the sun. Cross-modal matches build an association between various sensory modalities like matching a sound to a smell or visual experience to touch. Physiognomic matches involve attributing emotional qualities to inanimate objects. Psychological-physical matches refer to relating a physical aspect of an object to a psychological characteristic like "He is very tough". Taxonomic matches associate abstract qualities of two distinct things when there is no physical resemblance, like comparing a cheetah to a car. These examples indicate that at the origin of a metaphorical association lies a certain level of similarity between target and source, and the content of this similarity can be based on various aspects of these domains.

When it comes to analogy literature, the most common distinction is made between surface similarity and structural or deep similarity between target and source [15], [10], [5], [16], [17]. The use of these terms are also metaphorical: surface similarity is described as the easily accessible similarity since the similar attributes are on the "surface", and deep similarity refers to the similarity that is more difficult to notice because the similar attributes are rooted in "deep". Most of the time, surface attributes are addressed by physical descriptive attributes like color, form, sound, etc. because perceiving tangible attributes are quicker and easier than the others. On the other hand, deep attributes are defined as non-physical abstract qualities. For this reason, it is argued that the ease of accessibility of the surface similarity comes from being based on physical and tangible attributes, whereas deep similarity is difficult to notice since some kind of an abstraction is necessary [18], [10], [5], [17]. However, Vosniadou [17] maintains that this argument fails to take into account the status of the similar attributes in people's underlying representations. If the attributes in question are salient with respect to underlying representations, the easily accessible similarity can also be based on relational,

abstract or conceptual properties. For this reason, Vosniadou does not differentiate surface from deep similarity according to its content, and argue that any kind of attribute can be in surface or in deep as long as it is prominent.

Regardless of the discrepancies of the arguments related to its content, we can state that the accessibility of a source lies on a continuum that has surface similarity at one end (i.e. easily accessible similarity) and deep similarity at the other (i.e. difficult to access similarity). Having a surface similarity with the target makes a potential source to be easily identified when building associations, whereas it is more difficult to find sources that are based on deep similarity because the domains may differ in many subtle ways [15]. This makes noticing deep similarity relations a more sophisticated way of building associations. Correspondingly, in the problem solving literature poor analogies are ascribed to the tendency to notice superficial attributes while failing to see deep structural relations [19], [17]. Similarly, designers may also find it difficult to notice the relevant relationships if their problem at hand carries structural similarity but no surface similarity [16]. For this reason, it is argued that seeing deep similarity between two distinct entities requires expertise [19], [20], which we will investigate in the next section.

## 3  The Effect of Expertise on Seeing Similarity

There is a substantial and long history of work on understanding the differences between experts and novices in various disciplines, including physics, chess, music, sports, architecture, ballet and medicine. However, it is interesting to see that all these studies mainly show a similar trend regardless of the discipline: experts are able to abstract the situation at hand and see the underlying structure, whereas novices' actions tend to be limited with the surface attributes of the situation. As an example, it is argued that there are fundamental differences in the representations of physics problems among experts and novices [20]. When asked to categorize problems according to the similarity of their solutions, experts mainly use underlying principles as the similarity criteria and novices focus on surface features. For this reason, novices tend to be misled in identifying similar problems because their surface features are different.

These kinds of examples are given by many scholars from different fields. It is argued that the acquisition of skills to abstract the essence of the situation and see underlying relations are related to the development of expertise. As maintained in Casakin [19], "Experience in a certain domain allows the generation of abstract or conceptual problem representations and enhances the probability of analyzing a problem more in-depth, by focusing on structural features". On the other hand, the fields that are mentioned are domains where the constraints of the problem are well defined, and a limited number of rules apply (e.g. chess, physics, etc.) [21]. However, the problems in the design domain are described as ill-defined problems, meaning that there exist many possible solutions and there are no rules to obtain these solutions [21], [22]. For this reason, the expertise in the design domain is an "adaptive expertise", which the experts adjust to situations [22]. Despite this difference, expert designers are also able to see an underlying pattern and make a connection with a solution, which can be from an entirely different context. As Lawson [23] aptly puts forward, "Experienced designers have simply seen more and made more connections already than inexperienced designers". This brings us to the metaphors, in which Casakin and Goldschmidt [19] found out both expert and novice designers are able to employ visual analogies and associations in solving design problems, however using them in a better way requires expertise.

Based on this literature, the aim of this study is to investigate the effect of designer's expertise on the accessibility of the sources that are employed in the metaphors. In other words, we aim to find out if novice and expert designers tend to select sources from different levels of the accessibility continuum.

Our hypotheses are:

• Novices are likely to select easily accessible sources whose similarity with the target is obvious.

• Experts are likely to select difficult-to-access sources whose similarity with the target is less obvious than the sources used by novices.

## 4  Methodology

In the sections that follow, the experimental set-up designed for investigating the hypotheses will be presented.

### 4.1 Participants
In this study, 24 expert designers (20 male and four female) and 25 novice designers (12 male and 13 female) participated. The expert group comprised of professional designers who had an average of six and a half years of working experience within the field, varying from two to 16 years. The novice group included second year Bachelor students studying in the Industrial Design Department of Delft University of Technology, who took two design courses within the first year of their education.

### 4.2 Experimental Task
In order to minimize the possible effect of the product type on the experimental task, four different products were used in the study: MP3 player, chair, nail clipper and self-cleaning trash bin. Each participant generated a metaphor for each one of these products. Two other experimental conditions were also utilized – the time allotted for completing the design (short-long) and the intention of the designer to use the metaphor (pragmatic-experiential) – however, the effect of these conditions on the ease of accessibility of the source will not be reported in this paper.

After getting an introduction to what a product metaphor is and how it is used in the design domain, the participants were given the design tasks one at a time. These tasks were set up by systematically altering the combination of the product type and intention, and their order of presentation to the participants. The design session always followed the sequence of long task (40 min.) – short task (8 min.) – long task (40 min.) – short task (8 min.), and a break was given between the second and third tasks. The whole study took around two hours and 15 minutes. Upon completing the session, the participants were asked to explain their designs orally and explicitly point out the sources they associated with the target products together with its reasons. Then, they were debriefed and compensated for their participation.

### 4.3 Assessment of Similarity
Two naïve judges who were blind to the aims of the study and the experimental conditions scored independently the ease of accessibility of the sources considering the targets they were associated with. They were provided with a questionnaire that included the sources that are selected by the participants and the

targets in random order. The targets and sources were presented to the judges as words, and they were asked to rate word pairs (e.g. nail clipper – scissors, chair – cloud) regarding "how easy it is to see the similarity between the items" on a 9-point-scale. The ratings were then compared, and if there were minimum 3 points of difference between the ratings for each item, the judges reconciled their assessments by discussion and came to a consensus. The remaining scores were averaged to form an overall similarity index.

## 5 Results

The sources employed by participants can be seen in Table 1. The mean ratings indicate that novices tended to employ sources that were easier to access (M = 5.48, s = 2.59), whereas experts selected sources that were less accessible (M = 4.07, s = 2.71).

Table 1. **The sources used by novice and expert designers in our study.**

| Expertise Level | Sources associated with target products* | | | |
| --- | --- | --- | --- | --- |
| | Nail clipper | MP3 player | Chair | Self-cleaning trash bin |
| Novice | Beaver | Battery | Arrow | Broom |
| | Biting nails | Cassette (2) | Bottom | Canon |
| | Caterpillar | Cassette player | Car seat | Cleaner |
| | Crocodile (2) | CD (2) | Cave | Drain |
| | Door | Clef | Clothing | Droid |
| | Finger | Disco ball | Clouds (2) | Elephant |
| | Fingerprint | Ear (3) | Cushion | Flushing toilet (2) |
| | Guillotine | Frog | Dinnerware | Garbage bag (2) |
| | Ladybug | Guitar amplifier | Hammock | Maid |
| | Nail polish | Headphones | Mushroom | Paper recycle bin |
| | Nails (2) | LP player | OK hand gesture | Recycle sign |
| | Peg | Music note (5) | Sitting human body (6) | Red cross |
| | Pencil sharpener | Music sheet (2) | Stop sign | Rug |
| | Scissors (3) | Turn table | Trace of butt | Soap bar |
| | Shark | Samba balls | Vertebrae | Space pod |
| | Teeth (5) | Walkman | | Trash car |
| | | | | Trash tube |
| | | | | Wiping hand (3) |
| Expert | Animal | Cap | Alarm clock | Automatic vac. |
| | Biting nails | CD rack (2) | Arrow | Cleaning wipes (2) |
| | Cutlery | Cloud | Being in dark | Dining plate |
| | Door | Comforting stone | Bird nest | Dyson fan |
| | Finger | Dragonfly | Birthday decoration | Chlorine bottle |
| | Guillotine | Ear | Cake | Hourglass |
| | Heart | Headphones | Cloud (3) | Hygienic smell |
| | Monster | iPod nano | Log | Jail |
| | Paper cutter | LP player | Nail bed | Kitchen paper roll |
| | Pencil sharpener | Microphone | Pants | Lotus leaf |
| | Perfume bottle (2) | Music note | Piece of a pie | Paper bag |
| | Pincers (3) | Navigating in car | Shovel | Shower |
| | Scissors | Necklace | Sitting human body (2) | Transparency (2) |
| | Snake | Pirate's hook | Supporting hands | Soap bar |
| | Stapler | Rubik's cube | Tensegrity cons. | Supermarket belt |
| | Teeth (2) | Roulette | Thread ball | Toilet (3) |
| | Vending machine | Sea shell (2) | Toilet roll | Tongue |
| | Washing machine | Storage box | Wheel | Twisting bolt |
| | Whale | | | Windshield wipers |

* The numbers in brackets indicate the number of participants who used that same source.

In order to investigate the main effects, the data was analyzed using ANOVA on the ratings for the accessibility, with the "order of the presentation of each product", "product type" and "expertise level" as between-subject factors. With regard to the first two control factors, the results indicated no significant effect on similarity and interaction effect with the expertise. This means that the order we presented the products to the participants and the four product types did not affect the tendency of the participants to employ a particular similarity degree, and the effect of expertise is independent of these two factors. Although not significant, the means of each product for similarity ratings show an interesting trend. MP3 player and self-cleaning trash bin lead to the association of sources that are easier to access, whereas chair and nail clipper lead to the association of difficult-to-access ones (Fig. 2).
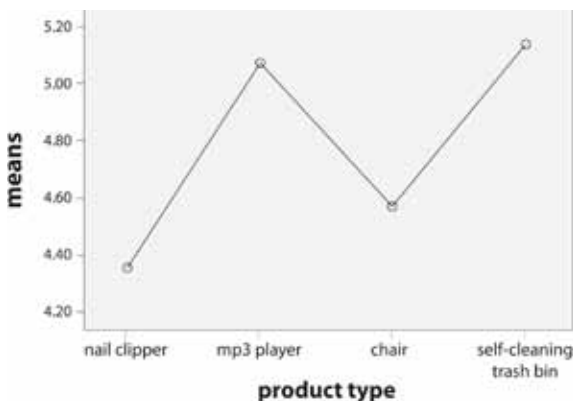


**Fig. 2. The means for the accessibility of the sources associated with each product type.**

ANOVA analysis yielded a main effect of expertise on source accessibility F(1, 31) = 13.39, p < .001, 2 = .086. This finding indicates that expertise significantly influences the accessibility of a source. When combined with the mean scores, our results show that novices tended to employ sources that were easier to access, and experts selected sources that were more difficult-to-access.

## 6  Discussion and Conclusions

The research findings indicated that expertise had a significant effect on the selected sources to be employed in the products. Novices were likely to select easily accessible sources whose similarity with the target product was rather obvious when compared with the sources selected by the experts. On the contrary, experts' preferences were more on the "distant" sources, in which their similarity to target was less obvious. Therefore, both of our hypotheses were supported with the findings that novices used easily accessible sources while experts used more difficult-to-access ones. This means that the abilities of novices are yet to be limited with noticing the sources that are similar to target in terms of the attributes on the surface only. This situation is also apparent when we have a look at the sources that participants selected (see Table 1). Let's take the MP3 player task as an example. Some of the examples of the sources that the novices used in their metaphors are music notes, music paper, CD, Walkman, record player, etc., which are all highly related to a MP3 player but meanwhile this relation is somewhat obvious since they are all in the "music" and "music listening" domain. On the other hand, experts associated sources like dragonfly, Rubik's cube, seashell, etc. with the MP3 player. The relationship of these entities is in fact quite abstract: dragonfly was chosen because it buzzes in your ear, Rubik's cube was chosen because it is a lovely way of entertainment, and seashell was chosen because you can put it in your ear and listen to the humming of the sea. Compared to the music notes or CD's, these entities are rather meaningful and novel associations. As can be seen from these examples, novices built more obvious relations but experts used more distant sources in their designs most of the time.

Accessing sources that are based on deep common attributes with the target and being able to build associations in between might be a natural tendency that is acquired with expertise because metaphors or analogies that are based on a distant relationship between target and source are deemed more creative and original than those based on close relationships [1], [15], [18]. Bringing two very similar entities together may lead to hackneyed and uninteresting metaphors [7], [8], and correspondingly, it has been shown in the design literature that distant associations play a significant role in the design of creative products [15]. In that sense, the tendency of the professional designers to use more distant sources in our study might support their desire to attain interesting metaphors. Our results are preliminary to make generalizations and require

a follow-up study to investigate if the designs of the experts were more creative, but we argue that with the acquisition of expertise, the designers are likely to prefer more distant and less obvious relationships between target and source.

It should be noted that the source whose relationship is obvious with the target does not necessarily mean that it is highly similar to the target at the same time, and vice versa. We acknowledge that they are parallel mostly, but there might be conflicting cases. For instance, in one of the cases the designer associated a lotus flower leaf with a self-cleaning trash bin (see Table 1). The reason was that the lotus leaf has a special surface structure that repels dirt and water, which eventually provides the plant to clean itself. The transfer of this attribute to the trash bin fulfills the self-cleaning function of the target product. For this reason, a self-cleaning trash bin and a lotus leaf becomes highly similar since they both do self-cleaning. However, seeing this connection might be difficult in the first place because these are two distant entities belonging to different domains and self-cleaning is a rather hidden attribute of a lotus leaf. Especially for a person who is not knowledgeable about this attribute, accessing this association might be difficult. For this reason, the answer to the questions "how similar these two entities are" is very similar, whereas "how easy it is to see the similarity of these two entities" is not very easy. Thus, we maintain there might be some cases like this that overall similarity of a source with a target differs from the accessibility of this similarity. In this study, we only focused on the accessibility since we consider it one of the main aspects affecting metaphoric quality. Two entities may be quite similar, but as long as seeing this similarity is not very easy, their association leads to clever connections like in the magic wand –flyswatter example (see Fig. 1).

In addition to this, we want to say a few words regarding the type of similarity of the sources that are associated with target products. As can be seen in Table 1, participants employed various sources that have perceptual and/or conceptual similarity with the target products. A summary of the content of these similarity types can be found in Table 2, together with example associations. We mentioned earlier that some scholars use perceptual similarity and conceptual similarity

for referring to surface similarity and deep similarity, respectively; and some others do not differentiate the content of surface similarity from deep similarity. As Vosniadou (1989) argues, conceptual and abstract attributes can also be on the surface as long as they are prominent, and vice versa. Within the context of our study, the first argument leads to the assumption that novices would select perceptually similar sources while experts would go for conceptually similar ones. However, our initial analysis on the sources used by the participants shows no such tendency. The entities associated with the target products by novices were also somewhat conceptual as much as the ones associated by experts, and the experts also used perceptually similar sources commonly. For instance, if we take the nail clipper as an example, novices used sources like beaver, shark and crocodile that are conceptually similar to a nail clipper since they all cut something with their teeth in an abstract level. On the contrary, experts associated sources like pincers, scissors and stapler, which are similar to a nail clipper perceptually. For this reason, there is no difference in the tendency to use a particular type of similarity more often among the novice and expert designers. We can state that our sample supports Vosniadou's view that the surface attributes are not necessarily perceptual, and deep attributes are not conceptual all the time.

| Type of similarity | Similarity in: | Example |
|---|---|---|
| Perceptual similarity | | |
| Appearance | Form, color, texture, material, size, proportions | Chair – Sitting human body |
| Movement | The way main body/ parts move (direction, position change, force) | Nail clipper – Guillotine |
| Sound | Sounds they make | MP3 player – Dragonfly |
| Interaction pattern | The way a person uses, holds, etc. | Nail clipper – Stapler |
| Conceptual similarity | | |
| Function | The main purpose | MP3 player – Walkman |
| Working principle | How they work; the mechanism/ structure behind | Self-cleaning trash bin – Lotus flower leaf |
| Emotions they evoke | What they make people feel | Chair – Bird nest |
| Environment/ context | The environment they are in, the people who use them, the time they are used, etc. | Nail clipper – Perfume bottle |

Table 2. The types of similarity between target and source

A final remark is about the products used in this study. We mentioned earlier that MP3 player and self-cleaning trash bin were associated with sources that are easier to access, and the case with the nail clipper and chair was the reverse. For the former two, we observed that participants aimed to convey the purpose and usage of the product first, and therefore looked for sources that "do the same", i.e. play music or clean itself. In particular, the self-cleaning trash bin is a rather novel product concept. The participants aimed to make this special function apparent and understandable. For this reason, the similarity of the sources that were associated with these products were obvious, which aims to convey to users the function, usage and interaction pattern as clear as possible. On the other hand, a nail clipper and chair are products whose function is fixed and easily understandable. Therefore, we observed that participants were able to experiment with associating various entities with these products without worrying about the functionality. They tried to communicate a specific message, improve the visual look or associate it with an entity for fun purposes. That is why we think the sources these products were associated with had a more distant relationship. The product type did not have any statistical effect on our findings, however we acknowledge the fact that certain product types would be more suitable for focusing on a particular level of similarity.

To summarize, our results indicate how ease of access affects the selection of a potential source and how different groups of designers behave while selecting a source. Novices used sources that are easier to associate with targets in general, while the tendency of the expert designers was the opposite. The present study is one of the first attempts to investigate how target and source of a metaphor are associated with each other during metaphor generation, yet this issue needs further attention. Metaphors are powerful tools for conveying meaning through the product, and if we are to understand how to make good and creative decisions in this respect, the designers can create comprehensible, aesthetic, interesting and pleasant metaphors, and rich and meaningful user experiences.

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# Design and iconicity: Design, materiality and the meaning of things

## Abstract

The semiotic problematic to be addressed in this paper is the construction of meaning in serial objects or multiples. At least three 'thing-identities' are in play during the lifetime of a merchandise, and the question is how things actually attain meaning in their different contexts of design, production and consumption and how to differentiate methodologically between stages within the commercial and cultural trajectories of one particular item (a thing).

Since Jean Baudrillard posed the question of the model-series relation as defining "a perpetual dynamic which is in fact the very ideology of our society" [1], it has been a permanent challenge to design studies to address the question of how meaning is construed in mass produced objects for use. There seems to be three levels or stages of meaning production; in relation to, respectively, (1) the model or prototype for a series, (2) any produced item in the series, and (3) any singular object in the series. New approaches to the problematic have, by employing terms such as 'indication', 'affordance' and 'agency', furthermore emphasized the differentiations in regard to the ambivalent statuses and meanings of mass products, especially the relation of model to singular objects. The status of the latter has been described as, for example, 'personalized objects' (Baudrillard, Sophie Woodward) and 'singularized objects' (Igor Kopytoff). However, nor the processes neither the specific 'sites' of meaning production have not yet, in my view, been addressed properly or convincingly.

This paper will consider the possibility of differentiation between the three levels mentioned above, by introducing the semiotics of Charles S. Peirce's, and, more specifically, his so-called first trichotomy and the concepts of legisign, sinsign, and qualisign, (or, in another terminology of Peirce's, type, token, and 'tone/ tuone', and in a third listing, potisign, actisign, and famisign). This modeling, so it will be claimed, provides a theoretically satisfying conception of how and 'where' and by whom the multiple meanings in design objects are being produced, as well as the consequences of this for appropriate analytical strategies with regard to the processes of design, production, distribution and consumption.

## 1 Introduction: Jeans as Art and Jeans as Jeans

The German 'fat and felt' artist Joseph Beuys (1921-86) was highly visible and easily recognizable, due to his personal dress code. From the early sixties he used to appear in public in an outfit consisting of four elements: trilby hat, fisherman's vest, white shirt, and blue jeans. As synecdoche, each of these elements has

been iconized as a sign of avant-garde attitudes and of deviation from mainstream values. As indicated in the photos from commercials found on the internet, the Beuys name has in particular served as a label in promoting new, fashionable clothing, and younger artists have paid their kitschy tributes to the master by hinting at the Beuys-fat-felt connection.

Beuys included jeans in some of his artistic statements, not as ready mades, but modified in various ways. Two years prior to his death, Beuys conceived a so-called multiple with the title of The Orwell Leg – Trousers for the 21st Century, 1984. The work was issued as an unlimited series, and by now, approximately 35 exemplars, with variations within the edition, have been produced. The series consists of new blue jeans the modification of which is the stamped-out circular holes on the legs, the one on the front right leg, the other on the behind left leg It seems that Beuys originally donated the Multiple concept and the right to sell the whole series to the Korff Foundation in Germany, a foundation which finances projects for children in Germany and worldwide.. In this case, due to the possibility of alternation, that is to say differentiation within the series, one may speak of The Orwel Leg as a conceptual object, and not as a prototype of a pair of jeans. The latter, in contrast, is the case with a pair of jeans, modified too, from 1957, with the mystifying title, Aquarius, which is the astrological name for the Water Carrier (not Beuys' constellation). The work is catalogued as an object belonging to a series named Healing Objects 1951-75 in the context of the first retrospective of Beuys' works, the famous exhibition organized by the Guggenheim Museum in New York in 1979 [2, p.216]. The Aquarius-object is a pair of the artist's own, old and outworn blue jeans. The modifications include the elongated slits in the leg cloth and the small patch attached to the band. Rather untypical in shape for worn holes, the slits are very probably made by force. The patch exhibits the imprinted circular logo or emblem of "Fluxus Zone West" with a red cross and a symbol of something that Beuys made use of in order to brand his actions, installations and drawings while being associated with the international Fluxus group during the late fifties and early sixties. Indetectable from the photo are a number fish bones stuck into the fabric. The Aquarius is in the private collection of the German medical historian and

art collector Hinrich Murken who acquired the "jeans as art", as he said in an interview in which Murken also stated that the imprinted patch, the slits and the fish bones in particular gave the jeans a fascinating expressive quality: "But the bones were what make the work really mysterious and puzzling and gave it the aura that it now has" [3].
Beuys' jeans based art works pose questions of authenticity and meaning, not only questions concerning the art status of his objects and actions with things, but also in relation to how the artist break into and disturbs the 'normal' trajectory of serial products.

The Orwel Leg series is based on preexisting, mass produced standard jeans, seemingly of the same model he used as part of his outfit. Beuys is not the origin or designer of these jeans, and in the first place, he or his assistants bought a pair of standard jeans in a shop somewhere, and the Korff Foundation or whoever has the right for producing The Orwel Leg have had to buy the jeans successively and subsequently modify them in accordance with, for instance, Beuys' written instruction or his first pair of modified jeans. One may say that Beuys is the designer of the first issued exemplar of The Orwel Leg which functioned as a prototype for the rest of the entire edition. His role as designer, rather than artist, is emphasized by the fact, that most of the edition until now has been produced by others than Beuys himself, at the latest from 1986 and onwards. The post-1986 exemplars of The Orwel Leg are not produced as reconstructions of the originally modified pair of jeans. On the contrary, the whole edition consists of singular realizations of a Beuys concept like this (for example): "a pair of standard blue jeans with circular holes stamped out on the front right leg and the left behind leg, both indicating the approximate position of the knees". All the jeans from the edition are authentic, and if two exemplars are completely identical, they are both still evenly original and authentic since they are made individually as singulars and may deviate from the prototype or, more correctly, the first original, without losing their status as unique manifestations of that particular work of art titled The Orwel Leg.

The original pair of standard jeans bought by Beuys or someone else is a specific and individual manifestation as is each pair in the series of 'jeans as art'. The original pair that was bought with the intention of turning them

into an art work by means of partial molestation, was chosen in a shop from a pile of identical jeans, that is, jeans of the same model, size and colour tone. The point of departure for Beuys could have been any item from that pile of jeans. It would not have affected the character and material or design quality of the first Orwel Leg. The subsequent manifestations of the artistic concept may have been realized on the basis of equally arbitrary choices from the right pile of jeans. The fact that allows for this arbitrariness or freedom of choice is, of course, that all the jeans are 'the same' only because they are all manufactured from one and the same prototype design and additional specifications and instructions with regard to materials and making. In the case of the uncountable number of standard jeans in shops worldwide, probably no original exists, and the first pair manufactured may be considered a curiosity, and maybe these jeans will gain a status as collectible. However, the very first pair and pair number 1000 or 1 Million are identical and have the same material and functional qualities, provided no alterations of the design or revisions of the instruction to manufacturers have taken place. Nevertheless, any single pair of jeans from any model and of any mark will inevitably have the potentiality of becoming one among a number of the unique and personal belongings of a particular owner and user, who has the occasion and right to handle the jeans as he or she may wish. For instance, the owner may hang them on the wall as 'jeans as art' in order to decorate or memorialize.

In this way, they share a cultural destiny with Beuys' jeans, though in different settings; in both cases, a pair of jeans has been derived of its performativity as garment and its practical function as protection of a user's lower body, and they are both attributed a new status as one exemplar of a 'jeans as art'' edition, and, say, 'jeans (as decoration) as art', respectively. The Aquarius case is different in one respect. The pair of jeans used here is the artist's own jeans, showing signs of wear and active elaboration. The change performed by Beuys are the applications, if one may say so of the elongated slits in the front of the legs, the undetectable fish bones, and the imprinted patch attached to the band above the left front pocket. While the applications are intended, the traces of wear are not, the latter being signs of both Beuys wearing the jeans while working, sitting, sleeping etc. and the

gradual outwash of indigo pigments. In principle, what happened to Beuys' individual pair of jeans is what any user-owner may experience in relation to his or her own jeans. On the one hand, the gradual alteration of colour and loosening of the twill structure of the fabric is the inevitable effect of wear and maintenance. On the other hand, from time to time user-owners add to their favourite jeans symbols, marks, patches, embroidery, tapes, coloured patterns or slogans in the same way as they voluntarily cause marks of molestation by means of scissors, knives, and other instruments. The aim of this performance may be to indicate the owner's individuality or the owner belonging to some sub group. Formally, there is no difference between Beuys' actions in relation to Aquarius and what the average user-owner of jeans may do to them, since ownership grants the privilege freely to create details not inherently part of the jeans as once being bought in the shop. Of course, the average user is also free to hang a favorite pair of jeans on the walls of the living room as a gesture of veneration or because they are seen as a suitable decoration.

The only special thing about Beuys' Aquarius is the art status of this particular pair of jeans, a status that is guaranteed not by their specific physical or functional characteristics but by their status as being a part of a celebrated, yet controversial artist's oeuvre. This transgression of the sphere of the ordinary by a pair of regular jeans is due to a kind of institutionalized mystique that eventually is of no concern to this paper. It should be noted, however, that the mechanisms hinted at above in relation to jeans are also active in the case of Beuys' general oeuvre. The prominence of one of the most famed and discussed artist of the second half of the 20th Century suffice to ensure any of his objects the status of an interesting art work and to turn this object into a collectible. What characterizes this process is that the Beuys' signature establishes a Beuys-type, thus any of the pictorial, material, theatrical and other kinds of rebuses he is famed of are Beuys-tokens, while each of the works has individual characteristics, even if, as in the case of The Orwel Leg, the work is a Multiple. The legend of Beuys' jeans may seem to be but a metaphorical use of the mechanisms governing the acquisition of status and meaning in serial products, but the general point is that any serial product has a triple status, and one and the same object refers to three

identity contexts, which is, at the same time, three logics of meaning formation. Firstly, it is an individual object characterized by its physical quality. Secondly, it is a member of a series of identical objects, and, thirdly, the identical qualities are determined by the design, that is to say, the design process as concluded by the final version of a prototype or a model which does not have to exist, showing or comprising the same material qualities as the serial object. In other words, the issue at stake here is the relation of the individual serial product to the model, hence the meaningful connection between the singular object, the users legal property, and its designer. In the end, an interconnected question may be asked; by which means are the intentions of the designer as revealed by the model transferred to the final user? Has the designer a real opportunity of protecting himself or herself, as well as the commodity against completely arbitrary meaning attribution from the side of actual user(s)? Is it the designer's job more likely to enable or service the user-owner in her or his efforts to turn commodities, physically or mentally, into rarified, unique signs of personal or collective identity?

## 2 Model and Series
The problem of the model and series as presented above, has been addressed by a few scholars in a way that has had an echo in subsequent research in design semantics and semiotics. Two contributions stand out, the first of which to be referred to in the present context is Jean Baudrillard's chapter on "Models and Series" in part four of his early critical work, Le système des objets published in 1968, English translation some 30 years later [1, pp. 137-155]. The chapter, as does the book in general, focusses on the market as the cultural matrix of late capitalism, that is to say the cultural function of consumption. In his discussion of the relationship between what he terms 'model' and the serial product he makes some interesting observations concerning the dialectics of uniqueness and multiplicity in serial objects. Only two brief comments should be made in this place on Baudrillard's theorizing, remembering also that the book represents a round off to his occupation with design matters during the sixties, and that in 1970 he served as a member of the jury of the 'Compasso d'oro', the design prize presented by the Milanese department store, La Rinacenta, the same year he attended the legendary design congress in Aspen, Colorado as a keynote speaker.

First, it is worth noting that his distinction between model and series seems surprisingly insensitive to the reality of industrial design. This means that a 'model', as he defines it, always is superiour to a series; models have 'style', that is to say, a specific chronological and geographical identity, while series products have no such characteristics. In his view, models are originals, the series products are imitations or copies of the original. This also means that the serial product is of inferior cultural value in comparison to the model. For example, he exemplifies the differences between model and series by citing a prestigious car, the Facel-Vega, as opposed to a Citoën 2CV, or between haute couture in contradistinction to ready to wear garments. One of Baudrillard's most puzzling ideas is expressed in his statement that at the level of "pure function … there cannot be any models …". In general, he plays down the meaning of what he calls the "primary function" of objects. And as he suggests a process of "personalization" as part of the operation of "the psycho-social dynamic of model and series", he only leaves room for this process at the level of the "secondary function" of objects [1 p. 140].[1] Finally, it seems that to him the privileged instantiation of personalization is the process during which art works attain their metaphysical value. But this model applies to industrial artifacts only on rare occasions, such as the fictional one alluded to above where a user is hanging jeans on the wall in a place usually reserved for posters, prints or paintings.

However, the standard situations in everyday life with their numerous, trivial examples of people making use of objects in their doings, are no more than hinted at in Baudrillard. In everyday life tools, articles of furniture and clothing, etc. continuously afford their assistance to their users and perform their function as expected and, at the same time, the objects in question are personal belongings that gradually receive traces of having been used or soiled. The effect of this daily intercourse is that the user-owner may be able to recognize the particular object – his or her object - among hundreds of similar objects. Eventually, in everyday life the process of 'personalization' is not least a material one.

Second, and in order to proceed from this point, what is missing in Baudrillard's essayistic reasoning is a more focused discussion of actual processes of

[1] This argument is very similar to Roland Barthes' distinction between 'denotation' and 'connotation' [14 p. 89].

personalization. The determinations and definitions offered in the text are merely abstract semiological references to t systems of differences as the cultural system. Such a discussion could have been informed by ethnographies of groups and individuals. In relation to jeans, a number of such ethnographies have been published recently along with cultural histories of exemplary cases within the framework of the international research project, Global Denim [4]. The absence of a more elaborate strategy of how to get valid knowledge of the processes in which things are being personalized, has as its consequence that Baudrillard does not really provide a methodological framework for addressing how, where, when, and why these processes of appropriation are accomplished.

Another keyword for such processes is 'singularization', as suggested by anthropologist Igor Kopytoff in his contribution to Appadurai's seminal book on the social and cultural trajectories of commodities [5, pp. 64-91]. In his search for a symbolical economy (or "moral economy" as he writes) behind the monetary framework of exchange, Kopytoff discusses the processes of commoditization and de- or recommoditization, and his general point is that the decommoditization is a precondition of singularization, a process which implies that objects are "culturally redefined".[2] Not the change of status per se, nor change as such is enough to allow for the singularization to take place [5, p. 67]. The social position of singularized objects is due to the fact of "being pulled out of their usual commodity sphere" [5, p. 74], hence the objects have become "priceless", meaning either "uniquely valuable" or "uniquely worthless" [5, p. 75]. There are several forms of decommoditization and singularization, both public and private – from a state enforcing singularization of places, buildings, and objects – via change of status by social groups to the common consumer using applications or other alterations to single out, say, a pair of jeans.

According to Kopytoff's analysis the logic behind this is that in complex, capitalist and heterogenous societies the in-build and dominant tendency of the market economy is to subjugate and commodizise whatever can be turned into marketable entities. On the other hand, Kopytoff states:

There is clearly a yearning for singularization in complex societies. Much of it is satisfied individually, by private singularization, often on principles as mundane as the fate of heirlooms and old slippers alike – the longevity of the relation assimilates them in some sense to the person and makes parting from them unthinkable [5, p. 80].

The 'assimilation' issue in relation to singularization is of special interest in the present context. Singularization is not necessarily the same as privatization. The intertwining of persons and objects may reflect general cultural patterns, for instance when specific groups or classes of objects for some reason or another are conventionalized as signs of a social category, once named status symbolism. Singularization concerns not only the kind of assimilation Kopytoff points at in the above quote, but includes also the social dynamics of singling out objects as something special and of invaluable importance to national heritage, cultural identity, etc. In this case, singularization is effected by use of various forms of power based on the possession of necessary amounts of a relevant type of capital - political, economic, social, cultural, rhetorical, etc. All this is actually included in Kopytoff's grounded theorizing, but the core question of how, where, when, by and for whom things are singularized is only answered in general terms, while instantiations are what they are, namely concrete ethnographies that do not add up to a proper theoretical stand, nor do they outline methodological strategies that may stimulate further scrutiny of the double and triple statuses of objects. What will be the concern in the remaining part of this paper is, firstly, the theoretical issues of how to identify what may be termed the status stratification of serial objects; next, this theoretical framework will be applied to the case of jeans, not in the shape of concrete ethnographies, but of an analytical model. And finally, the possible role of design (the design process) will be addressed speculatively. In this connection it is worth noting that neither Baudrillard, nor Kopytoff are focusing the fact that the objects they talk about, the consumer's commodities in the market and the user's personal belongings, are not reflected as forms the character of which has been suggested or determined by a form-giver, a designer.

The theoretical framework to be introduced briefly and applied more or less schematically to the issues of model and series is Charles S. Peirce's sign theory.

[2] It is Kopytoff who introduces the term 'commoditization' (with various prefixes). This spelling will not be questioned here, though other writers (including the present writer) prefer 'commodification'.

## 3 Things and Signs

In contradistinction to the various semiologies bases on Saussure's structural linguistics, in the case of Peirce's theory of a general semiotics, we do not have to operate by means of metaphorization. While Saussure's is a theory of conventional signs, the privileged instance of which is language signs and sign systems that function as the system of language signs do, Peirce's semiotic theory is based on the assumption that anything may function as a sign in so far as it is actually perceived as a sign of something. This is the first general point to be made in this context. The next is that in Peirce for anything to be understood as a sign it must exist as a perceivable entity. Both conditions are of immense importance to any attempt to explore the functions of things as signs.

To put these arguments more precisely, anything is not a sign per se, and the implication of this is that meanings do not simply reside in things, nor does it in designed objects. At the very moment an observer (onlooker, listener, etc.) decides to take something for a sign, a meaning of that sign is inferred, and this inference is grounded in the observer's mobilization of relevant quantities of acquired knowledge, learning, proficiency, understanding, and mental disposition as well as a fund of life experiences. What trigger off the inferential act is the specific interests that urge the observer to try to understand what exists or happens around him or her in order to sense, conclude and act accordingly. This is why things and actions may mean differently to different observers and actors.

Another point is Peirce's stipulation of the physical character, the material quality, of a sign manifestation. European semiology or semiotics is based on metaphysics, a metaphysics that does not evaporate when applied to meanings generated by material substances. In Peirce a sign manifestation is defined as (1) an interpretation of the materiality, hence sensorial characteristics, of the sign; (2) The interpretation is accomplished by either focusing exclusively on the material features, or by relating the perceived material features to something else. This other is what the material features actually are (or have been) in direct relation to, or what a convention has established as a interpretative rule; (3) The interpretative act takes place in the mind of someone who has an interest in knowing the meaning of something that comes to the same someone's mind via the senses.

More formally, the above points are phrased like this in a definition from 1897, at the time Peirce used the term 'representamen' as substitute for 'sign', since the meaning of the latter may be confused with his general use of the same term:

A sign, or representamen, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the interpretant of the first sign. The sign stands for something, its object. It stands for that object, not in all respects, but in reference to a sort of idea, which I have sometimes called the ground of the representamen [6, 228].

The general point is that all three components in the triadic structure of the sign – representamen, object and interpretant - are in play in a sign process, a semiosis. Peirce's semiotic theory is notoriously difficult to summarize since the theory was revised from time to time without reaching a final or conclusive form. As indicated above, he also employed various terminologies for his many differentiations. However, without any ambition of presenting an infallible representation, the model below is intended as a cumulative overview of Peirce semiotics.

In addition to the illustrative function of this model, it also makes explicit the underlying phenomenological structure of Peirce's thinking. His phenomenology (or phaneroscopy, as he also termed it) represents an attempt to reduce radically the number of categories to three. Instead of the 10-12 proposed in Aristotle's and Kant's epistemologies, it is Peirce's claim that all that is needed is to reflect that phenomena may exist as a first due to its inherent qualities; as a second referring to the relation of a quality to something else; and as a third since a phenomenon may exist meaningfully as such because of a law, a convention or a tradition. This categorization establishes the three so-called trichotomies. The places of operation for the trichotomies are marked by bold lines, arrows and dots in the model which, by the way, happens to be an icon, more specifically a diagram.

The icon is defined by Peirce as a sign, the meaning of which is based on its own qualities; the implication of this is that representamen share at least some

of the qualities the object has. The icon, then, is a representation that represents the object because of its own perceivable qualities. In other words, qualities are what matters in relation to icons. And qualities as analyzed in the first trichotomy are what are of interest in the present context. This means that 'the rest' of Peirce's notoriously complicated sign theory is left out here, with a few exceptions, in order to concentrate on the qualities of things as signs that exist in reality as design(ed objects), that is to say, the physical dimension of meaning as opposed to the metaphysical. There exist recommendable general introductions to the whole of Peirce's semiotic theory [7], [8], [9], while the following as elucidation is but an emergency ration.

This means that the determination of the qualities of signs has its own trichotomic structure: tuone is a first, token is a second, while type is a third. And again, tuone is a quality that functions as a sign, as when the very experience of a particular colour tone of blue is taken for a sign. Token refers to a blueness that functions as sign qua its actual presence as a determining quality in a specific case.  Finally, it is a type if a specific blue colour tone is a sign by convention, as is the case in all instances where blueness is an all-embracing and inescapable, 'law like' quality defining all manifestations of that particular sign.
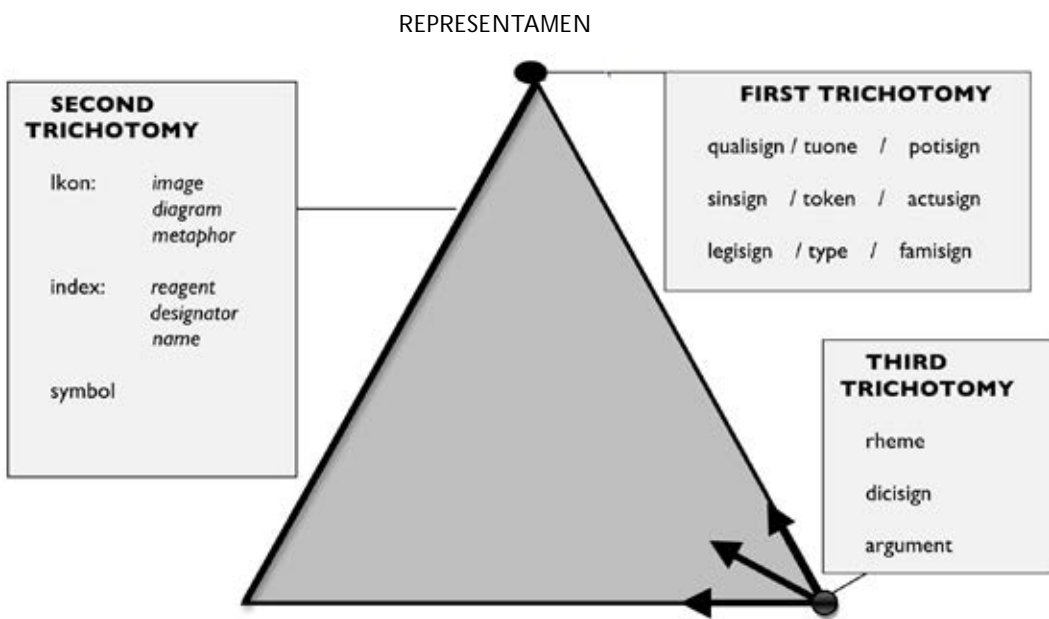
REPRESENTAMEN



**SECOND TRICHOTOMY**

Ikon:  image
diagram
metaphor

index:  reagent
designator
name

symbol

**FIRST TRICHOTOMY**

qualisign / tuone  /  potisign

sinsign  / token  /  actusign

legisign  / type  /  famisign

**THIRD TRICHOTOMY**

rheme

dicisign

argument

Fig. 1. **A cumulative model of Charles Sanders Peirce's semiotics.**

As indicated in the box concerning the first trichotomy, Peirce used various terminologies in different version of his sign theory. Since the term prototype has been used previously, the register of tone, token, and type [6, 4: 537] is used here. In one place he radicalized the idea of tone by terming its specific qualitative modality tuone (a modification of the terms tone and tune). By that he wanted to stress the very uniqueness of quality [10, 339d: 533]. Following Liszka's definitions, the first trichotomy of qualitative modalities is about the "presentative character" of signs [8 pp. 35ff.].

A very short version of this idea applied to design is, for example: the mug I am using for coffee in my office at the university has a number of traces of having been used (the rim is chipped in one place) and only cleaned occasionally. My colleague in the office next to mine has a similar mug and uses it for drinking coffee and, occasionally, tea. My mug is my mug, and I will never mistake it for my colleague's because of the chipped rim. We have both received the mugs some years ago as a gift from the university's vice-chancellor. In fact, all university staff have the same mug, and therefore I immediately wrote my initials on the bottom side with china painting in order to avoid future mistakes. The whole series of mugs were produced on the basis of an anonymous design, and the occasion that inspired

the vice-chancellor to act as a donor of china ware, was a board decision on a branding strategy which should bring public attention to the university, and at the same time engage the staff in discussions and the dissemination of the so-called values of the institution. To this effect, three value indicating slogans were printed in decorative bands on the exterior of the mug.

According to Peirce's concepts, my mug is a toune, in that chippings, cracks, and initials give it its unique quality, while my and my colleague's and the rest of the staff's mugs are all tokens, that is, singular examples from the series of university mugs, and they have all the potentiality of becoming singled out as tuones by being used intensively and by application of letters, figures, labels, etc. The shared quality of all the mugs is determined by the vice-chancellor (or the management, or the board) with a designer's professional assistance, hence the designer's final model or drawing functions as the proto-type of the series of mugs distributed around at the university's campuses.
One may now ask how the meanings referring to the quality of the mugs are established, and how far the designer's decision about material, shape, decoration, etc. affects the meaning of my mug considered a sign – by me and people around me who may encounter my 'private' coffee-mug. Suffice here to say that it depends solely on what is found relevant or necessary to know about it and – to be sure – which status is of interest: my mug, the mug as multiple, or this particular university mug as a particular type.

## 4  Jeans as signs
The exciting story of blue jeans will not be repeated or summarized here, though the function of blue jeans as cultural signs seems to be an inexhaustible source of information in relation to the issues discussed in Baudrillard and Kopytoff. And also, the function of jeans as artistic outfit and as works of art in Beuys depends to a certain degree on the histories and mythologies of jeans. As a case, the history of jeans is perfectly suited to serve as illustration of Peirce's semiotic thinking, both in general and in the particulars of, for example, the trichotomies.
However interesting this story is from a design historical perspective, the efforts in the present context are concentrated on the material aspect of this type of

trousers, and the kind of meaning construction draws on design, colour, texture, etc. of denim.[3] This means that once again the focus will be on the firstness, secondness, and thirdness of the firstness of the sign, i.e. the presentative capacity of jeans as sign, while the secondness of the sign's secondness – the index sign - will be included briefly.

A few remarks should be made in order to pin down an historical point of reference: The most famous jeans design is undoubtedly the Levi's 501. The first patented design was introduced in 1873. At that time it had three riveted pockets, two in front, and one behind. Later a second back pocket was added, and still later the small, so-called watch pocket was introduced. This five-pocket model is the distinctive form of Levi's 501 as far as the number of fabric units is concerned. Other distinctive features are the yellow stitching, double arcuade on back pockets, visible out seam, felled inseam, copper rivets, etc. Many of the design historical details of Levi's 501 are not settled definitively, but the introduction of copper rivets and the successive expansion of the pocket system from three to five units are documented in the archives of patent agencies. The first application for the 501 patent was based on the inventions made by a Reno tailor, Jacob Davis, whose supplier of fabric was a San Francisco merchant named Levi-Strauss. Davis offered Levi-Strauss a partnership in order to be able to finance the application for the patent, and by May 1873 the rights were granted. Several versions exist of the story of what gave Davis the impetus to invent this type of wear-proof dungarees, but it seems safe to conclude that he is the first to be credited the design of Levi's 501. The basic design has been modified several times. Its cut, especially in relation to the width of the legs, has changed gradually to keep pace with shifts in fashion. The Davis patent of 1873 is the master prototype, and in technical terms all subsequent modifications and adaptations of the original to fashion trends establish different prototypes, irrespective of how the modifying process is named: design, redesign or styling. However, the following arguments are based on the assumption that the prototype simply is a generic pair of Levi's 501 without considering their exact chronological and sociological dates.
In one form or another, Levi's 501 exists as a prototype, in Peirce's terminology: a type or legisign. The latter term means literally law sign, that is, a sign which

[3] For the time being, the most reliable accounts of the history of jeans are Sullivan [15] and Marsh & Trynka [16], while Miller & Woodward [4] include a number of fresh perspectives on both the history and cultural function of jeans.

meaning in terms of quality is a convention or rule. The function of the type is to stipulate the qualities of any materialization of the specific features that make an identification of type possible. Each instantiation of the type is a token of the type, also named sinsign, as registered in the schematic rendering above, meaning the actual, singular manifestation which is, in fact, a singular existing among identical singulars, each of them owing collectively their specific qualities to the type. As tokens, any exemplar in the series of tokens is replaceable by another exemplar from the same series. Tokens may gradually alter or suddenly change and thereby begin to diverge from its siblings. Alterations and changes produce a unique quality, a quality which singles out one particular token as a tuone (or qualisign) having now something of its own, and consequently becoming irreplaceable.

It is the tuone quality that allows for and facilitates processes of personalization and singularization. In relation to jeans, this is a point stated in several studies of jeans culture and in a number of ethnographies in relation to the Global Denim project, referred to above, in this and other contexts Sophie Woodward also employs the term 'personalization' [11], [12]. It should be emphasized that singularization also may be the case if blue jeans are established as part of a dress code for members of, say, a biker's club. In this instance, the singularization refers either to the token quality, in so far as it is stipulated that mark and model is, say, Levi's 501, or to the type, if the conventionalization only have a general reference to black jeans, for instance, as a piece of apparel. In the latter case, any pair of black jeans represents the required quality, blackness, irrespective of design, cut, or trademark, etc.
The type Levi's 501 warrants for the authenticity of any pair from any pile of 501s in any shop around the world. If a pair of 501s are lost or damaged during a trip abroad, an unproblematic replacement is possible as long as the wearer's need is confined to having the opportunity of wearing 501s. Any 501s will replace any other pair of 501s as long as focus is on 501 tokens. The type guarantees that the pair of jeans with 501 qualities bought in a shop somewhere is the real deal and that the price is acceptable, compared to cheaper jeans, which very probably have similar, but not identical, functional qualities. The wearing of 501s may secure acceptance among the user's peers. The opposite may

be the case if wearing of this particular mark and design of jeans is politicized for one reason or another, to the effect that wearing as well as not-wearing become a manifestation of a political standing. Semiotically speaking, for instance, non-wearing becomes a sign of protest to those fellow citizens who are familiar with the political code. The type may in this context be subjected to a boycott, and this means that the very appearance of 501s tokens on the lower body of a user causes condemnation from the surroundings. The user's relation to his or her 501s tuones may in this case be rather traumatic and something that has to be taken care of only in privacy.
The only quality at stake in relation to political activism is what establishes the type and not the functional qualities. Loyalty and disloyalty are a matter of attachment to or distancing from immaterial values that are shaped by culture. Of course, loyalty may arise from and grow in the course of the users long termed use of and interaction with a pair of jeans. The effect of this is that gradually the tuone quality develops and the relationship will pivot around that quality: the jeans eventually become representations of the user, and the user becomes a representation of the jeans. In order to unfold this argument, some ideas have been offered by sociologist Tim Dant, who has described nicely the appropriation process and what happens to jeans during periods of wearing and maintenance [13 pp.102f.]. The transformative potential of jeans with regard to their function in introducing alternative garment norms for both sexes in the 1950s is summed up by Dant as follows:

Jeans went against the grain of the dominant clothes culture of western modernity and reversed many established clothing signifiers. They were made of cotton (vegetable) instead of wool (animal); fixed in shape instead of tailored; had visible seams but no pressed creases; revealed the form of the body rather than covering it [13, p.103].

In particular, Dant wants to explore the last point concerning the body-clothing relation, while he only cites a growing number of accounts of jeans as fashion and of the design history of jeans.
Instead he focusses on "the nature of the material form" and what he calls the "ambivalence of meaning" [13, p.103]. The ambivalence hinted at relates to the many shifts in jeans' cultural meaning, from work wear to high fashion, but in the following, the issue of

ambivalence or, better, polysemy will be related to the nature of material and form, and this implies that Dant's observations are partly underlined, partly reworked. Most interesting is Dant's description of how the twilled denim gradually takes up the shape of the wearer's body. This is due to the thickness and stiffness of the denim which means that it is stretched against the skin, at least in the beginning. One may add that being worn and washed regularly, the fabric is gradually softened and becomes more flexible, thus the jeans will be even more 'susceptible' to the imprints made by knees, thighs and buttock. The result is that the jeans and their intimate coexistence with the wearer eventually turn into an icon for their user as they adopt the shape of the body. Originally a neutral envelope, now a second 'skin' the jeans function as a membrane reflecting the shape of the lower body and having developed the same shape as the wearer. The fact that the adopted jeans are an iconic representation is due to another fact: the iconic sign function is made possible only because the jeans also are an index, since the form modifications of the jeans is caused by the direct contact between them and their wearer.

In addition to this, the jeans may also over time reveal the wearer's habits as to sitting position, the placement of knees in relation to chairs, tables, etc., just as the jeans receives additional imprints of use: spots caused by tints of paint, acidiferous foods and liquids and the like as well as traces of small and big accidents with tools, climbing, falling, etc. All of this causes a process during which singularization and personalization become increasingly manifest. Such personalized jeans are indeed irreplaceable. Though, from the perspective of both type and token, the tuone quality is arbitrary.

The course in the direction of personalization may also go off another way as immaterial values, experiences and events, so to speak, are materialized by means of projection. The presence of the jeans in the life of the user implies that they may also function as a material anchorage for memories, dreams and traumas. They become monuments in and of the owner's life, and their presence is a constant reminder of events, people and happy hours, thus they are difficult to get rid of since they are a part of the owner's self. On the other hand, the scrapping and rejection of the jeans may be furthered in situations in which it becomes evident

that the many visible and invisible traces are no longer 'removable'. The jeans again function as a constant reminder, but this time of past events, people or feelings that the owner now wants to remove from the fund of memories. The jeans are disposed of as abjects, and the owner-user gains a new freedom of thought and action. To others the traumatized jeans may have appeared as a pair of ordinary, standard jeans, but to the owner-user they had an ambivalent, not to say intolerable, tuone quality that, however invisible, to a considerable degree limited his or her freedom.

## 5 Designing Qualities – A Double Strategy?

The jeans case is not unique to the realities of design and product culture. The observations made here may be adapted to other cases with due revisions of perspective if and when the model-series relationship is in focus. For example, one may ask how to identify the design issue in relation to the meaning function of the material dimension of design objects and product culture in general.

From time to time, the work of designers is self-evidently required as fashion trends demand changes, unless such changes are solved on the factory floor by the manufacturers' technical staff. The designers' contribution is certainly needed if jeans are planned to be marketed in the upper end of the fashion system as a creation by a designer with a high profile. And it is known that designers once were asked to include so-called slob lines in the fabric in order to facilitate and accelerate the appearance of traces of wear and tear. The 'correct' look of vintage jeans is considered a sign of age, but in this case age is a material illusion, while the tuone quality is genuine. The same may be said in relation to other techniques of artificial aging, such as stone wash, chemical de-dyeing, removal of the weft in selected places and other forms of intended decomposition of the fabric. In such cases aspects of design are involved in defining the effective quality. However, the material effects are developed arbitrarily since whoever decided the catalyzing attack on the fabric only initiated the process, not its actual direction. Then, one may state that in cases like these, users realize the designer's intention, that is to say, they are in fact completing the design process, while this is not the case with the university mugs discussed previously. In the latter case, partial destruction is caused by inappropriate handling.

The example of the production of tuone qualities in jeans makes some challenging dilemmas of design evident. It is obvious that the designers' job is best understood in relation to the production of prototypes, and the jeans case also indicates that the design may have a long termed impact on alterations, though the alterations in question are in fact also processes of accelerated decomposition. And in principle, this policy is not dissimilar to the strategy of planned obsolescence introduced in the 1920s. Both types of decision making are allegedly a service to consumers. Without moral pretentions, the question could be asked how far designers should be concerned with the material destiny of their designs, or to what degree the fate of materials has to be prefigured in and by the qualities of the prototype. In some cases, consumers would want, even need, things that are pre-demolished, in other cases they would certainly not. The jeans case obviously reveals that for body related designs to which an intimate relationship may develop singularization and personalization are at the core of how users relate to their things. The effect of singularization and personalization is the creation of a particular quality, both physical and emotional – a tuone quality.

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# Embracing relational agency in design process

## Abstract

Our research investigates how the design process can accommodate a relational view of agency. According to the relational view, agency - or capacities of action - is neither an attribute of subjects nor of objects. The relational view of agency in design may allow designers to recognize and support the diversity and richness involved in human agency. To this end, we developed six design qualities to embrace the relational view of agency in design process. Using these qualities, we have created design inscriptions in the forms of materials and process constructs and applied them in a series of participatory design workshops, focusing on the notion of connectedness. We present how effective our inscriptions were in supporting the ASD qualities in each workshop.

## Keywords

Design process, relational agency, participatory design, Actor-Network Theory.

## 1 Introduction

The concept of agency is defined in its simplest sense as the capacity for action or transformative capacity [1]. Yet, there has been ongoing debate surrounding definition, emergence and possession of agency in artificial intelligence, cognitive science, philosophy and many other fields. One particular point of controversy is related to the attribution of agency to entities.

As opposed to the traditional humanist view of agency as a property of individual entities, Barad [2] suggests that agency is not an attribute of subjects nor of objects or systems but is the ongoing reconfigurations of the world, an enactment. Agency emerges out of the dynamism between entities.

Our research aims to explore how design process can embrace the relational nature of human agency. We suggest six qualities to characterize a more relational design approach referred to as Agency Sensitive Design (ASD): relationality, visibility, multiplicity, accountability, duality and configurability. We used qualities in a similar way to those featured in Bardzell's [3] study. Bardzell developed a "constellation" of design qualities as part of a feminist interaction design program focusing on values like agency, empowerment, diversity and social justice. The qualities we propose are similar to those developed by Bardzell. However, somewhat different from Bardzell's approach, our qualities primarily focus on ways of promoting relational agency: more in the nature of process-oriented qualities characterizing how a design process might embody a relational view of agency, our qualities provide conceptual lenses through which to gain a relational understanding of the situation. As well, they aim to increase the designers' awareness of relationality of human agency, i.e., the relational, embodied and situated characteristics of human action, allowing them to tune their practices to recognize and support the diversity and richness involved in human agency.

In the paper, when required, we used the term human agency as a convenient way of highlighting the main actor of interest in a situation. It is a term just to refer to the human side of the relational agency. It is not problematic to use 'human' in front of agency as long as one is aware of the relational nature of agency. In this study, we run two parallel streams of research: research into ways of integrating ASD qualities into design process; and research into various forms of connections between humans and technologies. In parallel to this, our evaluation has two streams: we evaluate the forms of connections and, as well, our ways of exploring the forms of connections.

## 2  Design and Agency

Design activities, in varying degrees, ultimately aim to create, modify, enable and/or constrain some capacities of action through designed artefacts. Designers inscribe values, visions, programs of actions and modalities of perception into technology design. Akrich [4] explains the notion of inscriptions in technology design in the following way:

Designers thus define actors with specific tastes, competences, motives, aspirations, political prejudices, and the rest, … A large part of the work of innovators is that of "inscribing" this vision of (or prediction about) the world in the technical content of the new object. To be sure, it may be that no actors will come forward to play the roles envisaged by the designer. Or users may define quite different roles of their own [4, p.208]

The technical content of the objects embodies a script similar to a film script, defining the actors, roles and their settings [4]. A script involves, in varying strengths, "programs of action" that are "translated" in practice [5]. Translations are processes in which "the identity of actors, the possibility of interaction and the margins of manoeuvre are negotiated and delimited" [6, p.203]. However, should the translation processes vary, these inscribed programs of action may not succeed; in addition, actual interactions between entities may unfold in unexpected ways.
The strength of an inscription may vary from very strong, that is, imposing one particular inflexible program of action, to very weak, offering many flexible programs of action. Increasing the strength of an inscription can also be considered as an attempt

to confine the relational character of human agency. Strong inscriptions belong to a perspective of design that aims to predict, prescribe and control the kind of relations between humans and technologies and the ways in which their interaction unfolds. Repeatability, consistency and reliability are particular kinds of qualities that characterize the human-technology interactions shaped by strong inscriptions. Although these are definitely desirable qualities for some settings such as legal, medical and educational, they may not be very suitable for some other situations where appropriation, personalization, adaptation, entertainment and exploration are needed [7]. In practice, the human-technology interactions may happen in unexpected ways or as Akrich [4] pointed out users' definitions of roles may deviate from the intended roles. Thus, rather than assuming agency as a predictable and fully controllable phenomenon, we may acknowledge its relational character and develop sensitivities to manage relationality in the design and use of technologies. In this way, we can see relationality with its ambiguities and contingencies as a resource for design [7] [8] and formulate design solutions to deal with unexpected situations that may happen during the use of technologies.

## 3  Towards a Relational Approach to Design

A relational approach to design process might be beneficial in many ways: i) it provides resources and mechanisms to deal with unexpected situations [7] [8]; ii) it supports responsible and ethical practices by recognizing and supporting different and marginalized actors, and their ways of knowing and doing things [9]; iii) it supports the creative potential of users by supporting user appropriation and what Aanestad [10] refers to as design in use; and iv) it supports innovations by making design process as open and as inclusive as possible [11].

Our approach to developing a relational approach to design is referred to as Agency Sensitive Design (ASD). Our aim is not to replace existing design methodologies but rather to complement them by developing sensitivities in the form of design qualities. The fundamental principle of ASD is recognizing and supporting variety in the formation and exhibition of agency in the design and use of technologies. This principle includes a large range of aspects

of relational agency in design. In a design process, while the formation of agency refers to the construction of a heterogeneous network or assemblage of human and non-human actors, exhibition of agency refers to the effects of that network. We need to recognize the influence of multiple sources on design problems and then find ways to consider their concerns and effects. Similarly, we need to support variations in the network's effects, i.e., the collective actions of actors. However, it is important to note that variations in the network's effects may not be desirable for safety critical or high reliability required situations. Thus, relationality should be tailored very carefully in these cases.

Drawing upon the extant works and approaches in Human-Computer Interaction, Participatory Design, Actor-Network Theory and Science and Technology Studies, we developed six design qualities: relationality, visibility, multiplicity, configurability, accountability and duality. These broad categorical qualities, which may overlap and be further divided into a few other qualities, provide a useful starting point from which to articulate some of the implications of a relational view of agency for the design process. As well, they aim to increase the designers' awareness of relationality, allow them to tune their design practices to accommodate the diversity and richness involved in human agency. In the next section, we will explain these qualities briefly. For an extended presentation of these qualities, please see [12].

### 3.1 **Relationality**

The quality of relationality refers to the connectedness and relatedness of human and non-human actors comprising heterogeneous networks [5] or socio-material arrangements [13] in which humans and non-humans co-constitute each other through their interactions. According to Suchman, relationality emphasizes the "relational character of our capacities for action, the constructed nature of subjects and objects, resemblances and differences; and the corporeal grounds of knowing and action" [14, p.3]. In design processes, the quality of relationality asks for three sensitivities: (i) understanding of mutual influence, shaping and co-constitution of actors and artefacts; (ii) embracing and supporting emergent and improvised action and (iii) consideration of the system as an assemblage/network of actors, artefacts or collective hybrids. In order to develop these sensitivities, we first need to stop formulating design solutions based

upon the assumption of a well-defined individual with fixed characteristics and capacities of action. Design solutions should recognize and support the existence of the multiple individuals embodied in one individual and the possibility of multiple enactments of one individual within a network of other human and non-human actors interacting with each other and exhibiting different capacities for action [11]. Rather than prescribe or control, we may design for appropriation and design-in-use, interactive systems do not impose a particular pattern of action; rather, they provide a space of negotiation in which individuals can exercise their "multiple" capacities of action in creative ways.

### 3.2 **Visibility**

Visibility, one of the most essential qualities, facilitates responsible design and the emergence of different arrangements or couplings between humans and technologies. The quality of visibility, which plays a key role in developing other sensitivities such as multiplicity and accountability in the design process, involves variously making visible invisible work, human and non-human actors, and infrastructure and interactions in both design and use of technologies. Visibility not only facilitates a heightening of the overall awareness of human actors of themselves and of others, but also helps the performance of more responsible design practices [9] [15] and discovery of new opportunities, constraints and matters of concern in design process [5].

Quality of visibility operates in both technology design and use. Visibility in technology design refers to recognizing every human and non-human actor and their roles in the formulation of design problem and the design process. This means that the different values, views and concerns of the human actors - and various affordances of non-human actors - need to be explicated and considered. Moreover, the term 'visibility in technology use' refers to keeping the boundaries and interactions between all humans and technologies distinct and observable. Seamful design [7] advocates the use of (beautiful) seams in interactive systems: seams can be basically gaps and breaks in functionality, and boundaries between different components or systems. Seamful design deliberately makes the seams visible and encourages system users to appropriate them as a resource for reflection and creative engagement.

### 3.3 Multiplicity

The quality of multiplicity refers to multiplicity in ways of knowing, performing and representing, which entail participation of multiple and heterogeneous sources of influence in the design process. Collaborative, generous and flexible methods and tools such as sketches, low-fi prototypes, rich pictures, and cartographic maps could prove useful in obtaining multiplicity in representation. These rich representations are particularly important vis-à-vis keeping the concerns of the different stakeholders or multiple sources of influence visible. While the design process can embrace multiplicity by supporting participatory, democratic and open practices together with rich representations of multiple partial forms of knowledge, design artefacts can embody multiplicity by utilizing flexible, context-sensitive and adaptive mechanisms.

### 3.4 Configurability

The design process does not stop after the technology production phase but continues in the actual use of technologies. In this broader view of design, the activity of design continues in the sites of technology use and is performed by users in the role of designers [10]. Aanestad describes this activity as 'design in use', a process which mainly involves continuous organization of activities and the re-configuration of relations between human and technological actors [10]. Users may opt to reconfigure or customize technologies and tune their relationships with technologies. The quality of configurability asks for developing mechanisms of supporting design in use or tuning operations during the use of technologies. This can be achieved by designing open, modular and flexible technologies. Kahle defines "openness of technology" as "the degree to which it empowers users to take action, making technology their own, rather than imposing its own foreign and inflexible requirements and constraints" [16, p.35]. The quality of configurability, inline with other qualities, supports variety in the formation of human capacity of action. By virtue of their modular and flexible structure, technologies may become less isolated and take part in a network or ecology of other technologies and humans [3] [11].

### 3.5 Accountability

The quality of accountability is applicable to both humans and technologies. Button and Dourish [17]

define accountability as the property of action being organised so as to be observable and reportable. Whereas accountability of technological systems entails the existence of accounts that systems provide users with information about their own activities [17], accountability of human actors requires them to be aware of their own position relative to other actors and taking responsibility for their own perspectives and partial knowledge [18]. The quality of accountability might be promoted by making visible the actors, roles, their locations and system accounts. However, an essential part of the designer's task is to provide other actors involved in the design with resources for increasing critical awareness of the notion of located accountability and its implications.

### 3.6 Duality

The quality of duality refers to consideration of the dual characteristics of design decisions. Van der Velden [9] maintains that technology is never neutral; neither in use nor in non-use. Dual characteristics of design decisions should be considered. Duality can manifest itself in many forms, e.g., privileging/ignoring, inviting/inhibiting and amplifying/diminishing. Our designs can privilege the values of some actors while ignoring the values of some other ones [15]. The inscription of values into technologies is inevitable. However, the problem is less about the inscription of particular kinds of values and more about the invisible, unquestioned and taken for granted values embedded in our thinking and practices. Parallel to the quality of visibility, values shaping our thinking and design decision should be made visible and open to negotiation. Moreover, the quality of duality involves consideration of both kinds of invited and inhibited actions and accounting for their implications.

### 4  Inscribing ASD Qualities

In our approach to developing ASD, we employed two important concepts of ANT: inscriptions and translations. We aimed to inscribe ASD qualities into design process and assess the capacities of the inscriptions to support ASD qualities in translation processes taking place in design activities. To this end, we conducted participatory design workshops consisting of various activities in which we employed at least one of the six ASD qualities in each session. The workshops were situated in an early exploratory

phase of design process, in which a consideration of relational view of agency can contribute more. In early phases of design, actors or stakeholders of a design problem are not aligned yet, and it is valuable to explore various ways in which these actors might be aligned. As designers usually aim to get a broader view of a design problem, reveal concerns of stakeholders, and explore the alternatives, ASD qualities with their emphasis on variety and multiplicity of agency might particularly prove useful for conducting exploratory activities in early phases of design. Therefore, we decided to situate our workshop in early phases of the design process. Participatory design workshops, with their emphasis on negotiation, diversity and co-construction of meaning, provided us with a suitable play platform. Muller explains the key characteristics of workshops as follows:

[W]orkshops usually introduce novel procedures that... take people outside of their familiar knowledges and activities, and must be negotiated and collectively defined by the participants. Workshops are thus a kind of hybrid or third space, in which diverse parties communicate in a mutuality of unfamiliarity, and must create shared knowledges and even the procedures for developing those shared knowledges [19, p.9].

We imagined a system utilizing full body interaction and ambient feedback. Full body interaction was selected because of its capacity to support a large variety of interactions between human body and machine compared to more conventional ways of interaction based on screen, mouse and keyboard. In order to not limit the ways of interacting with the system, we decided to not use a screen-based visual feedback, which may confine the range of interactions between body and screen. Instead, we preferred to use sound feedback, which provides more ambient feedback and does not limit the direction of body in space. In a very broad sense, the system will capture the movements of people, process it and provide some audio feedback. Two researchers with backgrounds in interaction design conducted three workshops each lasting approximately four hours. We worked with two female dancers, aged 22 and 23, in the first workshop, two female interaction designers, aged 22 and 23, in the second, one female and one male musician, aged 34 and 36, in the third. As our study involves design of human full body movements and audio feedback, dancers with expertise in movement

improvisation and choreography, musicians with their expertise in music improvisation and composition, and interaction designers with their expertise in bringing together different aspects of interactive systems provided us with a suitable set of participants. They allowed us to view the design problem from different angles and reveal different concerns about the system to be designed. The main theme of the workshops was connectedness, which is a suitable concept to explore various relations between humans and non-humans. There were four sessions involving exploratory activities: a silence session, a physical sensitivity session, a rich-poster session and finally a machine-mediated performance session. The activities in the sessions were selected according to their potential of supporting ASD qualities. However, the important point is less about this particular set of activities than about bringing together a diverse set of activities supporting ASD qualities and facilitating multiple ways of knowing, performing and relating. Thus, other kinds of activities can be added or some extant activities might be removed. What is important is to inscribe ASD qualities into the design process.

Our focus was upon the quality of multiplicity as the quality of multiplicity plays a key role in supporting the fundamental principle of ASD, but we also supported other qualities at varying degrees. The quality of multiplicity was inscribed in the entire workshop containing different kinds of activities and, as well, in roles, representations, and mediums. Each workshop session provided opportunities and resources for the participants to engage in the design concept in various ways. In addition, we, as researchers, tried to be as flexible as possible: this was important as it eschewed any possibility of subjecting multiplicity to obstacles. In addition to the multiplicity as an overall quality of the entire workshop, each workshop session embodied at least one of the six ASD qualities. The qualities of accountability and duality were not considered at this stage. We conducted a pilot workshop and found that the accountability was not very relevant in such exploratory design activities and considering the duality at this stage complicated the workshop activities.

In the silence session, participants are asked to close their eyes, concentrate on and listen to the existence of their own and their partner's body and space. They are also asked to sit down on the floor in a back-to-back position. This session facilitates a connection between

participants through silence and breaks the dominance of vision as a main modality of connecting with other entities. In the silence activity, we aim to inscribe the quality of visibility by increasing the sensations of other modes of perception.

In the physical sensitivity session, participants perform physical exercises encouraging interaction through body movements. There are three short activities in the session; in the first, one of the participants was asked to touch the crown of her partner's head and lead her to and fro using pressure changes. The two are asked to keep the contact between hand and crown. In the second activity, the participants change roles, then pursue the same activity. In the third, they are asked to simultaneously touch each other's crown and to repeat the same to and fro movement. The first activity is called palm-crown exchange, the second, reverse palm-crown exchange, and the third, simultaneous palm-crown exchange. This activity enables participants to create a touch-based connection between two bodies and experience giving and receiving roles in a human-human connection. In the physical sensitivity session, we aim to inscribe the quality of relationality by introducing a physical touch-based exercise in which the sensations and movements of one body is tightly coupled with another.

In the rich-poster session, the participants make a collage of pictures provided on a sheet of A0-paper, then annotate them according to the particular kind of connection that each represents. In addition, participants talk about three objects that they felt a connection. In rich poster session, we aimed to inscribe the quality of multiplicity and visibility by making visible the various forms of connections illustrated by participants' selection of pictures and their annotations. In the final machine-mediated performance session, participants perform five short activities using three technological devices: two wearable devices - one with tilt and another with distance sensing capabilities - and one webcam with motion sensing capability. The task of participants is to explore different forms of connection with other bodies through technologies that allowed participants to create various sound effects through their body movements. In other words, they are invited to improvise movements and sounds by using different technological devices. When needed, we provide additional instructions for participants, which could guide their performance. These instructions

include selecting a theme for activity or using some constraints on movements such as making slow/fast movements or being mobile/stationary in space. In this session, we aim to inscribe the quality of multiplicity and configurability by providing participants with three technological devices enabling three different ways of coupling between human, technology, and space, and various straps that allow them to attach the devices to any parts of their bodies. Tilt devices generate sound effects based on movement in vertical and horizontal dimensions: the rangefinder devices produce sounds based on the changes in the distance within a 70cm range. Finally, the webcam detects motion and triggers musical notes according to the place of motion in space. While the Wii-motes and the range-finder devices need to be attached to the body, the webcam can be placed somewhere in the space detached from the bodies. The multiplicity in capacities of technological tools and ways of coupling with the technologies allow participants to explore and perform various connections through their movements and sound effects.

## 5 Analysis Methodology

We identified some indicators that show the effectiveness of session inscriptions on supporting the

| Session | ASD Quality | Indicators for Effectiveness |
|---|---|---|
| Silence Session | Visibility | • Amplified sensation of other modalities<br>• Emergence of any kinds of connections through amplified modes of sensation<br>• Appearance of previously invisible actors |
| Physical Sensitivity Session | Relationality | • Following the inscription of keeping the contact and maintaining the roles<br>• Comments of participants on the mutual nature of connection, strategies of coordination, and reciprocity<br>• Smooth coordination of movements |
| Rich Poster Session | Multiplicity, Visibility | • Variety in the themes of pictures and related associations.<br>• Manifestation of different personal understandings of connection<br>• Emergence of new connections |
| Machine-Mediated Performance Session | Configurability, Multiplicity | • Variety in ways in which humans and technological devices are coupled<br>• Variety in ways in which humans connect with other humans and environment through technological devices |

Table 1. **Indicators for effectiveness of session inscriptions in supporting ASD qualities.**

relevant ASD qualities (Table 1). These indicators were translated to the context of the design activity from the original definition of each ASD quality after watching all video sequences and reading all the transcriptions.

Our analysis is based on our in-situ notes, interview transcriptions, video sequences and posters. In the final session, we developed an extended version of Laban's [20] effort categories to characterise the different forms of movement-based connections. Laban's effort categories are useful for describing the temporal and dynamic qualities of human movement. There are four categories, each of which has two polar values: i) Space: Direct/Indirect; ii) Weight: Strong/Light; iii) Time: Sudden/Sustained; and (iv) Flow: Bound/Free. We segmented the video sequences according to the different body-technology-space arrangements. There were various arrangements during a session but not all of them allowed participants to create a connection, in which they were able to coordinate their movements and co-compose sound effects. After watching the video sequences multiple times, we concluded that the arrangements that lasted less than three seconds did not involve a connection between participants and could be considered as connection attempts only. Thus, our video segments included the arrangements that lasted three or more seconds. We analysed video segments by using a coding scheme, which included nine codes: form of body-technology-space arrangement, connection strategy, duration of connection, mobility of participants, proximity of participants, movement qualities of two participants, technologies, mapping strategy and finally the sound effect. When coding the segments, we also consulted our transcriptions of the reflection sessions of activities.

## 6  Results

In this section, we present the results of the first three sessions briefly and allocate more space to results of the final machine-mediated session in which we observed large differences between the workshops. In the next sections, we usually refer to workshop participants according to their area of profession as dancers, interaction designers and musicians. Our aim is not to make generalized claims on professions or casual connections between professions and the workshop outcomes; rather, it is just a convenient way we chose to refer to the participants of three workshops.

### 6.1 Silence Session
In fact, the silence session was not designed to be a fully featured session like the other three sessions in which we tested the effectiveness of our inscriptions to support the related ASD quality: it was more like a prelude session preparing participants for the following more demanding activities. Our inscriptions simply aimed to support the visibility of other modes of perception. According to participants, the temperature of their partners' body was the most dominant sensation. The participants stated that they also noticed the sound of air conditioner, noises from outside and the sound of their watch. The participants said that they did not feel any strong connection with their partners. The temperature of bodies and previously insensible sounds were new actors that emerged out of the activity. The participants sensed the previously insensible things in the space. However, they were not able to create connections through the amplified modes of sensations.

### 6.2 Physical Sensitivity Session
Dancers and musicians performed the activities in a similar way. They maintained the contact between palm and crown during all three exercises and demonstrated a very fine control of their movements. They were also very attentive to the leader and receiver roles assigned to them. In contrast, interaction designers were not able to coordinate their movements smoothly and frequently lost their connection. Their movements were usually very fast and sudden. While the comments of dancers and musicians described the subtleties of the connection: "to what degree I'm sure that we are connected or not?... It doesn't feel like it is organic, particularly in the simultaneous giving-receiving one"; "There are lots of questions around to what degree to keep a straight line"; "it was not until I was receiving I really understood how it was to be at the other side of the conversation... I realized that I didn't have to push... a little touch was sufficient to give a signal and initiate the movement", the interaction designers' comments described more like a playful exploration: "To see how far she can go! It was funny... It was just to see what happens, and she jumped. It was like she was a toy-puppet"; "I was pre-determining what she was going to do". All participants developed some strategies to explore the dynamics of the connection such as making the movements at the same/opposite direction or in different speeds.

## 6.3 Rich Poster Session

The objects that participants brought to the workshop included books, pictures, drawings, quotes, a compass, a pebble and a CD cover. The objects revealed many different types of connections: connection as a memento, connection as a feeling of absence, connection as a shared interest, and connection as transformation. The objects enabled participants to make visible their personal understandings of what makes a connection significant for them. Dancers and interaction designers created similar posters involving various pictures and themes. The diversity in the kinds of images facilitated the participants to share many stories and reflect on them. In contrast to the posters in the previous workshops, musicians' poster did not demonstrate a large variety in the selected images and associated connections. There were no stories or experiences accompanying the images. The selected images were either abstract patterns or images as colourful geometric shapes. Their meanings were abstracted away. In fact, in the final poster, collage of all the pictures represented a single manifestation of a visually balanced composition.

## 6.4 Machine-Mediated Performance Session

In this session, we needed to revise the software algorithm mapping movements to sound effects after the first workshop in which dancer participants could not complete all five activities because of the complexity of the mapping algorithm. In the first workshop, the tilt and rangefinder devices were coupled. When two devices are coupled, the sound producing system gets sensing data from each device and combines them to produce a single sound effect. Thus, participants using the coupled devices do not have a total control over the generated sound effects. The reason of using coupled devices was to evaluate whether a preset coupling between devices facilitates more collaboration and creative engagements between participants. However, the participants in Workshop 1 found the control of the coupled devices complex and felt frustrated and could not complete the session. Thus, for the workshops 2 and 3, we decided to have two versions of the devices: coupled and decoupled. When the devices are decoupled, each device produces a separate sound effect independent from the other device. A different sound effect is assigned to each device and participants have total control over the creation of sound effects.

Table 2 shows the number of connections constructed in each workshop session using coupled devices, decoupled devices and a webcam.

|  | D-Tilt | C-Tilt | D-Range-finder | C-Range-finder | Webcam |
|---|---|---|---|---|---|
| Workshop 1 | N/A | 5 | N/A | N/A | 5 |
| Workshop 2 | 7 | 3 | 14 | 4 | 12 |
| Workshop 3 | 6 | 4 | 10 | 2 | 5 |

**Table 2. Number of connections in each workshop using five devices: D-Tilt (Decoupled-Tilt device), C-Tilt (Coupled-Tilt device), D-Rangefinder (Decoupled-Rangefinder device), C-Rangefinder (Coupled-Rangefinder device) and Webcam.**

Workshop *1*. In this session, the participants were only able to perform the first two activities and could not complete the session because of some perceived technological deficiencies. The participants considered the devices incapable of doing what they were supposed to do. In the first activity, the camera did not capture one participant's large movements as required, and the sound effects seemed to be arbitrary. Therefore, the participant could not understand the relation between the sound feedback and her movements. As a result, the participant got frustrated because of not being able to get the feedback properly. In this activity, connections were created through movements rather than sound. The participants employed strategies of stopping, making similar movements and varying the tactile sensation to create connections. In the second activity using coupled tilt devices, the participants found the mapping between the sound and movements complicated, and again, they felt frustrated. Thus, we decided to stop the activities and continued with the participants' reflections and suggestions.
In the next workshops, participants used decoupled tilt devices, coupled tilt devices, decoupled rangefinders, coupled rangefinders and webcam respectively.

Workshop 2. While the highest number of connections, 14, was observed in the third activity using decoupled rangefinders, the lowest number of connections, three, was in the second activity using coupled tilt devices. Although there was a large variety in human-human and human-space couplings through technological

devices, individual human-device couplings did not demonstrate such variety. Participants preferred to use their devices with their hands although it was possible to attach them to many parts of body. They did not use the straps provided to them. Therefore, we observed a single form of coupling, device-at-hand. However, in the case of webcam, we observed a large variety in human-device couplings as well: participants performed ten connections by variously using their arms, hands, legs, torso or full body to create sound effects. The participants preferred to express some themes or phenomena that they decided upon at the beginning of the activities when using the range-finder devices and the Wii-motes. When using the camera, however, they chose to make free movements and express their emergent ideas and feelings.

Workshop 3. Similar to the previous workshop, the highest number of connections, ten, occurred in the third activity using decoupled range finders. Different from the previous one, the lowest number of connections, two, was observed in the fourth activity using coupled range finders. Again, participants did not use straps and hold the devices with their hands. Apart from the activity using a webcam, participants only used their hands and arms to create sound effects. Similar to the previous workshop, only the device-at-hand coupling was observed. Participants' bodies were stationary in space and facing each other all the time. Although they used their full bodies in the final activity with the webcam, they could create five connections. Different from the other workshops, they developed a vocabulary of expression involving various movement-sound pairs. When they discovered a good movement-sound pair, they included it into their vocabulary and then, used it again later to compose melodies in the activity. However, this was not the case for the interaction designers, who tried to find as many interesting movement-sound pairs as possible.

## 7  Discussion
### 7.1 On Visibility
 We aimed to support visibility in silence and poster sessions. In silence session, our aim was to increase the visibility of other modes of sensation. This was achieved according to the participants' statements. The participants sensed the previously insensible things in the space: the temperature of another body, sound

of watch and A/C. However, in order to be able to create connections through these different modalities, more time is needed. In the poster session, our aim was to make visible the various forms of connections between humans and other entities. Apart from the third workshop in which the poster was a single manifestation of visual aesthetics, the posters in the first two workshops exhibited various forms of connections like connection as memories, criticism and culture.

### 7.2 On Relationality
We aimed to increase participants' awareness of relationality of their capacities for action. The three exercises in physical sensitivity session were scripted activities amplifying the sensation of reciprocity of our actions through sensing the effects of our movements both visually and in a tactile way. The proximity of the bodies amplified the sensation. The exercises were extreme cases of connectedness where one body was strongly connected to another in a physical way. The sensations and movements of one body were tightly coupled with another. There was a very high degree of influence between the bodies, which increased the visibility of the relationality of our bodies. In all three workshops, participants' comments demonstrated sensitiveness to the shared capacity of their actions and co-construction of their performance. Apart from the second workshop in which the participants lost their connection frequently, the exercises, in general, were effective in emphasizing the quality of relationality.

### 7.3 On Multiplicity
We aimed to support multiple ways of engaging with the design concept, multiple roles for, and multiple mediums of expression.
Multiple ways of engaging with design concept: Different kinds of activities allowed us to understand different forms and dimensions of the design concept. In general, rich poster and machine-mediated performance sessions were effective in producing various forms of connections. Many different forms of connections were revealed: connection as movement, connection as sound, connection as criticism, connection as memories and so on. Many different strategies to construct and maintain connections were observed: making similar movements, making opposite movements, combining stops and repetitive movements, combining stops and varying movements and a-synching movements.

However, our inscriptions could not achieve their goal in the rich poster session with musicians and the machine-mediated performance session with dancers. While the musicians preferred to create a single visual form of expression, the dancers found the technology insensitive to perform together and could not complete all activities in the session.

Multiple roles. In the Physical Sensitivity Session, the participant performed the same activity by switching the roles of leader and receiver. It was effective in enabling participants to develop a relational understanding of their movements. Therefore, the quality of multiplicity served to support the quality of relationality.

Multiple mediums of expression. The participants used different mediums such as paper and technological devices for expression. For example, the rich poster session allowed the participants to express their views of the design concept on a 2D shared medium, i.e., on paper, in the form of a collage of pictures and texts. They created representations or proxies of the previous connections they had made in their lives. In addition, the totality of pictures and texts revealed forgotten or unknown connections between places, people and memories. Moreover, each technological device invited different patterns of action through different levels of connectivity. The connectivity can be defined as an entity's ability to make connections. The webcam and rangefinders with their high degrees of connectivity facilitated the creation of many different connections whereas the tilt devices with the low degrees of connectivity could only support the construction of a few connections.
Although we advocate the inclusion of multiplicity as a quality in design, there might be some undesired effects of multiplicity on the design process. One participant from the first workshop vocalized her concern about engaging with multiple activities and multiple media in the activities:

Ultimately, we are transferring, transferring and transferring through different media. But, in that transference, we are getting further and further away from proximity to actual sensitivity and composition.

This is an important criticism on using multiple activities and multiple mediums in a single half-day workshop.

The participants could only spend short periods of time in each activity, and this limited participants' capacity to obtain a deeper understanding about each of their relations with other participants, materials, and technologies. Multiple activities might enable researchers and designers to get a broader perspective on many dimensions of a design concept or problem, but the knowledge obtained from these short-lasting activities might be imprecise, shallow and scattered. This might be a disadvantage for design projects with a more specific focus. However, it might be advantageous for the design projects at an early explorative stage in which getting a broader perspective on many dimensions of a design concept or problem is very valuable.

### 7.4 On Configurability
We aimed to support configurability by making wearable devices compact and portable. They were attachable to different parts of the body by using various straps. However, the participants did not use the straps and hold the devices with their hands. The inscriptions of straps involving the quality of configurability were not translated in the practice in the expected ways as the particular characteristics of sensing technology and mapping algorithm, i.e. their inscriptions did not invite use of many possible configurations between human body and the wearable devices. The lack of expressive capacity in many of the configurations rendered those configurations useless or not preferable. Here, configuring the ways in which the device and the human body are coupled became less desirable for the participants since a particular configuration, tilt-at-hand, provided participants with the opportunity to exploit the expressive capacity of the device at maximum. The six qualities introduced here are a starting point towards developing ASD. Our aim is not to replace existing design approaches but rather to complement them by relativising how we think and go about design. What is needed is not to take these qualities as prescriptions or strict guidelines for action but to use them as lenses through which to see design problems and processes from a relational point of view.

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# Beyond metaphor in product use and interaction

**Abstract**

The overall aim of this paper is to demonstrate that there is a need for supplementing the theory of product metaphor with a more elaborate theory of product meaning. More specifically, we argue that the notion of product metaphor neglects three critically important aspects of meaning making in product use. First, the notion of product metaphor usually accounts for how the visual form and appearance of a product might cue people to conceive of the product in terms of another conceptual source (e.g. a coffee maker as a butler), while leaving the role of cross-modal sensory experience in product meaning out of consideration. Secondly, like other theoretical frameworks in design semantics, the notion of product metaphor primarily accounts for the semantic operations that are involved in the first initial phase of product categorization and interpretation, while eschewing the question as to how product interpretation might evolve over time as people interact with and use the product. Finally, in product use there often emerge more complex and even ambiguous forms of meaning, which fall outside the explanatory scope of the source-target construal principle – the key semantic principle of product metaphor. In order to remedy these limitations inherent in the theory of product metaphor we introduce a new semantic framework based upon Fauconnier and Turner's theory of conceptual blends.

**Keywords**

Sensory engagement, conceptual blends versus metaphor in product design, emergent forms of meaning, product blends.

## 1 Introduction

The overall aim of this paper is to demonstrate that there is a need for supplementing the theory of product metaphor with a more elaborate theory of product meaning. More specifically, we argue that the notion of product metaphor neglects three critically important aspects of meaning making in product use. First, the notion of product metaphor usually accounts for how the visual form and appearance of a product might cue people to conceive of the product in terms of another conceptual source (e.g. a coffee maker as a butler), while leaving the role of cross-modal sensory experience in product meaning out of consideration. Other fields of study have uncovered the role of cross-sensory experience in metaphor in language [1] as well as in film and advertising [2], [3], but design semantics still awaits further inquiry in respect to product metaphor. Secondly, like other theoretical frameworks in design semantics, the notion of product metaphor primarily accounts for the semantic operations that are involved in the first initial phase of product categorization and interpretation, while eschewing the question as to how product interpretation might evolve over time as people interact with and use the product. Karapanos et al. [4]

have developed an initial framework for understanding how a user's relationship to a product changes over time, but they do not offer any insight concerning product metaphor.

Finally, in product use there often emerge more complex and even ambiguous forms of meaning, which fall outside the explanatory scope of the source-target construal principle – the key semantic principle of product metaphor [5].

These inherent limitations of product metaphor theory will be laid bare through a detailed product analysis of Anna G, Alessandro Mendini's design of a corkscrew for Alessi. At the mere sight of it, Anna G seems to be a paramount example of product metaphor. However, we will demonstrate that the actual use and multi-sensory interaction with Anna G may cue people to construct new ambiguous forms of product meaning that fall outside the explanatory scope of product metaphor. More specifically, we shall refer to such ambiguous forms of product meaning as "product blends". Unlike product metaphors, product blends demand of the user that he or she conceptually unifies two divergent or even contradictory meanings. This kind of meaning construction has been largely overlooked in design semantics (for exceptions, see [6], [7], [8], [9]. Closely related studies have dealt with how, for instance, interaction designers can explore ambiguous forms of meaning as a resource for spurring users' imaginative interpretations of technology [10]. In a similar vein, [11] present an interesting study of how contradictory meanings often underlie experiences of product novelty and surprise. Yet, there is a lack of a coherent semantic account of how products cue users to construct ambiguous forms of product meaning. In this paper, we introduce a new semantic framework for understanding ambiguous meaning in the form of product blends and how it differs from product metaphors. In so doing we wish to shed light on processes of meaning attribution that emerge from multi-sensory interactions with products over time. By drawing upon recent research in cognitive semantics, notably Fauconnier & Turner [12], [13] we furthermore offer a basic diagram enabling design researchers to give an accurate formal description of the semantic principles of product blends. Finally, we compare weaknesses and strengths inherent in our framework with related work within design research.

## 2 Product Analysis of Anna G

The creation of product meaning is a dynamic process relying on the product-user relation. Product meaning is not an invariable entity, but is a result of a hermeneutic act of user interpretation. In this sense product meaning may vary according to people's socio-cultural background, past product experiences, gender, self-identity, and so forth. In fact, one and the same product may prompt users to construct multiple meanings, even meanings that contrast or contradict one another. Anna G provides us with a good example of such a product. In this section, we offer a product analysis showing how each author of this paper interprets Anna G differently. None of these interpretations should be seen as the authoritative one. Rather, what we want to demonstrate is that products like Anna G are able to prompt two alternative forms of product meaning: product metaphor or product blend. While research literature on product metaphor is vast, product blends have received little attention so far. The theoretical explanation of the difference between these two forms will be given in the following section.



**Fig.** 1. **Anna G, corkscrew by Alessi.**

### 2.1 Cila's Interpretation

Anna G is a tall and thin figure with a tall neck, big eyes and long dress call to mind the "gothic look" of the 1990s (Fig. 2a). Especially, the one with the black dress has almost a Tim Burton-esque image. The visual association grows stronger with the notches around the shoulders and neck, and the thin arms screwed to the body. This can be seen as more of a visual analogy

that is based solely on Anna G's appearance, which does not make a contribution to the functionality of the product. Still, its proportions and stylistic features make the product a beautiful and iconic object, which make it pleasurable to simply look at it.

## 2.2 Özcan's Interpretation

As a first impression Anna G looks inviting with her soft lines and colors, she looks like she would love opening wine bottles. After placing her on top of the bottle and turning her head to push the corkscrew into the cork, her arms start to rise in the air slowly (Fig. 2b). This movement is interpreted as the first sign that she gets happy. As she gets closer to opening the bottle, her arms rise higher and higher; consequently she gets happier and happier. The smile on her face strengthens this meaning attribution. Her happiness corresponds with the emotions of the user after opening a wine bottle; the user's feeling of accomplishment is reflected in the behavior of the product.

## 2.3 Markussen's Interpretation

In its visual form Anna G evokes associations to a holy, almost saint-like female figure with a glory surrounding her head. This metaphor is further entailed by the fact that, when standing on a shelf or table, the "arms" of the corkscrew can be placed in a position similar to those of praying figures found in so many Renaissance paintings or catholic visual culture (Fig. 2a). However, when the corkscrew is not simply looked at, but used to open a bottle of wine, the user is cued – through haptic interaction – to construct a thought-provoking counter-image. After opening a wine bottle, the cork is hidden under the skirts of the female figure. Because it is hidden, the user has to look up under the skirts and reach out after the cork to remove it (Fig. 2c). This is a rather rude gesture that actually conflicts with the product metaphor elicited through visual experience. Thus, it draws attention to the effects of wine drinking being associated with lust and desire, male-female relationships, gender issues, perhaps even sexual harassment, etc. This second product meaning is also motivated by the product's name – Anna G – which is a name a stripper may take on when dancing and performing in a nightclub.



**Fig. 2. Anna G in use (from left to right, a, b, c).**

## 2.4 Anna G as a Challenge for Design Semantics

While Cila's product interpretation is primarily grounded in the perception of the visual form and appearance of the product, Özcan's and Markussen's stories also include meaning attribution as they evolves from using the product. However, there is a central difference between the two last interpretations. While in Özcan's interpretation the image of the woman celebrating the opening of the wine bottle is consistent with the image evoked through her visual experience of Anna G, in Markussen's account the use of the product resulted in a counter-image of a woman that is contradictory to and violates the first image evoked through his visual product experience.

For design semantics it is a theoretical challenge to account for how one and the same product is able to evoke such ambiguous forms of meaning. Taken together the three product interpretations are useful for delving into (i) the interplay between multi-sensory product interaction and meaning attribution; (ii) the process of meaning attribution as it evolves over time through product usage; and (iii) how a product can cue people to construct a variety of different, and even conflicting meanings.

In the next section, we will show that while the theory of product metaphor indeed enables us to go a long way in addressing these questions, there is also a need for incorporating a new concept into the vocabulary of design semantics, namely "product blends". The notion of product blend is derived from the theory of conceptual blends as developed recently within cognitive semantics as a remedy for some limitations inherent in metaphor theory.

## 3 From Product Metaphors to Product Blends

Taken in its most basic sense, a metaphor is defined as "understanding and experiencing one kind of thing in terms of another" [14]. For example, in the phrase "love is a burning fire" an emotional state such as 'love' is understood in terms of a fire, which is uncontrollable and potentially destructive [15].

Until the 1980s it was usually believed that metaphors were primarily whimsical products of the poet's mind, but the groundbreaking study by Lakoff and Johnson showed that metaphors are better understood as a fundamental cognitive operation of the human mind allowing us to make sense and understand the world. This assumption has been supported by countless examples in everyday language, which is permeated with metaphors (some of which we are hardly aware of anymore). For example, "she is unable to defend her claims" is an instantiation of the metaphor 'Argument is War'; "you're wasting my time" instantiates the metaphor 'Time is Money', and so forth.

On the basis of their study of metaphors in everyday language, Lakoff & Johnson [14] developed a cognitive linguistic account of the underlying semantic principle involved in the creation of metaphors. More precisely they proposed that metaphor creation is governed by a source-target construal principle, which could be illustrated as in Fig. 3:
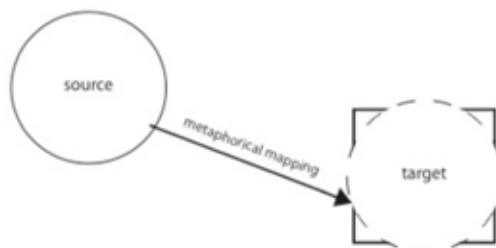


**Fig. 3. The rule of metaphor (adapted from Wulff et al. 1990).**

In "Love is a burning fire", fire is the source domain, the qualities and structures from which are metaphorically projected onto love being the target. When an argument is compared to war, 'war' becomes the source domain that lends its action structures to a metaphorical mapping onto the phenomena of 'verbal dispute' being the target, and so on. Further, it is forfeited by Lakoff that the metaphorical mapping of

meaning structures from source to target cannot take place unless there is a structural isomorphy between source and target (also known as the invariance principle [16]). Hence, the metaphorical mapping can only be processed if love is malleable in some way according to the structural qualities of fire.

In their work, Lakoff and Johnson have succeeded in uncovering how the source-target principle is responsible for organizing meaning on a wide range of levels ranging from abstract thought in mathematics to gestalt laws of perception as well as neurobiological processes [17], [18], [19]. The cognitive semantic theory of metaphor has also proven useful for understanding how metaphors work in product design. In product metaphors, the target is the product in question and the source is the entity that is associated with it in order to modify the target to convey particular meanings. This modification is provided by projecting some attributes of the source onto compatible attributes of the target. The metaphorical mapping is quite tangible in this case; the mapped qualities are visible to users in the appearance, movement or interaction pattern of the target [20]. In this way, the target is seen through the lens of the source, which leads to cognitive and emotional effects in the users [21], [22].

By applying the notion of metaphor, it is possible to uncover semantic principles underlying Cila's and Özcan's product interpretations. In both cases, the corkscrew is understood and experienced as a women-like figure: for Cila a Tim-Burtonesque figure and for Özcan a celebrating woman. Despite their differences each of these two product interpretations are governed by the source-target principle as depicted in Fig. 4:
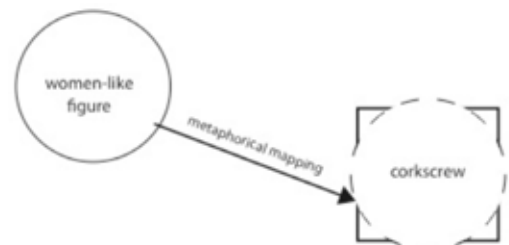


**Fig. 4. Anna G as a product metaphor.**

However, in Markussen's product interpretation, a new meaning emerges that cannot be adequately captured by this diagram. As Anna G is used to open a bottle of wine a counter-image is evoked which is laden with entirely opposite connotations of a woman than that

of a saint. This counter-image is contradictory to the initial product interpretation, but nevertheless calls for integrating the elements and meaning structures into the same overall product interpretation making it highly ambiguous. Now, for design semantics, what is central to ask is, what are the underlying semantic principles of this type of product meaning?

### 3.1 Semantic Principles of Product Blends

In order to answer the question in the previous paragraph, it is valuable to take a brief look at some of the more recent developments within cognitive semantics. In particular, those made around the mid 1990s, when Gilles Fauconnier and Mark Turner discovered some forms of meaning making that appears to be instances of metaphor, but which, under closer scrutiny, turns out to be governed by semantic principles violating the source-target and invariance principles. Moreover, Fauconnier and Turner suggested that these new forms of meaning should be termed 'conceptual blends' [12].

A conceptual blend is not the result of meaning structures from a source being projected onto a target. The creation of a blend relies on conceptually integrating structures from two so-called input spaces into a third space: the conceptual blend. This third space is not the sum total of meaning structures form the two input spaces. On the contrary, the third space represents emergent new meaning, which cannot be explained by refuge to any of the inputs. In order to illustrate the semantics principles behind this conceptual blending process, Fauconnier and Turner [13] suggest the following basic diagram (Fig. 5):

In Fauconnier and Turner's diagram, the dashed lines from the inputs into the blend represent conceptual projections of structures. Since structures from both inputs get projected and integrated into new hybrid meaning structures in the blend there is a violation of the source-target construal principle. Moreover, the full lines in the diagram between input elements represent one of Faunnier and Turner's key insights, namely that conceptual blends "can operate along strong clashes between the inputs" [13]. Let us try to somehow substantiate these theoretical arguments by applying the basic diagram as an analytical framework for understanding Anna G (Fig. 6):
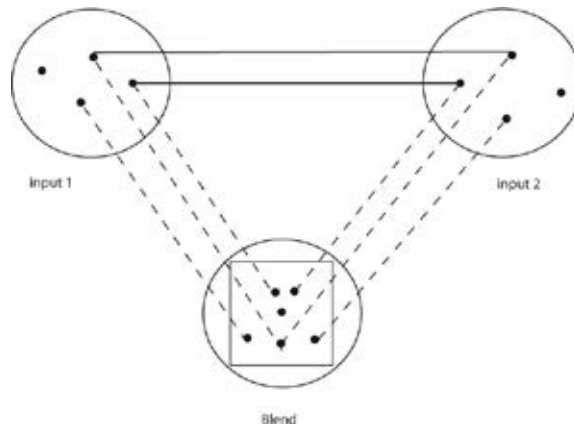


**Fig. 5. Basic diagram illustrating the semantic principles of conceptual blending [13].**
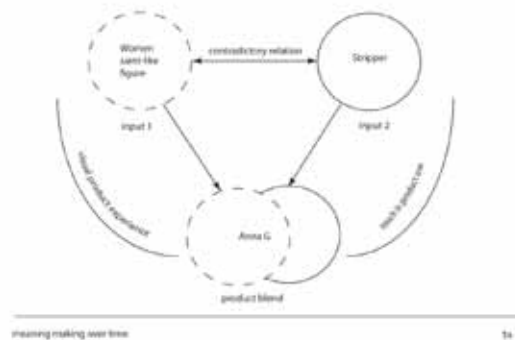


**Fig. 6. The semantics of product blends.**

In Fig. 6 we have elaborated on Fauconnier and Turner's basic diagram making it more fit for describing the construal principles of conceptual blends in product design. For instance, we have added visual experience and touch in product use in order to depict how meaning is attributed differently according to how the product is experienced. The saint-like woman arising from visually perceiving Anna G is represented by a dashed circle in input 1. The stripper being evoked from touching and using Anna G is represented by a full circle in input 2. Now, what makes Anna G a prompt for a conceptual blend is that it opens up for a process where the saint-like woman and the stripper get mixed into one ambiguous female blend associated with the product. All of this takes place through time (the arrow below the diagram, where time is indicated as tn). By adding a temporal axis to the diagram, we wish to mark time as an important factor for product interpretation. This should be seen as broadening product metaphor theory,

which is usually focused primarily on the first initial stages of visually perceiving a product.

Further, we propose the notion of "product blends" rather than conceptual blends as a new concept for working with ambiguity and contradictory meanings in product design. As a start, we predict that product blends can be found on various levels of product experience, most notably on a sensory, a conceptual and an emotional level.

## 3.2 Conceptual Structure of Product Blends

As we demonstrated, meaning attribution is a complex process that is facilitated by sensorimotor and semantic systems. Although the verbal correspondents of a meaning may be stored in the semantic system, the attribution of the meaning is primarily triggered by multi-sensory interactions with objects. During meaning attribution, these two distinct types of mental representations (i.e., sensorimotor and semantic) do not interact with each other directly. Paivio [23] suggests an amodal system, i.e., a conceptual system that bridges the representational gap between the semantic and the sensorimotor systems. Thus, a concept is the melting pot of mental representations. A conceptual representation of an object can be activated earlier than its semantic representation [24]. That is, as soon as people are confronted with objects (e.g., an apple), a network of mental representations will be automatically activated (e.g., the image, taste, sound and smell of an apple, and other meanings stored in the semantic system). Because, sensorimotor and semantic representations are connected via conceptual representations, a concept can be activated either by the semantic system or the sensorimotor system. Barsalou [25] presents a further explanation for conceptual systems. He suggests that a conceptual representation is an embodied representation construed by prior experiences taking place not only in the sensorimotor and semantic systems but also in the emotional systems. According to Barsalou's account, object representations can also be variant resulting from infinite arrangements of experiences. Furthermore, Bar [26] suggests that all objects belong to a context frame, which a network conceptual associations again construed by exposure to real world events. Thus, conceptual representations of an object cannot be disconnected from its context of existence, and thereby from other objects within the same context.

Furthermore, because everybody experiences objects and events in their own settings, conceptual associations also become idiosyncratic to people. To summarize, the word or the image 'apple' activates a network of mental representations referring to sensorimotor, semantic and emotional systems, and other conceptual associations (i.e., sub-concepts) resulting from a contingent activation (a farmer, an orchard, grandmother's apple-pie, happiness, Adam & Eve, guilt, sin, iMac, Steve Jobs, etc.). Thus, when a product such as Anna G is experienced, it is very likely that Anna G evokes all kinds of associations intrinsic to the product and idiosyncratic to the user (see Section 2 for interpretations the authors provided from their perspectives). Therefore, it is more logical to explain such rich interpretations and the underlying mental processes with conceptual systems in consideration. As opposed to the semantic system, which provides a narrow linguistic account, the conceptual system tackles first the sensorimotor representations and relates them to several meaning structures occurring in the semantic system [27]. As a result, a blending occurs between the conceptual associations (rich in multi-sensory, emotional and action content) activated by one single product.

As we mentioned before, product blends tackle human-product interactions over time. Interactions with products occurring at different stages may evoke different conceptual associations. Barsalou's [28] account with ad-hoc categories may explain this phenomenon. That is, people depending on the context and situation may activate a network of items associated by one common goal and/or function. Moreover, concept structures are not fixed and can be updated depending on the new inputs and new situations [29]. Thus, in the course of product use, the activated conceptual associations can take different forms and may prime the following associations to be activated. Therefore, in the essence of product blends, a continuous negotiation for meaning attribution occurs between the primary concept that is activated (e.g., saint-like woman in Figure 4) and sub-concepts that are subsequently activated. For example, visually experiencing Anna G as 'a woman' (i.e. the primary concept) activates woman-like knowledge in the beginning of product interaction. Later haptic and tactile interactions with the product (e.g., holding Anna G from the waist, turning it around looking under her skirt) activate another concept, which is the 'stripper'

(sub-concept). Accordingly, the primary concept of Anna G gets updated starting from a saint-like woman figure and becoming a stripper. In this example, it is the ambiguous form of Anna G and the conflict in the conceptual associations that mainly underlie the occurring product blend.

Product blends can be constructed as a result of product experiences on different levels (i.e., sensory, cognitive and emotional). In Markussen's account of Anna G, both the primary concept and the sub-concept are activated by sensory product experiences (i.e., the visual and tactile product experiences, respectively). However, the activations of primary and sub-concepts may also be a result of emotional and cognitive product experiences. In Özcan's account of Anna G, an emotion (i.e., happiness) is identified in the course of the product use, which serves as a sub-concept that updates the 'woman' concept. However, in this case, the occurring concepts are not contradictory but complementary to the overall product experience. In Cila's account, the visual experience refers primarily to 'a gothic woman image' and a further cognitive elaboration into the primary concept activates the sub-concept of 'Tim Burton's heroines'. Consequently, the primary concept gets stronger making the product more pleasant to the user. Although product blends can occur as a result of different types of product experiences, what makes its effect strong lies in the (in)congruency between the activated primary concept and the sub-concept. We suggest the notion of product blends as a new concept for understanding the semantics of ambiguity and contradictory meaning in product design. Over the years, there has been an increasing interest in design research in ambiguity and contradictory meaning. In the following section, we review some of the contribution and relate and discuss them in relation to our own framework.

## 4 Contradictory Meaning and Ambiguity in Design

Without doubt, we can consider Anna G as a rather atypical product within the product category of corkscrews. For some atypical products, the functionality is not the primary concern from the perspectives of both designers and users. For example, Phillippe Starck states that he mainly designed the Juicy Salif (the famous Alessi lemon squeezer) as a conversation starter in awkward situations [30].

Products such as Anna G and Juicy Salif are rather ambiguous in their physical constitution – physical constitution of a product normally gives rise to a 'lexical level' meaning attribution (i.e., corkscrew or lemon squeezer). These products rather refer to complex meaning structures beyond a lexical association, which makes them good examples for product blends. Thus, ambiguity in product categorization is an essential factor for product blends to take place in the first place. Furthermore, contradiction in occurring concepts is what makes the product experience intriguing.

If the designers of ambiguous products have similar concerns as Starck's, then facilitating the activation of contradictory concepts in human-product interaction can be seen as a deliberate design decision for creating richer product experiences (that is, experiences that go beyond the functionality of the product).

In the following paragraphs, an overview will be given on how ambiguity and contradictory meanings have been studied within the design literature and shortcomings of these studies will be discussed.

### 4.1 Sensory Incongruity

Sensory incongruity has been studied in the context of surprise in product design [31]. Ludden studied three types of sensory incongruities (i.e., visual – tactual, visual – auditory and visual – olfactory). For evoking surprise reactions, visual-tactual incongruity was found to be the most effective. Furthermore, it was shown that the surprise reaction had a long-term effect on other emotions such as interest, fascination and confusion. Ludden's main interest was to observe the emotional effect of the synthesized sensory incongruities in product use in order to understand whether sensory incongruity could be used as a design strategy. However, Ludden's doctoral dissertation has not covered the semantic impact of sensory incongruities.

Sensory incongruities by eliciting conflicting emotions may further influence the meaning attribution process to the product experience. Our framework on product blends assumes emotions as part of the embodied experience [c.f. 25] and therefore part of the activated concept frame. Thus, we assume that emotional responses are involuntary and play an important role especially in assessing conflict between the emotional responses towards the primary concept and the sub-concepts.

## 4.2 Contradictory Meanings

Hong and Chen [11] offer a study of simultaneous use of contradictory meanings in product design. More specifically, they focus on how meaning attribution triggered by a product may manifest itself in the semantic continuum between two opposite adjectives: typical-unique, traditional-modern, simple-complex, rational-emotional. As an example of how products can be designed according to the typical-unique polarity, they mention a chair that makes double use of one of the legs as an umbrella stand and a flowerpot. In this instance, contradictory meaning occurs as a result of adding functions from other product categories (umbrella, flowerpot) to the existing product category of a chair. By merging typical product genres in a unique way in its design, the chair plays humorously with the typical-unique polarity. We argue that, by introducing the notion of product blends, we have added a new perspective on contradictory meaning, which is absent from Hong and Chen's study.

First of all, Hong and Chen's framework is too coarsely grained to capture contradictory meanings like the one we find in Anna G. Anna G does simply not fit into any of the four categories of contradictory meaning. Secondly, many of Hong and Chen's examples such as the chair provide insight into lexical level meaning attribution, i.e., the process of associating primary concepts with a product. In this paper we have broadened the perspective so as to include the interplay between primary concepts and sub-concepts. Thirdly, for Hong and Chen meaning attribution is primarily a matter of how people react towards visual images of products, whereas we see meaning attribution as emerging from multi-sensory product use, which is a time-based interactional process. Finally, as Hong and Chen base their study on the so-called differential semantic method, they end up conceiving of contradictory meaning as being manifested in between two opposite adjectives. However, product blends are contradictory forms of meaning, which cannot be adequately accounted for in bipolar terms. Thus, a product blend is not the sum total of two adjectives or something in between, but a new third structure. The basic diagram enables us accurately to account for the semantic principles behind this structure.

## 4.3 Ambiguity as a Resource for Design

Gaver, Beaver and Benford [10] have developed an analytical account of how ambiguity in design can be roughly grouped into three categories: (i) ambiguity of information, an example of which would be Mona Lisa's smile where the technique known as sfumato is used to create a certain sense of indeterminacy in the viewer; (ii) ambiguity of context which is exemplified by Marcel Duchamp's Fountain from 1917, a urinal brought into the context of an art gallery; and (iii) ambiguity of relationship is a third type of ambiguity illustrated by Lieshout's Bais-ô-Drôme which is a trailer designed to become a love caravan that in a strange way mixes utility (a trailer) and sexual debauchery.

While Gaver, Beaver and Benford [10] offer many central insights into the nature of ambiguity and how it can be used by designers in various ways to increase user creativity and interpretations, they do not offer a semantic explanation of this phenomena. We argue that the basic diagram of conceptual blends can be valuable as an explanatory tool for providing a more fine-grained understanding of the semantics of ambiguity in design. Thus, the diagram can be used to account for the semantic principles underlying ambiguity of information, ambiguity of context and ambiguity of relationship.

## 5 Conclusion

Alessandro Mendini who designed Anna G for Alessi, once said that as a designer he wishes to communicate through his objects and work in general, "trying to say things that encourage people to deepen meditation and spirituality". As a product, Anna G surely encourages people to meditate upon a series of topics related to celebration, wine drinking, gender issues and so on. In this paper, we have demonstrated that the product's ability to trigger this rich variety of interpretations has to do with a certain ambiguity of product meaning. More specifically, we have shown that this ambiguity can be explained in terms of two divergent semantic principles: product metaphor and product blend. While the existing research in design semantics has a lot to say about product metaphor, little has been written so far about product blends. To fill in this lack of knowledge, we have found it necessary to introduce conceptual blending theory as a supplement to metaphor theory. In so doing we have remedied the inherent limitations of metaphor theory that has to do with its inability to account for:

- Contradictory forms of meaning that violate the source-target principle;
- How multi-sensory product experiences give rise to different interpretations of the product;
- How meaning attribution evolves over time through product use and interaction.

Needless to say, our contribution must be further elaborated by future work as it is built up from only one single product analysis. In particular there is a need to study the many forms that product blends can take, and to support such studies with empirical findings and user tests. For example, we could empirically study the shift in product semantics over time through experiences deriving from a range of non-rich (mono-sensory) and rich product interactions (multi-sensory), that is, from visual only to multisensory or auditory only to multi-sensory. Despite this missing body of work, we argue nonetheless that the notion of product blends marks a new interesting research topic for design semantics. As they increase user creativity and interpretations, product blends could serve as a resource for deriving new design ideals for designing richer and meaningful user experiences.

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# Graphic design and the tyranny of connoisseurship: An argument for a semiotic approach to graphic design pedagogy

## Abstract

In design pedagogy, a connoisseurship model prevails, while semiotics has struggled to become a significant pedagogical tool outside of the theory class. Yet whilst it has much to offer, connoisseurship is a limited approach that struggles with current philosophical and political concerns. This paper describes its historical trajectory and influence on design discourse and then suggests how semiotics can be an important addition to this system. Foregrounding the relationship between forms, perception and social communication, semiotics can provide more effective approaches to design instruction. More importantly, its robust theoretical framework allows for in-depth enquiry into the social and cultural meanings that spring from and traverse graphic media. I argue that semiotics should be approached in design pedagogy, not as a minor area of theory, but as a larger system through which many other design issues can be explored – in effect to generate a 'semiotic sensibility'. This can help to impart a richer awareness and deeper understanding of how design works, resulting in more informed, responsible and professionally capable design practitioners.

## Keywords

Semiotics, connoisseurship, graphic design, pedagogy, discourse, design history, design theory.

## 1 Introduction

This paper is in two parts. The first section deals with the emergence of what I refer to as the connoisseurship model, and its historical influence in setting a particular understanding of design practice and pedagogy. The second section describes how semiotics can work alongside this approach to create a more effective pedagogical process, the result of which can be more informed and professionally capable graphic designers. Although I use the term graphic designer, everything here applies equally to the communication designer and will have resonance across a range of other design and design related disciplines. By semiotics, I mean the broad notion that originated with de Saussure [1] and was developed by Roland Barthes in the following sense: Semiology aims to take in any system of signs, whatever their substance and limits; images, gestures, musical sounds, objects, and the complex associations of all of these, which form the content of ritual, convention or public entertainment: these constitute, if not languages, at least systems of signification [2].

Elements of semiotics of particular import for graphic design are signification and its component elements (sign, signifier, signified and referent) as well as second order signification and the notions of denotation, connotation, myth and ideology. In this regard, it aims to present a model, or way of seeing, that foregrounds the relationship between communication, culture and the making of meaning.

## 2 Graphic Design Discourse

It is useful to regard design as a discourse in the Foucauldian sense [3], whereby certain practices are brought together as a unity. Through this process, previously disparate components of the discourse are linked and officially sanctified through a professional language with concurrent systems of accreditation which specify what may be practiced and who may practice it. An important part of the process of gathering together these disparate practices is the defining of various sub-categories such as graphic design, industrial design, interior design and the like. In graphic design, the traditional practices of aesthetic construction of type elements on a page and the 'laying out' of images and type together, as well as many other traditional and modern practices, are drawn together under the 'graphic design' banner, whilst other previously related practices, such as much of the preparation work for printed media are excluded. Precisely what is chosen to be included and what remains excluded from the category 'graphic design' and thus what is and is not to be considered within the boundaries of design discourse are seen here in terms of the historical power struggles of various social and institutional groups.

It can be argued that graphic design emerged out of a social, economic and a political shift which designated the legitimate creative aspects of printing as separate from, and beyond the grasp of, the traditional printing industries [4]. As these practices became the practices of a newly emerging professional – the graphic designer – hierarchies, new historical trajectories and structures of legitimacy of this profession were found from various fields, but I argue much of the language took its form of expression from the discourse of fine art. Fine art, after all, had been at work separating itself from the uneducated and uninitiated, for 150 years.

### 2.1 Connoisseurship and Graphic Design History

The Oxford dictionary defines connoisseur as an 'expert judge in matters of taste' [5], yet it is much more than this. Connoisseurship involves membership to a certain group with a certain specialized knowledge, access to a special language, a keen awareness of the hierarchical relations of power and processes for the conferring of legitimacy. Indeed, all of these things fit well with Foucault's notion of discourse, and we might regard the connoisseur as a stakeholder, or speaking position, within a discourse which positions 'taste' as a key discursive element.

Beatrice Warde was an influential figure in the early emergences of what was to become known as graphic design, particularly through her role working for the Monotype Corporation to promote their typefaces to the printing industries. She worked alongside other key figures in printing history in Stanley Morrison and Eric Gill. Belanger gives the following account of her work for British Monotype:

Beatrice Warde gave a talk pretty much everywhere; for many years she was the British Monotype Corporations's [sic] promotion director, and part of her job was going around talking up good typography in general and Monotype typefaces in particular [6].

Warde is perhaps best known for her book published in 1955 and the title paper, originally published in 1932, The Crystal Goblet, in which she presents what is often considered the quintessential modernist perspective of typography and also in which she is considered to have coined the term 'transparent-' or 'invisible-' type. The text is still used in classes today, and most students of design would be familiar with it. Through this text, typography and a relation to social distinction becomes apparent.

Imagine that you have before you a *fl*agon of wine. You may choose your own favourite vintage for this imaginary demonstration, so that it be a deep shimmering crimson in colour. You have two goblets before you.
...if you have no feelings about wine one way or the other, you will want the sensation of drinking the stuff out of a vessel that may have cost thousands of pounds; but if you are a member of that vanishing tribe, the amateurs of *fi*ne vintages, you will choose the crystal, because everything about it is calculated to reveal rather than hide the beautiful thing which it was meant to contain [7].

Ironically, although Warde's job was to speak to the trade-skilled printer, her metaphor of wine connoisseurship was hardly likely to 'speak' to them in a language they could relate to. In fact it was the growing numbers of college educated 'book artists' and graphic designers that proved to be Warde's real audience. Indeed, at one point she remarked that 'real' book readers constituted: 'a relatively small élite... distinguished by their ability to concentrate continuously on one fairly long piece of reading matter' [qtd. in 8].

To understand the shift exemplified by Warde's approach, it is necessary to see the historical lineage that Warde comes from. This is a historical trajectory that emphasises the creative as connected directly to art discourse. This lineage tends to follow the same historical progression as that of printing history up until about the time of the Arts & Crafts period of the late 1800s, when fine art and printing reach a climactic embrace. In 1891 William Morris founded the Kelmscott press, one of the key highlights of typographic histories in design literature [9]. Morris's press was to spawn a generation of artistic printing but more importantly was to set a language for typography as it could emerge in the discourse of design. Shortly after the Kelmscott Press opened, Charles Ricketts founded the Vale Press (1896-1903) and Kinross makes the following observations:

He may stand as one of the clearest representatives of a new *fi*gure who appears in printing and publishing at this time: the book designers… Before the appearance of the book designer, 'designer' had, in the context of publishing, meant essentially 'illustrator'. The work of Ricketts, and other designers for commercial publishers of the late nineteenth century, represents the incursion of art into machine production [*10*, p. 38].

Kinross notes that "artistic printing occurred at the moment when a change in taste became apparent: between highbrow and lowbrow, between a minority and a mass-market" [10, p. 40]. Although Warde herself states that "it is mischievous to call any printed piece a work of art, especially *fi*ne art" [7] her positioning of typography as a creative endeavor steeped in a historical tradition *fi*rmly aligned with connoisseurship values has done much to dictate the constitution of the discipline.

## 2.2 Connoisseurship and Contemporary Graphic Design
In 2002, Satellite interviewed a noted typographical designer and the prelude to this interview is revealing:

He walks into the basement of Eshleman, our interview spot, and homes straight in on a framed poster leaning against a corner. "THIS IS A PRINTING OFFICE" the elegantly printed and not entirely subtle sign says, "CROSS-ROADS OF CIVILIZATIONS, REFUGE OF ALL THE ARTS". Andy Crewdson stands next to the sign, his neck craned

down at it, and says practically without introductions: "That's a Beatrice Ward from *1*932. That's really cool." …I look at the sign and he's right (the sign is a reprint), but he's right on both counts. Andy, a senior who has more or less devoted his free time to typography and reviving long out-of-use typefaces, goes on for about a minute about the history of the sign (Ward created several important typefaces), the methods of printing it (Letterpress), and its rarity ("You don't see many of those"). He has all this to say about a sign hanging in my own of*fi*ce, a sign that I'd only given half a look at about three years ago, and it occurs to me that this is what graphic design is all about: recognizing type. [*11*, n.p.]

We can see here how the author recognises the language of typography as the language of graphic design, but it is equally important to understand the nature of this language – that is, one which has all of the mysti*fi*cation of the discourse of *fi*ne art. Aside from the misspelling of Warde's name (a common mistake), there is an unmistakable quality of traditional fine art connoisseurship within this article. "That's a Beatrice Ward from 1932" smacks of the elevation of the artist's significance over the work, similar to how one might say "The Picasso is in the hall" or "We've just purchased a Rembrandt". The author is quick to point out the work is not an original but a reproduction, even though the work is a piece of printed copy. The language of fine art connoisseurship is unmistakable.

## 2.3 Problems with Connoisseurship in Design Pedagogy
I argue that in most design departments of universities and colleges, graphic and communication design is taught largely through a connoisseurship model. This is especially so, when it comes to typography. One of the most popular typography textbooks, Stop Stealing Sheep describes the difference between the expert and the amateur:

It is a bit like having been to a concert, thoroughly enjoying it, then reading in the paper the next morning the conductor had been incompetent, the orchestra out of tune, and that the whole piece of music is not worth performing in the *fi*rst place… The same thing happens when you have a glass of wine. While you might be perfectly happy with whatever you're drinking, someone at the table will make a face and go on at length why this particular bottle is too warm, how that year was a lousy one anyway… [*12*, p. *17*].

There are a number of problems with the connoisseurship system. The fascination with what is, that is, with the tangible, can work against the recognition of what is not; of what is missing from the picture. The connoisseurship model privileges object at the expense of context; detail at the expense of wider philosophical or sociological perspective. The question must surely be asked here: why should any model have to address any wider enquiry than its specific area of interest? My answer takes up Freire's [13] perspective that everything is political – that, in fact, one acts politically whether one recognises it or does not. If there is social imbalance and one acts within the social sphere, then one acts to maintain that imbalance or to critique it. The connoisseurship model acts to maintain and propagate class distinction, not only in the producer of type, but also in the consumer. For the model to work, a correlative degree of mystification around aesthetic values is supported – a form of distancing of the language of type from the uninitiated. Bourdieu reminds us that the language of art is a language of exclusion which privileges certain social groups over others, noting that "the 'naïve' spectator cannot attain a specific grasp of works of art which only have meaning – or value – in relation to the specific history of an artistic tradition". [14, p. 4] This is as much the case in the art of typography, as in any other art form.

There is a more immediate and vocational difficulty with the connoisseurship approach. Students who have learned their art through this approach are well-suited at designing logotypes and the like for banks, lawyers, and other elite clients, but often tend to see what they constitute as 'good design', as universally appropriate. Thus, anything that does not fit with the aesthetic to which they are inculcated, is seen a 'bad design'. This means that, as communication designers, they are limited in their abilities to communicate to anyone outside of the 'high design' aesthetic. If the need arises, as it occasionally does, the approach tends to be one of maintaining this aesthetic, as a form of educating those of lesser taste. This is not always a successful approach. The emphasis of the connoisseurship model is very much more on the producer, rather than on the consumer, and although it may be recognised that what is deemed good design changes over time, there is still a certain essentialism in the value system. Good design is seen as good, no matter the make up of the audience.

## 2.4 The Benefits of Connoisseurship in Design Pedagogy

For all its possible failings, however, there are many benefits offered by the connoisseurship approach. In the first place it offers individuals a sense of belonging. Well-respected Australian designer Alistair Morrison had this to say about typography:

I like the discipline of it. I've always had the feeling of satisfaction of belonging to an international and almost timeless brotherhood which included people like Bodoni and Aldus Manutius, a feeling that I am just another link in the chain [qtd in *15*].

For students, this sense can be a powerful incentive to learn, and staff have commented that students have 'found themselves' after discovering the world of typography. These students are given constant reminders of their newfound abilities, skills in type recognition and aesthetic discrimination by the world around them. Every menu, road sign, and website offers up delicacies to be savoured, or crimes to be abhorred. Every unrecognised font becomes a challenge and each challenge becomes a reminder of the club to which they now belong. As Garfield notes: "Identifying a particular font can be the most infuriating task, and designers can spoil their whole day by walking past a shop and seeing something they can't name." [16, p. 174] Students become more immersed in their art than any teacher could otherwise hope for, and soon know as much, if not more about the subject, than their professors.

Genuine engagement is the best of tutors. The joy felt by the student is a combination of deep aesthetic appreciation and the kind of excitement one has at demonstrating (if even only to oneself) a finely tuned skill. For those students who perhaps never excelled at sports, or were not socially integral members of any clubs in their younger years, typography can open up a whole new aspect of their personality. This can be an immensely rewarding experience that sees them not only develop an interest, but often, sets them on a career path, with a fascination and deep sense of enquiry that lasts a lifetime. The flow on effects in terms of self-confidence and personal sense of direction are immeasurable.

## 3  Semiotics in Design Pedagogy

I argue that semiotics taught in conjunction with the connoisseurship approach can not only address the failings of the latter, but also contribute to a world-view that can benefit design students immensely. Semiotics is particularly useful in terms of relational values. The object is always understood within, and with respect to, its context. This context highlights that design is always political, and although graphic design is visual in nature, at its core there exists an element of the invisible. As Fry notes:

Whatever design exposes, it also conceals. For instance, architecture, product and industrial design aesthetically hide the nature, quality and assembly of structural components and operative functions, this most overtly via styling brought to facades, casing, cladding, mouldings, etc. Packaging also acts as more than just a protective wrapping that conceals what it contains – its design often obscures the difference between the projected image of the object packaged and the experience of the object itself. Graphic design likewise both exposes and masks what is seen... [17]

At the same time, a poststructuralist approach to semiotics regards the language and value systems as fluid. In this semiotic model, 'good design' has no meaning outside of its particular context. If the model is one of communication, then no particular aesthetic can be placed 'above' another, and 'good design' becomes that which is the most effective solution.

### 3.1 Combining Semiotics and Connoisseurship in Design Pedagogy

There is an initial resistance of some students to exploring the realm of semiotics in design. It seems they are already familiar with Paddy Whannel's statement: "Semiotics tells us things we already know in a language we will never understand." [Whannel, qtd. in 18]. At first, certainly, it does seem an unnecessarily complex set of concepts and language to discuss sometimes the most mundane of things. However, once students grasp the concepts involved, they often relish the knowledge. In fact, the discourse around semiotics works in a way similar to connoisseurship – it provides a deeper, or at least, different knowledge to which they are familiar, along with its own historical lineage, language, hierarchies and the like. It is in this sense, than van

Leeuwen's notion of social semiotics, which "requires immersing oneself not just in semiotic concepts and methods as such but also in some other field" fits well [19].

An important aspect that semiotics brings to graphic design is an emphasis on the connotation, both in a direct and immediate sense, but also in a wider political sense. In the local sense, we become aware of a clear differentiation in the way design writers articulate how type, for example, works. In one section Garfield discusses type from the traditional connoisseurship perspective:

Will the ear be level (Jenson) or droopy and tear-shaped (Century Schoolbook)? Will the upper bowl be more voluminous than the bottom one (Century Old Style) or vice-versa (Walbaum)? And what about the bowls? These are not arbitrary decisions, but are tied to the pedigree of the type [*16*, pp.*175-6*].

In another, the effect through connotation is clear:

Was the TIGER WOODS scandal a little too grubby for the glossy magazines? Not if his *first* name was set in a huge capitalized version of BODONI on the cover of Vanity Fair. Then the story would look sophisticated, classy and re*fi*ned [*16*, p. 205].

That values such as class, sophistication and refinement can be imparted by a choice of type may seem an issue of connoisseurship, but semiotics can also be put to work here and in this way students begin to see the value in both. Similarly, both class and connotation are suggested when Spiekermann points out that 'wine menus look different from snack menus... because wine is more valuable – so that's serif. The snack menus are sans serif' [qtd. in 16].

What I am advocating here then is not a rejection of traditional connoisseurship approaches, but the addition of a deeper sensitivity to connotative meanings and possibilities. A thorough knowledge based in historical knowledge and awareness of detail can be combined with a sensitivity to connotation and meaning. As an example, we can consider this passage discussing the typeface Avant Garde, from Heller:

Avant Garde was adopted as symbolic of the raucous sixties and me-generation seventies. While the face had roots in

modernism, it was also eclectic enough so as not to be too clean or cold. As a headline face it said 'new and improved', and as a text face it added quirkiness to the printed page. It came alive on advertisements, and was appropriate for editorial design too. Eventually, after excessive overuse and rampant abuse, its quirkiness became simply tiresome – something like the paisley of type fonts – no longer fashionable, but not entirely obsolete either [20].

Here we can see that connotation can emerge out of historical knowledge and experience. It can be tempered by fashion, and artifacts that strongly connote a particular historical era are highly susceptible to the fortunes of fashion. The notion of the 'classic' can escape this by a call to a particular elitist aesthetic (it is a classic because it has a beauty, elegance, etc. above the whims of fashion). This is a traditional connoisseurship approach enhanced by an appreciation of semiotic analysis whereby each informs the other.

## 3.2 Impediments to Semiotic Approaches in Design Pedagogy

It may seem obvious that semiotics has a place in design pedagogy, and yet currently it struggles to make any impact on design practice and indeed, as Storkerson notes, across design disciplines, semiotics lacks any "broad visibility" [21, p. 7]. In fact, it is found in many courses where graphic design is taught and it is promoted by a number of interlocuters [19, pp. 21-28]. However, it often tends to sit firmly within the theory area and competes for attention with the history of art, the history of design and a range of other important design concerns. I would argue that semiotics can provide language, which allows for a much richer discussion of many of these other design issues, and has the potential to add significantly to the design creative process. One of the impediments for an uptake of semiotics is that it removes the emphasis from the producer. It appears to give no direction in terms of what should be done. In fact, it de-emphasises the authorial role of the designer, and introduces aspects of marketing, a prospect disparaged by many a professional designer. There is a politics to overcome here. Designers have long seen themselves as quite distinct from advertisers, and have often been keen to maintain the distinction. There are many reasons for this [4], but a significant one is that advertising is seen to have less of a connection to art, whilst designers have in many ways tended to

maintain their historical connections to commercial art. This connection marks a sense of authorial power over the end product, and reifies the artistic skill of the design professional. Marketing has been a key element of advertising since the 1950s [29] and has often been seen as a threat to the autonomy and expertise of the designer [4]. Currently the boundaries between advertising and design have become blurred and an appreciation of what each area has to offer is beginning to filter through to both discourses. Some would still argue, however, that a knowledge of semiotics even interferes with the creative process. Van Leeuwin makes a salient point here: "Just as the 'rules' of spelling and grammar did not destroy the possibility of linguistic creativity, so an explicit semiotics of typography will not destroy typographic creativity.". [27]

Another important aspect of semiotics that militates against its development in design education is its emphasis on context. Whilst this, as I have noted, is what makes it so attractive for those wishing to see designers with a deeper awareness of their designs and their social communicative impact and implications, this is seen by some as having negative repercussions for pedagogy. Professional design emerged out of the industrial revolution, as a fundamental process of the capitalist economic system. It is of course implicated in the production of goods and in the selling of those goods, and since the 1950s in the production of markets to buy those goods [30]. In bringing to attention the political context that surrounds design production and promotion, there is an aspect that emerges that can be seen as possibly vocationally discouraging to students. Design often works to maintain and propagate hegemonic ideological positions that can be seen as restrictive to individuals and globally destructive. Semiotics draws attention to the ideological import of design as we can see from Kress and van Leeuwen:

Pictorial structures do not simply reproduce the structures of 'reality'. On the contrary, they produce images of reality which are bound up with the interests of the social institutions within which the pictures are produced, circulated and read. They are ideological. Pictorial structures are never merely formal: they have a deeply important semantic dimension [28, p. 45].

Illuminating this aspect of design could be viewed as having a negative impact on design courses and

the argument for globally responsible and ethical designers needs to be strenuously upheld when semiotic approaches are part of design pedagogy. As it is, I argue that these fears are unfounded. Not only has the course I teach in semiotics had continuously excellent student feedback, but I have had numerous students impart to me that the course has "changed their life", and added immeasurably to their appreciation of design. Even many years later, ex-students have told of the lasting positive effects from their course in semiotics and design, which positively affect their work still.

## 3.3 Understanding the Design Process and the Significance of the 'World-view'

One of the major hurdles for the introduction of semiotics in design discourse is functional in nature. Numerous authors [31-35] have written on the subject of the creative design process, conveying a number of differently nuanced versions, yet all reject the notion of design thinking as a simple linear process. Influences and inspiration come from many directions, and at different, sometimes unexpected points in the process. There is often backtracking, restarting, learning from errors, finding inspiration in mistakes, and importantly, risk taking. General leanings can be as important as specific intentions. It can be directed along a certain path, but the requirement for creativity militates against the formulaic.

Visual Rhetoric has been one approach to bringing semiotics into design with a connection to the creative rather than the analytical in design. As Buchanan notes: "rhetoric is traditionally characterized from antiquity by many of its leading theorists and practitioners as an art of invention and discovery" [36] However, visual rhetoric is often applied as a visual 'version' of linguistic rhetoric, with a recipe book approach listing the various tropes. Whilst it is relatively easy to find visuals demonstrating figures of addition, subtraction and the like; and examples of visual tautology, ellipsis, or asyndeton, students are left with little understanding of how these can be used in any creative process. Used to a design process that is more organic than this approach allows for, this tends to reinforce the notion that rhetoric is an exercise in analysis and categorization rather than a creative tool. For this reason, both semiotics and visual rhetoric have been regarded unsuccessful as creative tools for the designer. Instead, terms like 'intuitive' are employed when discussing how

designers come up with their concepts or treatments. I argue, however, that the perception that semiotics cannot add to this process is a simple misconception about how designers work.

In describing designers in the process of practicing their work, Schön [37] introduces the concept 'knowing-in-action' whereby observed practitioners drew on 'prestructures', in his terms "familiar models and prototypes that shaped their views of materials, their interpretations of the task, and their images of a completed product, in order to design".[37] I argue that prestructures are not necessarily as 'structured' as Schön describes. Instead, they are also informed by what 'world-views' – models through which we make sense of, that is, make usable, our world. It is these world-views that allow for, or make necessary certain specific models to surface at certain times. To use a simple example, if we give students a word such as 'angry' and ask them to draw it – the images will be different for each student. Some may seem familiar, but for others, when we observe what they produce, we are left with the sense: "I would never have thought to do that". Sometimes this is judged as good, and sometime the reverse, but the important thing here is that each brings to bear, whether recognised or not, their own personal lived experience. This is the foundation for art therapy, which sees what a person draws as directly connected to their psyche [38], [39]. This can be seen as a direct reflection of 'who we are'. But who we are cannot be separated from how we see the world, our world-view – they are two sides of the same coin. Someone whose world-view includes an awareness of semiotic theory cannot but have the impact of that theory in the work they do. Schön notes further that: "Paradoxically, it was their subjective appreciations that enabled them to make sense of what would otherwise be a mess and to construct design worlds in which the problems they had framed could be said, objectively, to be solved." [37] Semiotics gives designers a model for how the world works – not every aspect of the world but certainly of how their world works. Hopefully too, it is an expanded version of their world as it was before they undertook semiotic enquiry. Thus, their world-view incorporates both what they know from the connoisseurship model and the semiotic model. These models do not live separately in the designer's mind but coalesce, with sometimes one having more resonance for a task and

sometimes the other, and yet there will be times where both will have an influence – depending on the many other experiences that have shaped the individual. To use a somewhat pedestrian example, a student who has a fear of dogs and who is asked to visually represent the word 'happiness' is unlikely to come up with an image of puppies. Similarly, a student who has developed an awareness of gender politics through their semiotic analysis of advertising, may be less likely to jump first to a design solution that is inherently sexist in its connotation and ideological effect.

### 3.4 Benefits of the Semiotic Sensibility in Design

In terms of its vocational advantage, a semiotics perspective puts greater emphasis on the consumer, and on the act of communication, than the connoisseurship model does. As early as 1916, advertising executive and critic Charles Higham had voiced the recognition of the persuasive powers of type, stating:

A clever manipulator of type can make it serve the purpose of publicity with a forcefulness that the uninitiated always feel but seldom understand [qtd in 40].

This is an interesting perspective as it raises the connoisseurship notion (initiated–uninitiated), but not in the disinterested way of fine art – indeed the term 'manipulator' here seems to act not only on type but also on an unwitting audience. Although this certainly sounds morally dubious, it nevertheless makes clear that type has a connotative effect beyond any notion of aesthetics. It refers to effective communication. My pedagogical approach to type works from the following notion:
A piece of type 'speaks' to you, even before you read what it has to say.
This may seem paradoxical, but of course I am using 'speak' in the semiotic sense, and 'what it has to say' in terms of the written content of the words. By drawing attention to how typography 'speaks' or hails you in the Althusserian sense [41], we foreground effective communication, over any aesthetic dimension, as we might find in a purely connoisseurship approach.

### 3.5 Teaching Semiotics in Design

My approach to semiotics in graphic design pedagogy is largely through the work of Roland Barthes [2], [42], primarily because of the strong connection here of

signification to culture. As noted above, connotation is perhaps the most important aspect of semiotics for design, and Barthes allows for the political and social implications of design to become visible. The notion of myth is also particularly useful for students and we employ the description 'little stories that help us make sense of the world'. Students are taught Marxist and post-Marxist conceptions of class and ideology, and Freudian and Behaviorist psychology, as well as race and gender politics; but importantly all of these are explored within a framework of Barthesian semiotics. This means a common language becomes available through which these different theories, or metanarratives can be approached. Although this growing knowledge is applied at various stages to design artifacts, semiotics as a recipe to develop the creative process of designing is avoided.

Semiotics in design works best as a sensibility rather than as a set of rules or structures. The linguistic emphasis on structure is problematic for the design process, which requires a fluidity and often a freedom from strictly directive or formulaic methodologies. The term 'sensibility' is used here to mean a familiarity with, and working knowledge of, semiotics. In a sense, it involves more of a sense of 'background' from which the designer operates. It might be considered a 'world-view' and something that operates on an almost subconscious level. Van Leeuwin uses the notion of semiotic resource from Halliday:

The term 'semiotic resource' is therefore a key term in social semiotics. It originated in the work of Halliday who argued that the grammar of a language is not a code, not a set of rules for producing correct sentences, but a 'resource for making meanings' [*19*, p. 3].

The means by which a semiotic sensibility is achieved is through an inculcation of the notion of semiotic connotation across a wide range of different media, such that students see the semiotic implications of an artifact without necessarily having to consciously 'switch' into an analytical perspective. This involves at first a very directive and thoroughly researched semiotic analysis of film, to be followed by one of advertisements, then of product labels and packaging. Throughout the process, there is constant reinforcement of the language of semiotics with discussion of how it can be applied to other systems, like architecture or even of how

someone dresses. Students also undertake a project in which they swap the signifiers, but not the actual words, of two different common supermarket product packages. This highlights the powerful effects that design signifiers like colour, typography and layout can have in supporting and propagating social myths about class, gender, and the like.

Although I have largely limited my discussion here to typography, semiotics is a powerful tool in approaches to all aspects of graphic design. What are the connotations of lots of different typefaces and a multitude of photographs on the cover of one magazine, for example, compared to say a single typeface with sparing use of text and a single full-bleed photograph? How can one discuss the 'meaning' of a photograph that bleeds off the page, as opposed to one where the edges of the image are contained within the layout? [43] What is the connotation of white space? [44] These questions are opened to a much richer investigation through the language of semiotics, than through the limited and directive approaches offered by a connoisseurship model. The end result is a language which students can apply to a vast range of artefacts and systems, allowing them to compare and contrast design decisions and effects in ways previously inaccessible to them. This is the practical application in design of Kress & van Leeuwen's [28] multimodal approach:

We seek to break down the disciplinary boundaries between the study of language and the study of images, and we seek, as much as possible, to use compatible language, and compatible terminology in speaking about both, for in actual communication the two and indeed many others come together to form integrated texts [28, p. 183].

## 4 Conclusion

This paper is not a call for the replacement of the connoisseurship model with one of semiotics – indeed, it sees many profound positive effects of both models and regards that they can work together to produce more informed, more impassioned, creative designers. Desmet and Hekkert [45] quote Green, stating in his introduction to the Proceedings of the 1st International Conference on Design and Emotion, "there remains a strong element within the design profession which regards all analysis of design activity as merely attempts to produce 'recipes' for those who can't emulate those who can!" Desmet and Hekkert's response is that:

We were driven, however, by the intention to support and empower designers rather than to unravel the mystery of design expertise and craftsmanship. Or, in the words of Green: "Our objective is not to provide recipes for non-designers to become designers, but to provide tools for the design profession to do what they do better. [45]

Teachers who employ what I am calling here the connoisseurship model often place much stake in the 'intuitive' process. Far from opposing this approach, I see semiotics as providing students with a richer historical and philosophical world-view, out of which their 'intuitive' processes of creativity can flourish.

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# Grace: A gesture-controlled wake-up light

## Abstract

We investigated the use of a deviceless gesture control for a wake-up light, a type of alarm clock which wakes the user through both light and sound. We explain the interaction design challenges for the wake-up light and discuss the drawbacks of deviceless gesture control. These challenges and issues were explored through an experience prototype which we call Grace. We argue that deviceless gesture controls fit the sleepy interaction associated with the wake-up light and help in realizing a calm product appearance. Our key finding is that gesture control needs continuous guidance: real-time, augmented feedforward and feedback, which helps to increase the user's confidence during interaction and to improve gesture recognition.

## 1 Introduction

In this project, we focused on an interaction style called deviceless gesture control. Deviceless gesture control allows users to operate devices from a distance without the need for physical remote controls, body-worn electronics or markers [1], [2].

One of our use cases was a wake-up light, a type of alarm clock which wakes the user through both light and sound. A wake-up light fades in the light over a set period of time (default 30 minutes) before the alarm time. By the time the alarm sounds, the lamp has reached full strength. This slowly increasing brightness causes the user to gently wake up. The intended experience is captured in the product's tagline of "a natural, gradual way of waking up".

In this paper, we first describe the wake-up light's interaction design challenges. Then we discuss the interaction issues with deviceless gesture control. We describe two participatory innovation events, one with developers, the other with users. We then argue the benefit of gesture control for a wake-up light. Finally, we present a concept called Grace in which we address the wake-up light's interaction challenges and discuss the interaction principles we used to mitigate the drawbacks of deviceless gesture control.

## 2 Wake-up Light Interaction Design Challenges

Designing the interaction for the wake-up light is challenging for four reasons: multi-functionality, programmability, sleepy users and conflicting inter-action and product design requirements.

### 2.1 Multi-functionality

A wake-up light is a multi-functional product which combines an alarm clock, a dimmable light, a radio and a digital music player, operated through a single user interface. Many of these functionalities are inter-twined. For example, the brightness of the light is controlled by the alarm time of the clock. As a result, a modal approach to the interface is not possible as many functions 'straddle' two or more modes. It would

also require users to switch back and forth between modes to access functions which experientially belong together.

## 2.2 Programmability

Many of the parameters are programmable, including the wake-up time, the fade-in duration, wake-up brightness and the wake-up sound. Both this programmability and the aforementioned multi-functionality stretch the interface of the current generation wake-up light which consists of an alpha-numeric display and push buttons. Such a 'display + push button' interaction style is known to put a heavy burden on users' cognitive skills and to be slow and cumbersome for adjusting analog parameters [3].

## 2.3 Sleepy Users

Another reason why users may have more difficulties with operating a wake-up light than with other products is simply because of sleepiness. Immediately after waking up people suffer from sleep inertia, a physiological state characterized by diminished motor dexterity and a feeling of grogginess [4], [5]. This impaired alertness may interfere with our ability to perform mental or physical tasks. Similarly, sleep homeostatis–the physiological process whereby our need for sleep increases the longer we stay awake – results in sleep pressure which leads to diminished cognitive performance [6]. Clearly, these are the very moments – just after having woken up and just before going to bed – when users interact with their wake-up light. At these moments, tasks which are trivial when fully awake suddenly require effort.

## 2.4 Interaction vs Product Design Requirements

A Wake-up Light has many analog parameters (e.g. brightness, volume, wake-up time) and long-list parameters (e.g. radio station presets, MP3 tracks) which in current models are operated through binary, up-down controls. This requires the user to press buttons multiple times when making large adjustments, leading to a staccato style of interaction.

From an interaction design perspective, one approach to improve the interface would be to add dedicated, analog controls so that key analog parameters may be controlled directly instead of via menus and up-down buttons, resulting in a more fluent interaction style. However, one of the starting points for the product design is that a wake-up light should have a calm

appearance which fits the bedroom environment. To create such a calm appearance, the design should avoid the overt use of control panels and displays which are likely to create visual clutter. This then is where product design and interaction design potentially clash. Product design on the one hand calls for minimizing the number of controls and for repeated use of the same type of control to realize a calm appearance which makes it difficult to realize intuitive interaction. Interaction design on the other hand calls for dedicated, differentiated and analog controls such as sliders and rotary controls, all of which results in the visual codes which typify the consumer electronics 'gadget' genre. Part of our challenge was to investigate how deviceless gesture control could contribute to solving this conflict.

## 3  Gesture Control Challenges

Gesture control is often perceived to offer the ultimate in interaction simplicity, a popular view which is strengthened by science-fiction movies such as Minority Report [7]. According to this view, gesture control may add cost and technical complexity but will definitely result in a superior end-user experience. Considering how quickly the cost of the required technology decreases, some even envisage a day when we may interact with all our products through gesture control.

However, for the end-user, gesture control may have drawbacks more fundamental than a higher purchase price. Here we describe two user experience issues with gesture control: the need for an initiation method and the lack of inherent feedforward and feedback.

### 3.1 The Need for Initiation

If gesture control were continuously enabled, users may unintentionally trigger a function. For example, if the brightness of a wake-up light is controlled through an up-down gesture, any vertical movement in the active zone such as picking up a glass of water may influence the lighting. Clearly, such false positives are frustrating as they break the user's sense of control. To prevent such unintentional triggering, users need to switch on gesture recognition before they can make a functional gesture. Our term for such an action is the initiation action. The challenge in choosing an initiation action is that if we opt for a physical movement, this initiation gesture must not occur in daily ritual and is therefore unnatural by definition. Here then lies the contradiction

within gesture control: whilst gesture control is often described as offering natural interaction, the required initiation action can make it feel contrived.

## 3.2 Lack of Inherent Feedforward and Feedback
Physical controls such as mechanical buttons, switches and sliders have many interaction qualities, which we take for granted. For example, when using a light switch, we can see and feel the position of the switch on the wall as well as see and feel what action is required (e.g. toggling, pressing, rotating or pulling). When we switch on a light, we can see and feel the switch move and hear the click. Such inherent feedforward and feedback [8], [9] is not self-evident when it comes to gesture control. It may not be clear how to gesture or even where to gesture. In some gestural interfaces, the only feedback the user gets is when the functionality is triggered after completion of the gesture.

Though this may seem sufficient, it becomes troublesome if the system fails to recognize a gesture because it is not sufficiently well-defined, too quick or out of range. Users then seek to understand what went wrong but without feedforward and feedback it is unclear why things fail and they cannot correct their actions. As a consequence the user can feel lost, not quite knowing what is happening in the interaction dialog. We may draw a comparison with human conversation, in which we judge from non-verbal body language cues whether we are being understood. It is this body language which is lacking from gesture-controlled products: we gesture to the product but the product fails to gesture back.

Karam [10] proposes a framework for gestural interaction with three types of feedback: reflexive, recognition and response feedback. Response feedback occurs when the user is notified that the intended task has been completed. Recognition feedback is given when the system has successfully recognized the user's gesture. These two types of feedback are known from interaction design for traditional user interfaces. For example, the light switching on in reaction to the user flicking a switch is a form of response feedback. A beep as a reaction to a button having been pressed is a form of recognition feedback. Of particular interest to gesture control, however, is reflexive feedback which provides the user with feedback on the state of the input during performance of a gesture. Karam uses a



**Fig. 1. Ideation through bodystorming in context.**



**Fig. 2. Participant acting out gestures with WoZ experience demonstrator.**

window in a graphical user interface to provide reflexive feedback. In this reflexive window, users can see themselves performing their gestures and get feedback on what the computer sees in terms of objects being tracked.

## 4  Participatory Innovation Events
To explore the UX we staged two events: a multi-disciplinary ideation session during a multiple stakeholder workshop with developers and a multi-cultural Wizard of Oz test in which users were confronted with an early experience prototype.

## 4.1 Multiple Stakeholder Ideation
Twenty developers, including technologists, marketeers and designers, ideated in multi-disciplinary teams through bodystorming in context [11], [12]. In a staged bedroom, one team member acted out the gestures to control the wake-up light, while others simulated the reaction of the product (Figure 1). A rating session at the end of the day showed that participants particularly appreciated three features: brightness control through vertical hand movement, stumble light activation – to find one's way to the bathroom at night – through a quick flick of the hand, and direct manipulation of analog clock and alarm hands through touch gestures.

**Fig. 3. Vertical hand movement controls brightness.**



**Fig. 4. Lazy snooze. In the morning, waving in front of the Wake-up Light suffices to activate snooze.**

### 4.2 Multi-cultural Wizard of Oz Test

We turned the preliminary concept from the multiple stakeholder workshop into a low-fi experience prototype by back-projecting an interactive animation onto the casing of an existing wake-up light (Figure 2). This experience prototype was then evaluated in Wizard of Oz style with nine users of different ethnic origin. First, we explained the functions to be offered by the wake-up light. We then asked participants to act out the gestures they would choose to control these functions and simulated the wake-up light's response from behind the scene. After having shared their own preferred gestures, we explained to them the gesture-functions combinations which had come out of the multiple stakeholder ideation session. They were then asked to also act out these gestures and again we simulated the wake-up light's response in Wizard of Oz style. Finally we asked participants to reflect upon the differences between the two sets of gestures.

### 5  Benefits of Gesture Control for Wake-up Light

Our experiences with the multiple stakeholder workshop and the Wizard of Oz user test sharpened our understanding of how gesture control can be of

benefit for the wake-up light. Gesture control may help realise the wake-up light's promise of 'a natural gradual way of waking up', by complementing the functional light effect with a low cognitive load interaction style which fits the user's sleepy physiological state. Gestures can offer control over the wake-up light's key functions without the user having to interpret labels, icons or displays and without having to reach and fumble for buttons. Finally, gestures allow the user to stay snug and comfortable while operating the device from a distance. We chose the following gesture-function combinations:
• Brightness - vertical hand movement
• Volume - horizontal hand movement
• Snooze - wave on alarm
• Show the time left to sleep - wave during the night
• Stumble light - wave until active

The gesture vocabulary was intentionally kept small with only three gestures (horizontal, vertical and wave) to avoid it becoming like a modern day DOS language which requires users to learn and remember a large collection of arbitrary gesture-function combinations [13].

### 6  Concept Design

We designed and built an experience demonstrator of a gesture controlled wake-up light which we call Grace. Our aim was to address both the aforementioned wake-up light interaction design challenges and issues with gestural interaction.

### 6.1 A Sleepy Interaction Style

We designed Grace to allow sleepy, low cognitive load interaction.

### 6.2 Adjust Brightness/Volume Whilst Staying Comfortable

When reading in bed or listening to music, the user can simply adjust the light level through a vertical hand movement or sound volume with a horizontal hand movement without having to reach. Whilst adjusting the light level, the light ring reacts with a 'peacock' effect: the line between the dark and light part of the ring follows the user's hand movement (Figure 3).

### 6.3 Lazy Snooze

In the morning, waving in front of the Wake-up Light suffices to activate snooze (Figure 4).

## 6.4 Ambient Sleep Time Indication

A wave during the night suffices to make the Wake-up Light show the "time left to sleep". It will light up an arc from the current time to the wake up time. The length of the arc will give the user an approximate indication of the time left to sleep without having to interpret the hour and alarm hands (Figure 5).

## 6.5 Calm Appearance

Grace uses a combination of deviceless gesture control for the key functions (Figures 3-5) and a touchwheel for detailed settings (Figure 6). The touch wheel allows easy adjustment of analog parameters such as the wake-up time and the dusk duration. It also allows easy selection from long-lists such as radio stations and MP3 playlists. The combination of deviceless and touch-based gesture control allowed us to eliminate all but one physical control and to keep the product's appearance very clean and restrained. The final design is based on a round form factor with three concentric circles (Figure 7), the semantics of which suit an analogue clock, support the sun metaphor and refer to the traditional alarm clock product category. The inner circle is formed by a circular colour OLED display, the middle ring is formed by a touchwheel and the outer ring is formed by the light surface. To further strengthen the reference to traditional wind-up alarm clocks, the product stands on three legs, two in front and one at the back (Figures 8 and 9).

## 6.6 Initiation by Delay

One way to make initiation faster, less convoluted and less contrived is to use a multi-modal approach. For example, a physical movement can be combined with sound (e.g. handclap, finger snap) or voice [14]. However, when interacting with the wake-up light the user's partner may be asleep and initiation must be silent. Therefore we opted for initiation by delay: the user needs to hold her hand still for 1.5 seconds within the active zone before gesture control becomes active.

## 6.7 Continuous Guidance

As previously mentioned, inherent feedback is missing from deviceless gesture control. We therefore need to add augmented feedforward and feedback to provide users with information on what is going on [9]. With gesture control this augmented feedforward and feedback needs to change in real-time in response to users' gestures so that they may adjust their actions while
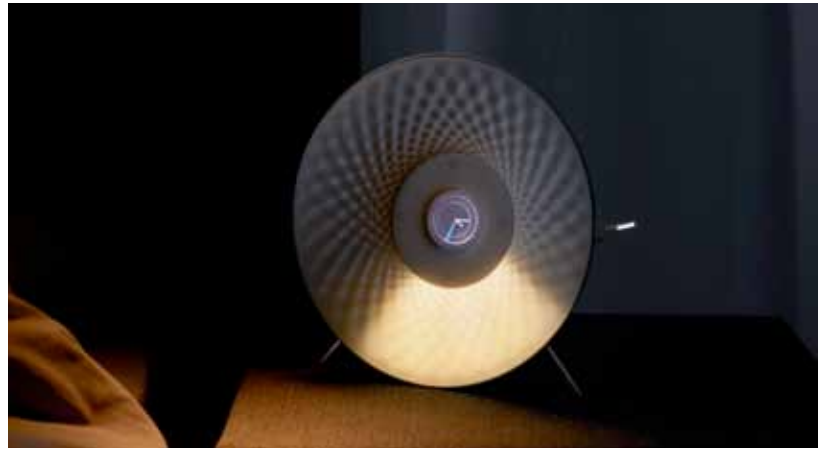


**Fig. 5. Ambient sleep time indication.**



**Fig. 6. A touchwheel is used to enter detailed settings.**

gesturing. For this we use the term continuous guidance (Figure 10).

With Grace, we provide continuous guidance by means of an animated point cloud effect on the circular OLED display to elegantly bridge the delay during initiation. There are two possibilities when the user's hand enters the active zone. The first option is that the user has no intention of operating the wake-up light and that the hand passes through the active zone incidentally, for example to pick up a glass of water, a set of keys or a mobile phone (Figure 11). In this case, the clockface which is shown in the idle state changes into a point cloud which follows the user's hand movement, to return to a clockface when the user's hand leaves the active zone. The second option is that user does intend to operate the wake-up light (Figure 12). In this case, the clockface changes into a point cloud which moves with the hand to then morph into a cross-shaped UI during the initiation delay. The cross-shaped UI indicates that horizontal (i.e. volume) and vertical (i.e. brightness) gestures are possible.

Grace's continuous guidance serves a purpose similar to Karam's [10] reflexive feedback. However, in the case of Grace the display shows an abstract representation of the user's gestures rather than a camera image.

**Fig. 7. The design of Grace is based on three concentric circles.**



**Fig. 8. The front legs are reminiscent of traditional alarm clocks.**
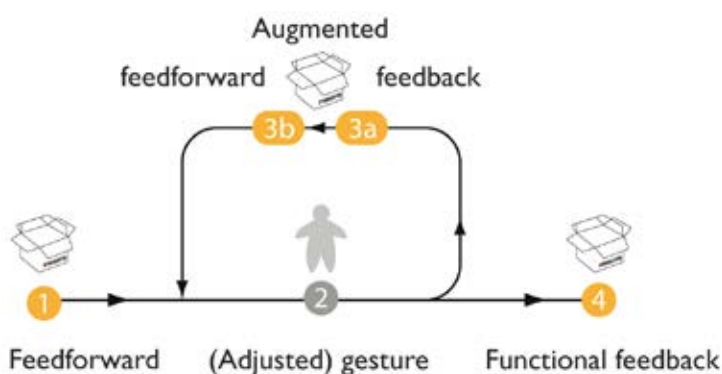


**Fig. 10. Continuous guidance is about repeating steps 2 and 3 until the intended function (4) has been triggered.**

## 7 Reflection

Gesture control's main drawbacks are the need for an initiation action and the lack of inherent feedforward and feedback. In our concept we tackled these issues together: Grace makes use of initiation by delay while an animated point cloud provides continuous guidance by mirroring the user's hand movements and bridging the delay through a morphing effect. This implementation shows that continuous guidance need not take the form of a literal camera image of the user but can also take a more abstract and impressionistic form.

Through this project, we discovered that gesture control has a number of lesser known user experience advantages. One is that gesture control requires less focus than traditional, physical controls and therefore is a comfortable form of control when the user is sleepy. Another advantage is that gesture control offers can offer direct, analog control over key functions without the need for traditional analog controls such as sliders or rotaries which clutter the product design.

In any case, gestural interaction raises many semantic issues. In contrast to physical controls, gestures can be coupled to form, feedback and function in any way desired. A gesture has no fixed meaning that is only suited to a particular function. Instead, the meaning of gestures is pliable and can be influenced through a product's form, its physical and screen based UI and light and sound. Gesture control puts much responsibility on designers to prevent these couplings from coming across as completely arbitrary.

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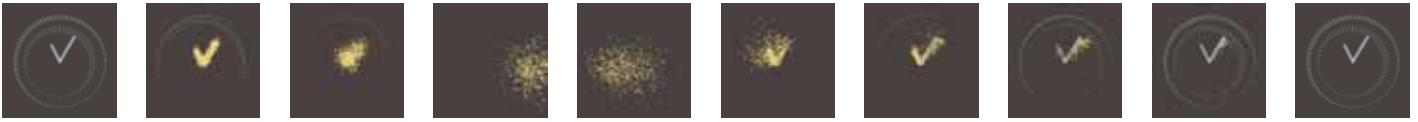
**Fig. 11. Presence detected but the user does not activate gesture control.**



**Fig. 12. User initiates gesture control.**

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**Fig. 9. Grace looks lighter than existing Wake-up Light models, and leaves space underneath for small objects such as mobile phones and keys.**

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# The aesthetics of immateriality in design: Smartphones as digital design artifacts

## Abstract

The paper is a philosophical-theoretical contribution to the conceptualization of the span of material extension and immaterial impact in artifacts employing digital technology. Using the smartphone as an example of a widely distributed type of material artifact that operates with immaterial structures of information, the paper offers a theoretical discussion of how immateriality can be conceptualized as a matter of aesthetics in the face of the challenge that digital artifacts pose to the role and understanding of materiality in design objects. The paper proposes a framework of aesthetics that describes sensual, conceptual, and cultural levels of meaning in and through the object. Further, the paper discusses how this connects to a notion of possibility in design. Thus, the paper contributes to a discussion of the sensuous character and impact of artifacts that are on the verge of immateriality. The relevance to design practice is motivated through the discussion of central concepts of design ontology and the proposal of a framework of aesthetics that in its discussion and structuring of levels of meaning in design can inform the process of developing design.

## 1 Introduction

Seen within the context of the material culture of design, artifacts employing digital technology, for example in ubiquitous computing and wireless communication, create a new culture of design where the elements of the immaterial, the invisible and the non-sensual in the design gain in importance. Increasingly, objects and products contain or are enabled by digital technology which, in turn, fundamentally structures the functions, usability and character of the object. This ranges from the interactive interfaces of computers and PDAs to cell phones and "plainer" low-tech products such as toasters and coffee machines which also incorporate electronics. Even if the world still has plenty of fairly low-tech material objects, we can still state that a revolution, a digital turn, has taken place in the way that objects are designed, constructed, and used. In a historical reflection on shifts in types of design, the German design theorist Gert Selle has described how the microchip can be seen as the founding design for our current era (following a line from the prehistoric monolith to the industrial-age paperclip), which is characterized, among other things, by a miniaturization of technology and a new culture of invisible design [1]: While the dictum of "form follows function" in industrial Modernism should make objects display their function, the hidden operation of the microchip in the digital age has lead to "black box" design with object surfaces that only hint at the function of the object.

We simply cannot directly detect the purpose of the digitally operating black box objects; as a basic condition today, we cannot assume that objects are easily decoded based on their outer appearance. Further, objects that rely on the wireless exchange of data can even create a network of meaning that operates invisibly, as they do not necessarily display their interface of interaction. This phenomenon, which is often related to the concept of ubiquitous computing, entails a change in perception, as our interaction with our surroundings is increasingly mediated by digitally operating artifacts and, to take this reflection further, even creates objects engaged in networks with other objects without any human interference [2]. In terms of programming, the media theorist Lev Manovich has claimed (mirroring Siegfried Giedion's classic 1948 book on anonymous design culture Mechanization Takes Command) that 'software has taken command' in "forming contemporary culture" whereby, furthermore, "cultural, social, and economic forces [...] are shaping development of software itself" [3]. The hidden parts of design are taking command. As a consequence, design objects are not only to be regarded as objects with a material extension but increasingly as objects of immaterial effect, communication, and information. In turn, the ontology of design objects is challenged, when their being and constitution is not only marked by materiality and physical extension but also by levels of immaterially operating digital technology. This new ontology of design needs to be conceptually described and circumscribed. The thesis of the paper is twofold: (i) Digital artifacts operate in the intersection of material and immaterial dimensions of design; (ii) the dimensions of the material and the immaterial in design can be productively described within a framework of aesthetics. Aesthetics in relation to design often deals with the sensual and material aspects of design, but the proposal here is that an aesthetics of immateriality in design can be formulated that also regards the conceptual and cultural aspects of the design. In relation to aesthetics, the level of the immaterial in design evokes and stimulates possibilities.

As an example for reflection throughout the paper, the smartphone will be discussed as a contemporary digital mass product that has entered the sphere of use and consumption in a seemingly frictionless manner, but which in its constitution manifests a ground-breaking

combination of material and immaterial design strategies. Thus, the smartphone will be discussed as a type of digital design that engages and widens the span of sensual, conceptual, and cultural possibilities in and through the design.

## 2 The Immaterial Through the Material: The Smartphone

In this section, I will discuss how the material and immaterial dimensions in design serve to structure digital artifacts; in this discussion, I will use the smartphone as an example, as the smartphone may be seen as a design object that exists at the intersection of material extension and immaterial implication.

To introduce the product type, a smartphone is a combination of a cell phone and a pocket-sized computer. Another example of this kind of portable computer device for the consumer market would be the tablet computer, invented as a product type by Microsoft and considered a failure [4] until Apple reinvented the product type with the 2010 iPad and reopened the market for the benefit of other manufacturers as well. With the iPhone from 2007, Apple similarly contributed to defining a cultural trend and enabling a market for the smartphone, where RIM's BlackBerry models have offered mobile email devices ever since 1999, and where other manufacturers, e.g. HTC, Sony Ericsson and Samsung are currently contributing to product diversity. The smartphone employs the wireless cell phone network, an accessible and visible interface based on a touch screen and the processing power of a small computer. Thus, the smartphone is not only a phone; it is more like a computer device that enables internet browsing and multimedia interaction. Most of the difference lies in the operating system (OS); in April 2011, Google's Linux-based Android system represented 33% of the US market, RIM's Blackberry OS accounted for 29%, and Apple's iOS held 25% [5]. A special feature to be noted in this context is the app, short for "application", which is a small program that can be downloaded and used to enhance the spectrum of functions and possibilities on the device: games, maps, search functions (best places to eat, etc.), fixed browser platforms with specific targets (e.g. the nearest recreational space, vending places for train tickets). A special smartphone 'meta-app' directs the user to the app store or the app market

(depending on the OS), where a variety of apps can be purchased or downloaded for free.

As a contemporary digital mass product, the smartphone has entered the sphere of use and consumption in a seemingly frictionless manner, even if, by virtue of its constitution, it operates on the basis of a ground-breaking combination of material and immaterial design strategies. It is defined as a product at the intersection of material and immaterial properties, which are mutually dependent. In this context, material properties include the tangible, material, physical aspects of the object or device, that is, the object as thing or the thingness of the object. Immaterial properties, on the other hand, include all the aspects of the device that exceed or transcend the physical extension of the object, such as its communicative effects and its ways of structuring and affording patterns of action. Often, the value that people attach to the smartphone derives from its connection to other phones through the network infrastructure. The apps are particularly interesting in this context, as they serve as a pathway for conveying wirelessly transmitted content into the material frame of the smartphone device. Thus, the apps contribute to the creation of the smartphone as an open-structured design that integrates streams of immaterial information and as a design that widens the span of sensual, conceptual, and cultural possibilities.

As a concept, immateriality entered the design debate through communication and media studies when computer technology emerged in the 1970s and 1980s, even if the new kind of immateriality carried by digital technology and structured as streams of information was, and still is, dependent on material hardware [6] in the often "artificial channels" of modern communication [7]. As a consequence of the increase in the circulation of immaterial information, the media philosopher Vilém Flusser has argued that a shift has taken place in existential concerns "from things to information," where people are "less and less concerned with possessing things and more and more concerned with consuming information" [8]. Similarly, design can be seen increasingly as a matter of information; thus, as early as 1973, Gert Selle pointed out that design objects not only carry "functions but also, always, information" [9]. Expanding on the argument of the content of information in design and

focusing on its social impact, with the dictum "design is invisible", design theorist Lucius Burckhardt stated in 1980 that design is not only visible but also invisible in its social effects and in the implications for the creation of systemic organization via design [10]. This is a point that Selle addresses in his recent discussion of the dialectics of the visible and tangible aspects of design on the one hand and its invisible conditions and effects on the other. On the level of the invisible, Selle identifies a phase before the design – all the aspects in the phase of designing that condition the design – and a phase after the design, which deals with the effects of design with regard to creating and supporting culture, structuring and guiding social behavior, and regulating action and corporeal-emotional responses [1]. On this point, Selle's discussion is very brief – he merely mentions these aspects – but illuminating and worth exploring: What are the immaterial effects of design, and how can they be divided into levels in the analysis?

The smartphone exemplifies how material and immaterial features apply to different logics of design but are nevertheless inextricably interlocked. On the one hand, what makes the smartphone relevant to users is its ability to communicate and serve as an aggregate for the wireless exchange of information, that is, the dimension of the immaterial; and, on the other hand, it is the tangible product, the actual device, that enables the immaterial effects through its material being. Thus, the design of smartphones is comprised of two elements that can be employed both individually and in combination to achieve differentiation between manufacturers and models: The design of the interface (and of the underlying OS) facilitates the user's interaction with information, and the material design of the device generates sensual and cultural appeal for the consumer, who can see him/herself reflected in the product and use it to create and flash an image of personal identity. In general terms, this type of design can be said to have two dimensions; although they point in different directions, in combination they form the complexity of the design:

(i) The design has an outer, *finite*, materially limited extension (the device) where shape, the choice of materials, and sensual interactions are crucial;

(ii) The design contains an *infinite* dimension of, on the one hand, inward expandability in the form of software

structures and information processing and, on the other hand, network links to information and other devices. In its handling of information, the interface is an outward-pointing gateway that structures the *flow* of information and makes it accessible for the user.

In a phenomenological reflection of meaning incorporated in sensually appealing materiality, all design objects have an immaterial dimension in the sense that they incarnate ideas in their process of signification (e.g. of use, relevance, or ideology) which, conversely, can only come into being by means of the tangible product: To summarize, we cannot conceive design as exclusively material or immaterial; the immaterial is nothing without a physical manifestation [11].

Of course, this phenomenological premise also applies to the smartphone. However, its employment of digital technology specifies the immaterial dimension as a structural openness of meaning where different kinds of information can be drawn into and mediated through the device. The immaterial dimension of the smartphone can be described not only in general terms as ideational content but even more aptly as a technologically enabled structure that offers new meanings which, at the same time, must be contracted in the interface of the smartphone and made accessible by means of the physical design. Thus, the immaterial dimension is a key defining element of the smartphone as a digitally operating artifact; yet still, its immaterial operation is confined and circumscribed by the material extension of the design.

## 3 Aesthetics

The role and function of immaterial effects in design and their challenge to the dominant material design ontology can be investigated within an aesthetic framework. In this context, aesthetics will not be understood in a classic sense, as issues of beauty and taste, but as a general framework for examining how design objects mange to frame modes of experience and processes of understanding. I will point to three dimensions of aesthetics and aesthetic theory: (i) a sensual-phenomenological dimension, (ii) a conceptual-hermeneutical dimension, and (iii) a cultural-contextual dimension which I have also, in part, described elsewhere [11]. With particular emphasis on the immaterial aspects of the design,

the three dimensions of aesthetics can be employed to study how immateriality affects design ontology; how the 'being' and 'essence' of design are conceived. With reference to the three dimensions of aesthetic theory, we can ask how the immaterial element in design aesthetically operates (i) on the level of sensual meaning and the material object in evoking emotional responses through the appearance and "feel" of the object, as (ii) a construction of paradigms of understanding which is expressed, for example, in the interface and in the aesthetics of use, and (iii) on a cultural level as part of the social impact and symbolic communication engaged by the use and consumption of objects. See an overview in Table 1, which anticipates the following discussion.

| Dimension of aesthetics: | Sensual-phenomenological | Conceptual-hermeneutical | Cultural-contextual |
|---|---|---|---|
| **Appeal to:** | Senses | Understanding | Identity |
| **Emphasis in design:** | Material device | Use | Social impact |
| **Material extension:** | Appearance, texture | Interface | Appearance, texture, function |
| | ↓ (effect on) | ↓ (effect on) | ↓ (constructing) |
| **Immaterial impact:** | Emotional response | Construction of meaning | Identity, framing of experience, symbolic meaning |

**Table** 1. **Dimensions in aesthetics in relation to material and immaterial aspects of design.**

Essentially, the aesthetic tradition has developed along two lines. Since Romanticism and German Classicism, there has been a tendency to connect aesthetics with artistic creation and works of art; this began with the philosopher Friedrich W.G. Schelling's Romantic-Idealistic celebration of the work of art in Philosophie der Kunst (1802) and reached its modern peak in cultural theorist Theodor W. Adorno's Ästhetische Theorie (1970). Second, aesthetics has been connected to questions of sensual impact; this line of reflection points back to the work Aesthetica (1750-58), written by the philosopher Alexander Baumgarten with the aim of investigating the "lower" sensual aspects of human experience as opposed to the "higher" realm of logic. Baumgarten is an important figure, as he invented the modern usage of "aesthetics" as a term that designates a specific area of human knowledge and awareness.

### 3.1 The Sensual-Phenomenological Dimension of Aesthetics

In recent years there has been a tendency to loosen the connection between art and aesthetic theory and to revisit, from various perspectives, Baumgarten's original idea of applying aesthetics to sensual matter (in Old Greek, aisthetá, "that which can be sensed"); in terminology there has been a similar tendency toward a shift from aesthetics to aisthesis [12]. Notably, this has been developed in works by the philosophers Martin Seel [13], [14], Gernot Böhme [15], [16], and, drawing on John Dewey's Pragmatist aesthetics [17], Richard Shusterman [18]. These inquiries deal with aspects of sensual appeal and the question of 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 response. I use the term "phenomenological", as this view on aesthetics deals with the experience of things and, more importantly, with the ways in which objects influence and condition experience. Key concepts here are "pure presence", a term that was introduced by Seel, and which designates special attention to and attraction from appearance, and "ambience", introduced by Böhme as a term for the influence from the surroundings on perception. Even if these concepts are only briefly related to design by the authors, they are nevertheless powerful means of examining how design objects specifically have a sensual impact, operate as appearance, and contribute to the creation of ambience.

Seen in relation to the span of the material and the immaterial in digital artifacts, this aspect of aesthetics mainly concerns the sensual communication of the indispensable material dimension of the artifact, how it is staged as appearance and a presence to be noticed or to slip more anonymously into the mainstream of products. With regard to the smartphone, this aspect of aesthetics deals with the sensual meaning of the artifact: the look, the feel of the texture, the application of materials, the execution of the detailing, for example in the assembly and seamless fittings, as well as the sensual appeal of the overall physical presence and the immediate emotional stimulation of the user. Here, Apple's iPhone 4 can be viewed as a paradigmatic example of a device that is characterized by a high degree of detailing and material-sensual aesthetics intended to be noticed and to evoke a kind of material

presence; consequently, and probably as part of a planned media strategy aimed at media specialized in mobile devices, Apple designer Jonathan Ive has been associated with an obsession with the physical materials and the sensual "feel" of devices.

Within the realm of the sensual meaning of the material device, the immaterial aspect can be described as the different kinds of effects that are triggered by the material dimension of the design. These may involve the various kinds of emotional pleasure that the design evokes (cf. [19], [20], [21]) or an appeal to the operation of the device, i.e. how it affords its use (cf. [22]) or the way in which it enables different kinds of functions (cf. [23]). Importantly, these effects are stated on the level of immediate, sensually engaging interaction with the digital artifact in its material extension. Addressing the sensual-phenomenological dimension of aesthetics in this context means acknowledging the material element of digital artifacts, i.e. the fact that digital technology is bound to a particular form of mediation or a representation in a sensually appealing material, and that these material manifestations constitute our immediate access points to the artifact. Without these access points, we would not be able to interact with the artifact: They condition our basic sensory experience with the artifact. Going beyond material representation would result in pure (fictitious) speculations on cyber space (still, however, mediated through the material device of implants as in William Gibson's 1984 science fiction novel Neuromancer, or through new devices of visual representation, see [24]), or virtual worlds (still, however, only accessible through the material medium of the computer screen).

### 3.2 The Conceptual-Hermeneutical Dimension of Aesthetics

While the emphasis on sensual issues can be traced back to Baumgarten, the conceptual-hermeneutical dimension of aesthetics has mainly been developed in relation to art. The key concern here has not been to celebrate artistic creation but rather to analyze art as a medium for the construction of meaning and new patterns of understanding. This line of investigation was initiated in Kant's Kritik der Urtheilskraft (1790), where aesthetics (albeit not in relation to art but to our experience of nature) was conceived as a basic aspect of epistemology: Kant's idea was to employ

aesthetics in bridging sensual appearance and conceptually formulated meaning. Following this line of reflection, much of so-called philosophical aesthetics has been guided mainly by philosophical concerns about epistemology and the construction of meaning and – sometimes – less by an interest in the specific communicative abilities and conceptual strategies of the medium in question.

Design research has given little consideration to this tradition of aesthetics, perhaps because of its focus on works on art and the often abstract philosophical vocabulary (an exception is [25]). My reason for integrating it into the present discussion is its focus on the enabling of meaning: the construction, articulation, conveyance and understanding of meaning. Hence, when dealing with the enabling of meaning, hermeneutical questions gain in importance with regard to the staging of processes of understanding (on behalf of the aesthetic medium) and with regard to their operation (in the perceiver). A crucial aspect of this line of aesthetic theory has been an immense interest in the extra- and trans-communicative effects of the work of art, that is, its ability to contain or communicate something 'more', an 'added value', or an aspect of meaning other than or beyond normal communicative abilities. This latter point of impossible communication that is only made possible in the closed space of the work of art has, for example, been the driving factor behind Adorno's aesthetic theory [26] and the line of aesthetic inquiry that he inspired (e.g. [27]; [28]; [13]). In this context, the questions to be asked of design objects in general and digital artifacts in particular are, on the one hand, how and by what means the aesthetic mediums enables and constructs meaning, and, on the other hand, what is the nature of this meaning, i.e. whether it transcends any limitations, and what its implications are.

Further, this line of aesthetic inquiry places itself at the intersection of immaterial concerns and material execution. On the one hand, issues concerning understanding as well as the construction, organization, and distribution of meaning relate to the immaterial dimension and the inner expandability of the design. On the other hand, the staging of understanding and meaning requires a material manifestation; without some sort of representation in a concrete medium, issues of meaning and understanding would remain

an abstract theoretical statement. The discipline of philosophical aesthetics acknowledged this aspect with its interest in the work of art, i.e. in the role and importance of materially based representation (although it has often been more interested in the philosophical points than in the actual works of art). When focusing on design objects with their prevalent material ontology and often direct sensual appeal, again, the material dimension of the representation of meaning is an unavoidable premise for reflection.

In relation to digital artifacts and the smartphone, I will point to the interface as a point of reflection for this dimension of aesthetics and its material and immaterial elements. In comparison to a "classic" cell phone where the user navigates the screen and the menus through a panel of buttons, such as arrows that allow navigation in different directions, the most striking characteristic of the interface of the smartphone is the large touch screen. The interaction is more direct than it is via the buttons on the cell phone; it is, however, still, mediated through the interaction of the fingers (or a pen) and the screen – and, hence, indirect. Thus, the operation of the screen is aimed at direct interaction with the interface and a limited use of buttons; beside the volume buttons on the side of many models, the number of buttons varies from one (e.g. the iPhone's on/off button) to several (e.g. the buttons on many HTC models: "home", "menu", "back", and "search"). The interface is the connecting touch point between the underlying operating software and the user's experience. Just as it is with regard to the sensual dimension of aesthetics, the interface establishes a two-sided relationship that involves the design of the interface itself and the user's experience of it. The dialectics between these two sides in the transmission of the interface is the source of meaning in the design. Taking the interface as the starting point, it is true that "software takes command" (cf. above), and that the design of the interface begins with the conception of the overall system, which requires a high level of cognitive skills in the designer (cf. [29]). Through the software, the interface establishes the horizon of our perception of the object; still, however, the software-generated opportunities that the interface affords must be met and actualized by an actual user interacting with it. Thus, the interface is nothing without the user. In contrast to the sensual dimension, which deals with the immediate sensual

meaning and stimulus (e.g. in effects of pleasure) of a given device, the design interface relates, on behalf of the user, to complex cognitive operations and matters of understanding. The connecting and transmitting role of the interface is already a stated fact in research in interaction design and HCI and in New Media Studies; in addition to proposing an overall framework for conceptualizing immaterial meaning in digital artifacts, my point in introducing a framework of aesthetic theory in relation to digital artifacts is, more specifically, to employ a conceptual-hermeneutical dimension of aesthetic theory to focus on matters of understanding and construction of meaning as these are articulated in the actual medium.

In relation to the questions about understanding and the enabling of meaning, the apps are of particular interest, as, on the one hand, they operate as part of the interface, while on the other hand they designate the element of inner expandability that I consider crucial to the immaterial element of the design of smartphones. As a vehicle for drawing external information into the smartphone, the app creates an open structure within the barrier of the material device; thus, the smartphone interface is not only a carrier of the often well-designed pictograms of the apps, placed in grids on a vertically or horizontally moveable menu – more importantly, it should also be seen as a crucial transmitter between the device and the functions of the apps, the material presence and immaterial structures of information. Of course, the functions of the apps vary; some of them simply point to pre-programmed functions in the device (such as a calculator, programs for opening documents in various formats, and the clock), others have been downloaded as small programs from the app market and operate enclosed within the device without an internet connection (e.g. small games, music devices such as a piano, or small art installations such as the interactive and generative music and picture app Bloom by Brian Eno and Peter Chilver for iPhone, 2008), and yet others rely on a wireless internet connection (and/or GPS) in order to work (e.g. maps, stock market information, shopping guides, social platforms, guides for good places to go kayaking, weather forecasts, etc.).

With their open structure, apps can be seen as an important vehicle for a new type of operation in and through a material device. They offer easy access to

the use of the device of the smartphone as a portable mini-computer with constant wireless internet access. By allowing various types of information to flow through the device, the apps not only enable a new notion of design ontology that gives material objects a limitless inner extension; often they also challenge paradigms of understanding and meaning formation. Through the apps, the smartphone lets meaning be constructed in an interactive dialogue with the user; that is, through the open structure of the apps, meaning is staged as unfixed and as something that evolves in a continuous construction that is related to the user's specific needs and preferences. Of course, most apps are rationally oriented with regard to their function (how to locate or become aware of desirable features in the local area) or mode of operation (they are designed to work well and should not lead the user astray). But because they are, by nature, dynamic and open-structured, the apps also create a paradigm for the user's interaction and engagement with them that requires flexible responses and an acceptance of new and sometimes unexpected meaning content, as for example when a search for a certain kind of shop leads to new discoveries, or when a slightly modified search profile points the user in new directions. Of course, search results rely on the search profile and on how the search elements have been tagged in relation to the search engine in question; the key point in this context is that searching for something, for example within a geographic area, is a dynamic process that relies on multiple factors such as tagging, the search engine and the user's expectations.

In a hermeneutical reflection, understanding is always a dynamic process; parts always relate to an ongoing construction of a whole [30], although the conditions for understanding may vary and change and even lead to non-understanding, the flip-side of understanding (cf. [31]). In relation to the smartphone, it is a basic premise that the user who carries the phone changes position, that meaning changes, and that, accordingly, the whole can constantly alter its basic constituents: The geographical position that limits the restaurant search changes, the search criteria can be modified, the point of interest can be displaced, etc. Hence, the smartphone is not a device aimed at understanding existing wholes of meaning but rather of constructing perspectives on and entries to engaging with meaning. Further, the apps enable a plurality of possible meanings that challenges the extension and limitation of meaning, even if does

not take place as an Adornian reversal or otherness of meaning. However, Adorno's reflection on the role of the specific medium as the only locus for communicating an otherwise impossible and incommunicable meaning is relevant, insofar as the processes of meaning discussed here can only take place within the medium of the digital artifact of the smartphone (or the tablet computer). It is an essential characteristic of the smartphone and its mode of operation that the integration of various types of meaning is catalyzed through the device interface and apps; they cannot take on any shape outside the medium of the smartphone. Thus, as a medium, the smartphone co-initiates a paradigm of understanding where the processes of understanding unfold in an interaction with the device itself and its medium-specific interaction platform (interface, apps). Thus, the processes of understanding is both (i) structured around an exchange of immaterial communication and information and (ii) bound to the specific device and its specific internal expandability of meaning. Thus, the smartphone condenses and keeps the meaning within its limitless boundaries – hence the fascination with this type of device, people's increasing dependence on and addiction to it, and the prevalent attribution of basic human functions such as memory and orientation to it.

### 3.3 The Cultural-Contextual Dimension of Aesthetics

While the two previous dimensions of aesthetics deal with aspects of meaning integrated in the given design object, the cultural-contextual dimension focuses on the wider implications of the circulation of objects on a cultural, social, and political level. According to the cultural theorist Jacques Rancière, who has influenced this recent trend in aesthetic theory, aesthetics can be investigated as a political power issue in relation to the distribution of sensual material and the ability to determine "what presents itself to sensory experience": Thus, aesthetics can 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" [32]. Rancière seeks to discuss possibilities that are determined by aesthetic media; these not only behave as transmitters of new possible meaning but also produce possibilities by defining and conditioning domains of the sensual experience. By pointing to new modes of experience, with acts of "distinguishing a sensual

mode of being specific to artistic products" and of disseminating experiential knowledge, aesthetic media can promote a "recomposition of the landscape of the visible, a recomposition of the relationship between doing, making, being, seeing and saying". This means that aesthetic media have the capacity to radically re-configure and transfigure the territories of "the visible, the conceivable, and the possible": They can propose possible models for accessing the world in new ways. In relation to the digital artifact of smartphones, this approach to aesthetics as a delimitation of visible and invisible and of what can be experienced and sensed is expressed in a variety of ways.

First, smartphones are designed with sensually appealing smooth surfaces and thus contribute to the aestheticization of the modern world. Today, aestheticization can be seen as an ubiquitous process of distributing sensual meaning (cf. [33]); not only are we surrounded by things that strive for sensual appeal, but as suggested above, even the immaterially operating knowledge society depends on materially present objects. But immateriality affects the state of the material. Thus, it can be stated at that we live in a time of light materials, as "things lose their weight and materiality through modern production technology. [...] [I]t is as if all matter has changed into a sovereign play of forms" [34]. In this perspective, smartphones can be seen as light and flashy objects that contribute to the overall ambience of e.g. an urban cityscape; they play a part in defining what it looks like when people speak and interact with each other through wireless devices.

Secondly, smartphones may have a social and cultural effect with regard to how people use and consume artifacts and attribute symbolic meaning to them and the ways in which they construct and reflect their personal identities in their own and others people's use and consumption of the artifacts. On this level, the artifacts form part of an exchange of value and symbolic meaning between people. The question of how people develop an attachment to objects is especially related to studies in consumption, to sociology, and to anthropologically informed material culture studies, but it should be acknowledged as part of the overall complex of various aesthetic effects of design objects. In particular, the role of symbolic meaning in design is important for the discussion of the immaterial in

design, as it can be conceptualized as an aspect of meaning that transcends purely functional, denotative elements of design and thus opens its space of meaning (cf. [35]). The potentiality of symbolic meaning operates as an immaterial asset of design objects and enables the attribution of personal and cultural meaning to material objects. Smartphones can enter the cultural circuit of symbolic meaning not only through their outer 'face value' where certain models, for example, bestow a certain status on the user. Remarkably, one of the problems for people wanting to obtain social differentiation through the use of smartphones is that even advanced models have become a mass product that are available to large market segments; thus, superficial and expensive styling in the outer casing (gold, diamonds) is the only remaining option. But even more importantly, smartphones can actualize symbolic meaning through the vast inner expandability that connects to many different contexts of meaning and lets people communicate, share values, and engage in acts of participation in new ways: Through the interaction with apps related to e.g. games, music, or sub-cultural content, the user's preference of choice and, in a wider context, value systems and preferences are actualized and, in a larger context that includes other users, put into social interaction.

And thirdly, smartphones are also subject to the distribution of sensual material and to the re-configuration of, in Rancière's words, "the visible, the conceivable, and the possible". On this level, smart-phones can be conceptualized as media for determining and conditioning perception and experience; they can contribute to the way we assign meaning to the world. Through their material sensual appeal and their inter-action with modes of understanding, they can serve as media for staging not only immediate and direct sensual effects but also cognitive impact that affects how experience is framed, that is, the boundaries and possibilities of experience. Partaking in the framing of the conditions of experience, digital artifacts such as smartphones have a potentially massive impact: They function as devices for organizing memory, keeping track of meetings and social events, and, in a radical sense, serve as an extension of human cognition and an interface for social interaction (through texting; apps for social platforms such as Facebook or Twitter). As digital artifacts, smartphones operate on the complex immaterial level of organizing experience.

## 4 Possibility

The immaterial effects of design objects employing digital technology activate the sensual, conceptual, and cultural possibilities that are evoked by the objects. Thus, the element of immateriality in the objects makes them open-structured and widens the span and number of possibilities. The philosopher Peter Sloterdijk connects the expansion of possibilities through design with the paradoxical ability of design of enabling "the capacity of incapacity" [36]. On the level of use, design objects, according to Sloterdijk, have a ritual quality in creating possibility by simulating a sovereignty that emerges when we are able to conceive of otherwise inconceivable objects. For example, the hermetic "black box" of a seemingly incomprehensible digital product can become "useful" and develop an "unlocked exterior" through devices of interface design. I will, however, propose to connect this "making capable" of the otherwise not capable not only to the material extension of the design, for example in physical artifacts that create new functions and uses, but even more to its immaterial dimension of operating invisibly on the level of information and its ability to configure new modes of experience. The immaterial dimension of design evokes possibility in the sense that its open structure lets the immaterial be potentially actualized in many ways and directions. Further, by introducing the role of possibility in relation to the aesthetics of immateriality in digital artifacts, the ontology of immaterially operating objects can be stated more precisely: They are objects of sensual, conceptual, and cultural stimulation of possibility.

In an exchange of material constraint and possible meaning, the design of smartphones should serve a dual purpose: In an outward, centrifugal movement it should act through its open interface structure and the apps, or rather its structure of opening up new meanings; and in an inward, centripetal movement, it should contract and contain the centrifugal aspect of the device within its design. Thus, we can assess the design from the perspective of the specific design with an emphasis on the ambition of the design to reach out for the space of possibility that it potentially engages. It may, of course, be poorly designed, and in that case it does not actually serve to frame possibility in a way

that makes the possible a potentiality for the actual. And from the perspective of possibility, we can focus on the ability of the design to condense and transmit possibility: How the smartphone, in its concrete being, conveys the open-ended structure of the possible while simultaneously defining a direction and a scope of operation for the possible which in turn becomes concrete, potential meaning. Thus, the possible partakes in a process of detaching meaning from the static closure of material objects: The object, the smartphone, is made transparent to its open-ended constitution. And at the same time, this 'abstract' aspect of its operation is drawn into the actual operating system, the interface design, and the interaction and navigation structures of the design.

The more the possible is made tangible and present in the design, the easier is the user's access to the world of possibilities and, further, the more intuitive in use is the design. The manufacturers of smartphones are, of course, aware of this aspect of the design, and the competitive and differentiating factor rests not only on the advanced technology (in a continuous flow of constantly upgraded software and operating systems). It also, and to an even greater degree, relies on the aspect of intuitive interaction that makes technology accessible (as in Sloterdijk's concept of design as giving way to the capacity of incapacity) and performs a task on the level of symbolic communication: Through their design of intuitive interaction – signaled through the often discreet cabinets of the devices with only a few bottoms outside the screen and marketed, for example, as "HTC Sense" by HTC – the smartphones enter the circuit of attribution and consumption of symbolic meaning, as it is the easy adaptation that enables the users to ascribe symbolic meaning to the product.

Plainly put, a smartphone not only has the potential of looking good but also of becoming an integrated part of the user's basic way of structuring experience and cognition. By creating a horizon of perception, it has the potential of becoming an extension of the primary sensory, tactile and mental interface through which the user meets the world. Thus, on a phenomenological level, smartphones have the potential capacity to define new ways of experiencing as well as "living everyday mobility and relating to information" [37]. Further, on a symbolic level, this experiential aspect

together with its integration in the open-structured search for the new and unknown – as every new app widens the scope of possibility – facilitates a type of product design that is easily attributed with symbolic meaning.

## 5 Conclusion

Concealing their technological secrets inside, digital artifacts need to be investigated in order to reveal how they create, stage, and articulate cultural meaning. Hence, the dual ontological premise of the material extension and the immaterial effects needs to be acknowledged. In essence, design objects have always incorporated this dual constitution (no objects without effects of information, and no design solutions without material extension), but with the digital turn in design, the immaterial aspect has come directly into focus, as the performance of objects far exceeds their outer, often discrete and miniaturized appearance. In this sense, digital artifacts, such as the smartphone, are limitless in their inner expansion of what they are capable of (there are, of course, limitations due to processor power and memory capacity which, in turn, are constantly increasing). The proposal of the paper has been to relate the discussion of materiality and immateriality in design to various aspects of aesthetics, ranging from directly addressing sensual questions in the sensual-phenomenological dimension of aesthetics, over the construction of meaning in and through the design in the conceptual-hermeneutical dimension of aesthetics, to the cultural-contextual creation of social meaning and structures of experience. The discussion has revolved around the device of the smartphone, but hopefully, the proposal can help to define and circumscribe how immaterial meaning evolves on a more general level, and how digitally operating artifacts act in constructing meaning and creating paradigms that frame our perception and understanding.

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# Elevating the everyday:
# Designed objects as companions

## Abstract

From fleeting interactions to long affairs, our relationships with things are diverse and complex. Like people, designed objects and environments are close companions in our lives. A constant source of comfort and delight, frustration and anxiety, their personalities inform our everyday dialogues and experiences. Creating objects with congenial personalities requires careful consideration of semiotics: syntax, semantics, and pragmatics within specific con-texts. Designed artifacts assume engaging and pleasurable personalities when they transcend materials, challenge perceptions, and garner active, reflective interactions. By constructing friendly and intriguing personalities through de-familiarization/recontextualization and human-centered designs, everyday interactions and experiences are elevated as users invest in pleasurable forays and relationships.

## Keywords

Experiential design, interactive design, semiotics, human-centered

## The Companionship of Designed Objects

The way we understand and engage with artifacts is parallel to the way we interpret and interact with each other. Both humans and designed objects are interpreted through formal and contextual information. The means of understanding this infor-mation is semiotics; the triadic relationship of syntax, semantics, and pragmatics in a given context. From form, content, function, and context, we find meaning. Perhaps, more significantly, we find personality – the conversational nature of a person or object. There are personalities who fade to the background and don't entice interaction – wallflowers, if you will. There are the strangely familiar, those who possess a certain familiarity and allure. And there are true companions and confidants, personalities that are supportive and compatible. The various relationships range from fleeting and ephemeral to enduring and intimate. We think with, invest in, and express ourselves through design; therefore, unconventional and human-centered artifacts are empowering, resonant, and key to creating extraordinary experiences.

Dig Deep (Fig. 1) is installed on the exterior wall of the Pollak Building, one of Virginia Commonwealth University's design facilities. This 16 foot by 4 foot typographic installation is made of treated plywood, white paint, galvanized nails, clear plastic straws, and pink and white outdoor sequins. Each nail on the one inch grid contains at least one sequin and a clear plastic buffer between the sequin and the board. The nails that comprise the message feature two sequins, a white sequin facing the viewer and a pink sequin facing the board. Reflected light creates the sprawling message. The discs flutter and form a living surface on windy days.

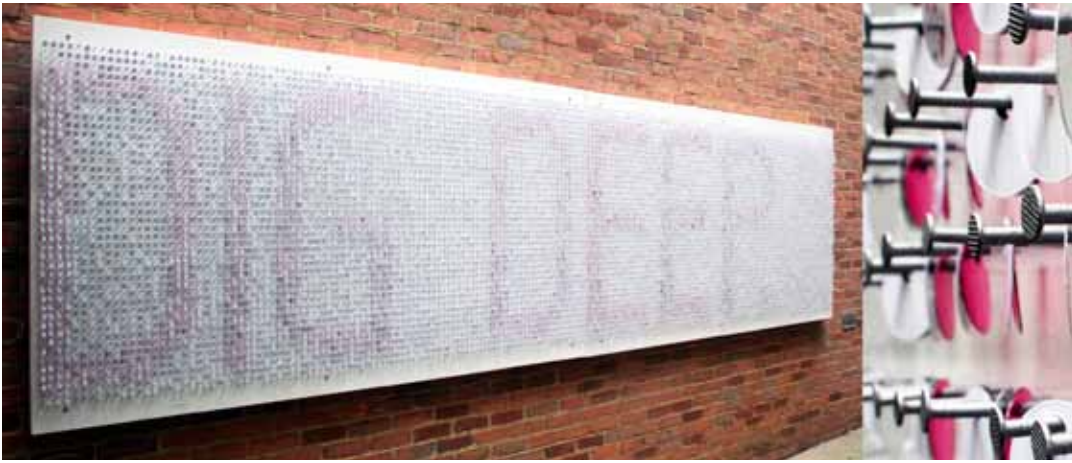**Cassie Hester**

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**Fig.** 1. **Dig Deep.**



**Fig. 2. Alphabet Shift**.



**Fig. 3. Make More/Worry Less, twenty minutes after installation.**



**Fig. 4. Make More/Worry Less, four weeks after installation.**

Alphabet Shift (Fig. 2) is an interface that facilitates the creation of messages in a public space – the third floor of the Pollak Building at VCU. The structure consists of birch strips supported on a frame of birch and aluminum braces. Each strip contains a full alphabet and one blank space. The strips can be pulled to the left or the right to highlight one letterform in the frame, creating a message. Many inhabitants of the third floor create messages alone or with the support of their friends. From "MID-TERM REVIEWS SUCK" to "FORM LIKE VOLTRON ON" and "ILLUMINATE MY COCK," the messages provide a brief ethnographic glimpse of the third floor.

Make More/Worry Less (Fig. 3 & 4) is a piece I installed on the third floor of Pollak. The installation seemed like a blank sheet of paper. With the markers provided, passersby doodled and wrote on the paper – starting conversations and responding to the contributions of others. As the paper filled, my message, "Make More/Worry Less" was revealed as marks made in the letterforms of my message did not appear. Like Alphabet Shift, the sociable personality of Make More/Worry Less promotes intrapersonal exploration while also allowing individuals to invest in interpersonal relationships by participating in collective conversations.

Please visit www.cassiehester.com for more information on these projects as well as the pieces exhibited at DeSForM.

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# Tradition and innovation: A study on reconfiguration of product language through innovative approaches

## Abstract

Based on the subject – object relationship which is reflected as user and product, this paper deals with the concepts of tradition and innovation where craftsmanship and redesign are included. Thereby, the reconfiguration of product language is examined within innovative design approaches to traditional cultural products as sample cases: Iznik tiles, nargile and coffee pot, where different layers of this reconfiguration can be observed.

## Keywords

Tradition, material culture, craftsmanship, innovation, product language.

## 1  Introduction

Innovation in design can be made in various ways: new technologies lead to new production techniques and materials; new marketing strategies lead to new organization models, and new product languages lead to new socio-cultural formations. Thus, considering the concept of innovation within its basic reference to the 'new', to define new ways of life is possible by defining new products and environments of use. So, the whole process actually generates new subject-object, or more concrete, user-product relationships in terms of product language.

Within new products that are pioneers of their own type, it is comprehensible that the whole communication should be built in a brand new way. However, it is also possible to approach the most traditional artefacts with new perspectives and re-configure the existing product language, which can sometimes be harder than to configure a language for a brand new product. Developing technologies and their implementations on traditional products that allow mass-production rather than craftsmanship techniques; discovery of traditional cultural values; global marketing strategies and changing socio-cultural lifestyles are the initial triggers of such an approach.

Based on the changing user-product relationship, this paper deals with the concepts of tradition and innovation where it questions whether an innovation in design of traditional cultural artefacts is possible. Thus, technological and socio-cultural innovation are taken as reasons and results on changing user-product relationships and examined in sample cases of three Turkish traditional artefacts' novel designs; the nargile (waterpipe), Iznik tiles and Turkish coffee pot, where the product language and consequently the user-product relationship are re-configured.

## 2  On Culture, Tradition and Craftsmanship

The diversity in definitions of culture arises from the fact that it can be approached from several perspectives and disciplines; moreover, there is no individual who is not involved with culture and can formulate a definition with an external perspective to it. As Lotman states

*We live in a world of culture. Moreover, we are in the thick of it, inside of it, and that is the only way we are able to continue our existence. The importance of the notion of culture, the difficulty of its definition, follows from this fact. [1]*

Thus, culture can be defined in that it refers to the cumulative deposit of knowledge, experiences, beliefs, values, attitudes, meanings, hierarchies, religion, notions of time, roles, spatial relations, concepts of the universe, material objects and possessions acquired by a group of people in the course of generations through individual and group striving or that it is the systems of knowledge shared by a relatively large group of people, or that it is a way of life of a group of people the behaviors, beliefs, values, and symbols that they accept, generally without thinking about them, and that are passed along by communication and imitation from one generation to the next, or that it is symbolic communication etc. Considering that culture consists of explicit and implicit patterns that shape social behavior acquired and transmitted by symbols, it is possible to speak of a certain coding with it. The term cultural code includes both meanings of culture and code. Cultural codes are defined as symbols and systems of meaning that are relevant to members of a particular culture [2]. They provide that individuals get a similar perception and understanding of certain facts and phenomena so that they go through a similar process of interpretation and come to similar conclusions [3]. Thus, common meanings and symbols serve as constituents of a society's paradigm since without a common perception frame, each sent message can be interpreted totally differently and a common behavior cannot exist. These characteristics help the individuals of the society to build a language through which visions, voices, colours, words, gestures and facial expressions can be interpreted in a common way [4]. Furthermore, Eco (1968) asserts that communication is based on codes, agreed upon in society. Understanding the codes and their meanings is necessary, as they are determinant in communication. He also claims that the general use of products is not only functional but also cultural, and the use also determines the meaning [5]. Since iteration and continuity are important for a social structure according to Durkheim [6] that can only be built with common values and behavior of a certain society, rituals stand out as basic carriers of both concepts [7]. Rituals are repeated acts reinforcing the sense of identity for the individual in society, building up the links with a shared past [8], and their support to social construction can thus be explained as the formality and repetitiousness that give much of the power to ritual and generate a sense of belonging and continuity between the individual and the group, as well as between present and past. Additionally, all differing approaches of culture emphasize the "affinity about transmission of sociological, physical and mental cultures to next generations which is called as tradition" [9].

Continuing with the definition of 'tradition', it is the transmission of customs or beliefs from generation to generation, as well as, an artistic or literary method or style established by an artist, writer, or movement, and subsequently followed by others [10]. Tradition contains every kind of belief, images of individuals and events, techniques and institutions [11]. Thus, cultural traditions are a continuation of the past, as well as a projection into the future, actually being elements of the continuity of a society's history [12]. At this point, craft products can be taken as one of the transmitting elements of culture and tradition. Craftsmanship and so, craft products, are material beings in the intersection of culture, tradition and society where historical production techniques and rituals generate the culture of craftsmanship. It is important to see craft products with their cultural depth because they are not only products of traditional hand-labor but also carriers of the tradition itself. A craft product offers the user to get informed about its cultural background visualizing the traditional usage of the object. Due to this kind of communication, the relation between the product and the user becomes a cultural interaction happening on a personal experience for each individual in the society. Also, this situation allows the user or the subject to share the traces of the unique object's or craft product's moments of creation [13].

Various interpretations of culture and tradition show that these two concepts are strongly related to each other; they have the power to define and transform each other. Craftsmanship, in addition, is a 'product' of them both; a more concrete outcome of their reflections on the society. Thus, the concept of craft products includes histories, cultures and traditions of societies; like myths which transform a meaning into a form [14]. Craft products, like all other products,

have their own language, however their languages are configured over a longer period of time and in a cumulative way. Thus the relationship between the user and the product is defined by a cultural and historical involvement with the related tradition, i.e. an internalization of the tradition by every individual since the craftsman's cumulative work is actually the cumulative work of every individual by means of society.

## 3 Towards the Relation between Innovation and Product Language

Innovation stands for "a new method, idea, product, etc." (Oxford, 2011). Rather than its most common connotation as "technological innovation", this study is grounded on its basic definition which emphasizes novelty. Since Steffen (2007) also claims:

*Science and technology are not the only sources of innovative product design. Alterations of basic societal conditions, socio-cultural upheaval, and the arrival of new viewpoints and values are just as important for the creation of innovative designs or new product languages. Artefacts that are not innovative with regard to technology might be epochal with regard to the expression of the spirit of the time [15].*

Keeping in mind that all products move from a technical system into a cultural system, having both (objective) denotations and (semantic) connotations, there is a constant interference between a practical and a technical system [13]. Design helps to explore the nature of the modern world since it is a reflection of the economic system showing the effect of the technology that is used. Thus, it is a kind of language, which reflects emotional and cultural values that stand beyond the function of products. Sudjic [16] emphasizes the importance of design language for the user-product communication:

*It is the language of design that serves to suggest an object's gender, often through the most unsubtle of means, through color, shape, size and visual reference. It is design that reflects a sense of authenticity, or its manipulative opposite; cynical salesmanship. And it is design that can serve to signal and reinforce the caste marks of a class system [16].* Design can react to different cultural conditions, in which designed products can accept the rules of existing conditions or go against them where it can offer new culture practices [17]. Combining innovation with

product design, several approaches occur focusing on new production technologies, materials, product languages, usage, markets etc. For instance, Verganti (2008) mentions:

*Innovation may concern a product's functional utility, its meaning, or both. In addition, functional innovation may imply an incremental or radical improvement of technical performance; innovation of the semantic dimension may also be more or less radical. In particular, innovation of meanings is incremental when a product adopts a design language and delivers a message that is in line with the current evolution of socio-cultural models [18].*

A certain innovation in technology can lead to an innovation in a particular product, and this furthermore, can lead to a socio-cultural innovation in the society. The important thing here is to notice that the innovative approach should also be conducted within product language since the communication of the product with its user is actualized by means of its language. Since language is a code with human history built in, it carries traces of cultures, perceptions and societies throughout time [1]. For products that went through technological and socio-cultural innovation, relationships between user and product should be re-defined and thus product language should be re-configured. The innovative approach towards traditional cultural products does not only lead to a change in these products' forms, usage or production techniques, but it also changes the perception of the user so that the physical and social environment of use is affected. Thus, such innovative approaches can serve as proposals to keep the traditional cultural products alive in today's society, to define new lifestyles with old traditions etc. Whether these proposals will be accepted or rejected depends on the communication between those products and their users, beyond the intentions of their designers.

## 4 Configuration of Product Language in the Intersection of Tradition and Innovation

The aforementioned theories and approaches related to culture, tradition and innovation in design and product language are profited to examine three cases, such as Iznik tiles, nargile and Turkish coffee pot. With innovative design approaches to these products, the forms, environments and socio-cultural contexts of use are redefined. Considering the characteristics

of these artefacts, nargile is for outdoor public use; Iznik tiles belong to traditional palace and mosque ornament tradition; coffee pots are for indoor private use. However, with innovative design approaches to these traditional artefacts, nargile is considered to be a product for indoor private use; Iznik tiles become a product for private use, and a Turkish coffee pot can be used in offices by the public.

### 4.1 On Iznik Tiles

The history of Iznik tiles goes back to the second half of the 16th century which is named as the classical age of Turkish art during Ottoman rule. Following the recent excavations of İznik kilns, it is stated that the Ottoman ceramics in İznik had a Seljuk background [19]. Tiles became such a predominant feature of architectural decoration that they took on an important function in the overall aesthetics of Middle Eastern cities. Mosques, mausoleums, madrasahs, libraries, public baths, fountains and palaces were all decorated with panels of tiles that covered walls, domes, shafts of columns, tympana and prayer niches (mihrab), in a profuse decoration that expressed the great wealth and power of Ottoman Empire. From the 15th to the 18th century, the glazed tile did in fact represent the main decorative element in Ottoman architecture. In this period, Iznik ceramic production was at its height, being almost exclusively devoted to meeting the orders placed for thousands of glazed tiles for civil and religious buildings in Istanbul and other cities of the Empire, planned by Sinan, the great architect of the court of Suleiman the Magnificent (ruled 1520-1566) [20].

In the geometrical design of the Seljuk inheritance, the palmettes and leaves were used. The plant motifs of the classical age were drawn on the white undercoats. A superficial abstraction is dominant in the naturalistic plant designs. The main examples of nature motifs were carnations, tulips, plum blossoms and branches in full blossom, pomegranates, peonies, broken leaves, rosettes, roses, bunch of grapes, acanthus leaves, vases and birds with black, thin countermines. There is always an effort to keep motion and dynamism in balance and symmetry both in the designs and the colours. Each motif is a whole in itself whereas it is also an inseparable part of the eternal whole (Ministry of Culture, 2010). Considering the characteristics of colours, at first, blue and white were the prevailing colors in the pots and

wall tiles. During the 16th century, the turquoise was introduced. The embossed red of the wall tiles of the mihrab of Süleymaniye Mosque (1555) marks the peak of Ottoman tiles and ceramics. Seven colors were used in various combinations (though there are many effective İznik designs using only two, three or four colors): blue, purple, red, green, turquoise, gray and black.

The recession in Iznik and the decadence of the workshops started in the beginning of the 17th century. The colors lost their vividness, the coral and tomato blues darkened. Quality deficits and cracks on the glazes began. The net lines of the contours were dispersed. The political regression was felt most at the Iznik tile workshops among all the handcrafts. Since the production technique details were kept secret, and the technical development knowledge was not mentioned in written documents, an important gap of information was formed for the following generations. The attempts for revival required thoroughly new efforts and these efforts could not be a substitution for the traditional training passing from one generation to the next.

After 1995, TÜBİTAK (The Scientific and Technological Research Council of Turkey) decided to produce İznik tiles again. However, it had been 400 years and it was a hard task. As a result of research and development, tiles started to be produced again. Today, İznik tiles are used as an architectural element in old and modern buildings by the discriminating decorator and art-lover alike. The production of handmade tiles of the desired quality in this era of speed and automation is a particularly difficult task.

Traditional Iznik tiles are reinterpreted by designer Defne Koz for Vitra so that they will be used in bathrooms as wall tiles. The process of this redesign is basically realized by abstraction of existing traditional figures and patterns. The designer reinterpreted characteristic İznik patterns and cypress motifs, adapting them to the contemporary bathroom. The stylized patterns, colors and texture of the hi-tech tiles aim to exhibit the same sensitivity and refinement as the handcrafted originals and the traditional İznik quartz glazing process. Contemporary techniques of tile, glass and glass ceramics manufacturing are used in order to mass produce these tiles. The aim was not to lose the sensitivity dedicated to handwork and bring a feeling of

depth and softness. The designer, basically, formated three lines of patterns: Line 1 consists of shades of azure, which heralds a return of the traditional İznik blue. It aims to display the taste reminiscent of timeless handcrafts (Fig. 1).
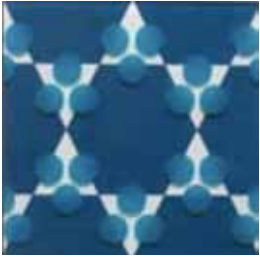


**Fig. 1. A sample wall tile from Line 1 of Vitra.**

Line 2 includes diagonal stripes, hexagons and trefoils. New patterns are built into the quintessential geometric patterns of İznik tiles. This line aims to achieve a contemporary look that is as powerful as the İznik originals (Fig. 2).



**Fig. 2. A sample wall tile from Line 2 of Vitra.**

And Line 3 focuses on the stylized cypress tree, lends its elegant form to the contemporary design. A traditional İznik tile motif, the cypress is painted in various green tones (Fig. 3).



**Fig. 3. A sample wall tile from Line 3 of Vitra.**

As seen in Figure 4, the original hand-painted tile pattern consists of blue, red, green and white as dominant colors. The pattern is basically constituted with flowers that are positioned at certain angles and within a symmetry. These characteristics belong to a craft history, tradition and taste in Turkish culture.



**Fig. 4. Iznik tiles in Selimiye Mosque.**

In Figure 1, there is an innovative product that is manufactured with new technologies in order to be used in bathrooms as wall tiles. The product kept the main elements of the traditional Iznik tiles, however, it configured a new language, as patterns, that is adapted to innovation rather than tradition. Still it is possible to say that the cultural core of the product is somehow kept.

The designer does indeed have a particular approach to design, "I see design as part of everyday life. I don't like it when design is presented as an elitist style, or even worse as the vulgarisation of an elitist style".

*Design is about what people do everyday. I hate to think that something I designed may remain on a shelf as a decoration. The ideal object is one that you adopt and use every day and one that possibly continues to surprise and excite you every time you use it." Additionally, she claims that she is fascinated by the history and tradition of Turkey's material culture, and thus tries to continue and discover it [21].*

To start a formal analysis of novel design for Iznik tiles, the designer abstracted traditional patterns of Iznik tiles. Figures of nature do not exist anymore, however, main colours are kept. Production technique of the tiles has changed since it became a product of mass-production rather than of craftsmanship. Thus the shades of colors and painting do not require any craftsmanship competence. Additionally, materials of which dyes and ceramics are produced have also changed. From the socio-cultural perspective, it is necessary to remember that Iznik tiles belonged to palaces and mosques during the Ottoman period. Since painting of human figures

was forbidden according to Islamic view, craftsmen focused on natural figures. Therefore the patterns of traditional Iznik tiles have such a religious-cultural background. The novel design for Iznik tiles is loyal to this understanding, and keeps its figures close to nature and geometrical shapes although it proposes an everyday use in bathrooms rather than being an element of a prayer environment. Considering the fact that traditional Iznik tiles were placed on inner walls of public buildings, such as mosques, they became a public possession that is shared by the society, mentally. By changing the production techniques and actualizing a mass-production, the designer allows the individuals of the society to keep a 'material sample' of this 'common possession'. So, a product that does not actually belong to individual use at home, changes its socio-cultural position, from being of everybody's mentally and nobody's materially, it becomes a commodity serving individuals with its materiality and thus, with its new language. The novel wall tiles have been manufactured and attracted attention. They are sold in wide numbers and bathroom walls of many people are decorated with them. The product has also had a Red Dot design award in 2006.

## 4.2 On Nargile

Nargile entered the Turkish culture in the 16th century during Ottoman period. It became popular in the 1700s, and even became a status symbol. Nargile, basically consists of four main parts: the body (gövde), the bowl (lüle), the flexible hose (marpuç) and the metal tube (ser). There are craftsmen who are specialized in the production of each of these parts, and even there are neighborhoods that are called with these parts' names [22]. All of these parts have their own function in this specialized way of smoking. Thus, in all three types of nargile designs (Fig. 5) it is possible to find these main parts.



**Fig. 5. Traditional nargile and its redesigns.**

Nargile, belonging to Eastern culture and tradition, carries the traces of Eastern lifestyle, as a craft product.

Although there are essential parts that a nargile should contain, in time however, nargiles became real objects of art. The bottles come in different colors and graceful shapes, the flexible hoses are often embellished with embroidery or woven handicraft art (holding the owner's initials), and the plastic mouthpiece may be of fine porcelain or the more popular precious amber. The bottles were usually manufactured in Beykoz. In this bottle, the bowl filled with water is placed to cleanse the filth made by burning tobacco. It also served as a filter to absorb the nicotine and to cool the smoke. The body was made of glass, porcelaine, silver or crystal and very elegantly embellished with floral motifs. Bowls were generally made in Tophane by bowl (lule) makers. This is the portion where the tobacco is placed and lit. A plug of the tobacco is placed in the bowl and covered with a conical cap pierced on top. A piece of oak charcoal was placed on top of the tömbeki or tobacco to generate the smoke [22].

As mentioned above each element of the nargile is given a particular form with particular materials, ornaments and even colors. The choice of these elements is made according to traditional usage and craftsmanship methods. In its varying forms and colors, nargile however, carries a continuity of a culture and a tradition. Even only considering its formal aspects gives some clues about the lifestyle to which it belongs: During smoking the nargile, it is possible to see how the water boils and bubbles in the bowl. The material, the glass, of which the bowl is made, serves for this show. The length of the tube decides how close the user should be to the nargile and the height of the nargile itself defines a lower sitting position for the user. Even these three aspects refer to the Eastern lifestyle and joy culture. The minimum time interval to smoke nargile is given as one hour. It is actually the "tömbeki" (a special tobacco) that is smoked. Nargile, thereby serves as a signifier of the joy during smoking this tobacco since the joy and the ritual do not only consist of smoking. It is a time for peace and relaxation; a time that should be spent slowly and quietly where only the voice of boiling water accompanies a tranquil conversation. To watch the movements of the boiling water, additionally, increases degrees of joy and tranquility [22].

Such an object that realizes itself as a craftsman's labour is totally integrated with cultural references and

symbols which overcome its functional use. To have a deeper understanding of it a deeper involvement with the related culture is required [14]. However, an innovative approach to this traditional product can change many things related to it from production methods to its relationship with the user. Thus, it brings out the question whether an innovation in tradition is possible.

While designing nargile, Kunter Şekercioğlu started with the idea of 'local product for global market'. He remembered Sotsass's proposal to designers 'not to loose one's cultural DNA' [23]. The first nargile he designed, is manufactured by him with traditional craftsmanship techniques. He used a glass-blowing technique for producing the bowl of the nargile. The aim of the designer is that this nargile should be appropriate for mass-production but it should also keep its connection to craftsmanship since he believes that craftsmanship products should keep their 'traditional essence'. According to this concept, the bowl would be produced by craftsmen, and the rest would be mass-produced. The second nargile design has another concept so that it can totally be mass-produced. So, the glass bowl in the first design is replaced by some plastic material (policarbonat) which eliminates the risk of breaking. Although all problems related to mass-production for this nargile design are solved, it is not produced. However, there are several reasons for it.

According to the designer, this nargile was designed with contemporary aesthetic perspective to be world widely. In the first example (Fig. 5) the novel design of the nargile, it is possible to notice a certain kind of simplification in the form and ornaments which refer to the mass production of the nargile rather than being a craft product. However, it also signifies some elements of traditional nargile. Especially the form and color of the bowl as well its relationship with the ground allows a closer perception to the traditional version.

On the second nargile design (Fig. 5), a totally new product language is configured. Traditional forms, colors and ornaments are avoided so that the four main parts of the nargile have lost their characteristics. Thus, they are hard to differentiate and became a main body like an outer shell. All traces of craftsmanship are eliminated and replaced by geometrical forms so that it can be produced in mass numbers. The elimination of crafts

signals lead to a partial elimination of the traditional perception and use. So, the product becomes an industrial product which fulfills its functional duty but does not really belong to a certain culture. Moreover, this nargile signifies to the innovation of manufacturing technologies, lifestyles, maybe new rituals, in short, to a non-traditional, to an 'innovative' way.

Analyzing formal and socio-cultural characteristics of both products, the traditional nargile and its novel design, the first thing to notice is that the traditional parts of the nargile and their relation to each other has been redefined which lead to a certain change in its form. However the dominant element in generation of the form actually had to follow again its special way of functioning. Thus the novel approach resulted in a product language which is more simplified, in terms of the designer's aim, more 'modern'. Since it will be mass produced its whole manufacturing process needed to be redefined where methods of craftsmanship are abandoned. Consequently, materials that are used by nargile production needed to be redefined, too, such as the replacement of glass that is used in the production of the bowl with polycarbonate. So, the designer with the aim of 'local product for global market' re-configured the product language for nargile. At this point, a discussion on the socio-cultural meanings of nargile should be included. First of all, nargile is traditionally for public use. It is an object of joy and is smoked in coffeehouses accompanied by company, conversation and table games. The culture of nargile is connected to the culture of the eastern coffeehouse [24]. The novel design for nargile proposes that it will be used at home. Thus, it changes the environment of use and also the traditional culture of use. So, it does not only change the traditional manufacturing technique of nargile, which is craftsmanship, but it also changes the tradition of use where a socio-cultural heritage is integrated. It is the adaptation of technology to a traditional cultural artefact and the adaptation of a local product to a global perception. However, it should be considered whether the novel nargile design has become a 'local product for global market' by losing its cultural references or whether this also caused the loss of locality. Moreover, the distinction from the traditional form may cause an alienation of the local society since the novel designed nargile may not reflect the common cultural code of this society

anymore. Thus, whether it became a local product for global market or a product which is neither local nor global is debatable. It is possible to say that some formal re-codings are not enough to reconfigure the product language in this case. Coming to the situation in practice today, the novel nargile design is not mass-produced, although all problems according to mass-production have been solved, because it could not find a 'definition' in the society's perception. Furthermore, it is stated that:

*What is specific about the nargile is that almost no new versions or designs of it are being used in these coffeehouses. The archetypal object, with its complicated silhouette and basic working principle, is accepted as it is. Furthermore, the more the object reminds us of an historical entity, with references to the oriental or Ottoman contours and lines the closer it gets to the idea of preservation of an essence about it. This objective resistance to change also becomes the symbol of resistance to modernity itself. It becomes an aesthetic as well as a cultural response. It defines its own space, time, and habitus, with its rituals and positioning towards life, with its own distinctive style, whose traces are visible on the object itself [25].*

As the designer also claims, companies that produce household electrical appliances have been interested in it at first, however, they could not position it into one of their categories. In addition, there are of course legal restrictions related to smoking, and whether it would be an encouragement for smoking is another ethical issue.

### 4.3 On the Coffee Pot

There is a certain ritual for making Turkish coffee which requires time and talent. The most traditional way is to heat coffee in a copper coffee pot slowly over charcoal embers for 15 to 20 minutes, and taking it frequently away from the fire to prevent overheating. Generally, a medium-size coffee pot is used to make two cups of coffee at each shot. The most important thing while making Turkish coffee is to decide when to take the pot away from the fire since it can suddenly overflow after boiling. In addition, the foam of the coffee is a signifier of how well it is made and taste which should be kept while serving the coffee in cups. The ritual of making coffee is usually followed by the ritual of fortune-telling. Coffee cup reading is a widespread and popular fortune telling method, which speaks of both the past and the future.

An old Turkish company, Arçelik, producing and selling domestic appliances came out with Telve (2005), a Turkish coffee machine. This was the first proposal for making Turkish coffee with a machine (Fig. 6) and was positioned for the market serving to working environments such as offices. It changed the whole way of making Turkish coffee and took it from the manual way to a machinic way for office environment. The product has won the IF Design Award in 2005.



**Fig. 6. Telve – The Turkish coffee machine.**

A formal analysis of the novel design for Turkish coffee pot shows that it proposes a whole new product with a novel language rather than being a redesign of traditional Turkish coffee pot. Besides, it does not only propose a new form but also a new way of making Turkish coffee which replaces the traditional process which basically depends on the 'talent'. The new design is called 'Turkish coffee machine' rather than Turkish coffee pot, which can easily be read on the product. Other essential differences are that the coffee machine works with electricity rather than being in direct contact with the fire; can make more than 2-3 cups of coffee; does not allow to mix the coffee manually, and actually does not leave any field for manual reach or interference during cooking.

This new machine proposes a new way of coffee making which is faster, easier and more 'serial', however, it demolishes the ritual of coffee making since it works exactly in an opposite way of traditional Turkish coffee making ritual. The traditional way depends on the talent of the coffee maker, and needs a certain time so that the coffee will taste good: It should be braised slowly and the person who is making the coffee should wait

watching on it because there is a risk that the coffee overflows when it boils. Still, it should be emphasized that this whole ritual actually belongs to a 'home environment' where everything can be done without a rush. So, the new Turkish coffee making product with its closed machine form and metallic color actually 'says' that it does not belong to this kind of home environment; it is rather supposed to be used out of home, mostly referring to working environments, i.e. offices. Basically it provides an answer for the need to consume Turkish coffee in offices. Thus, instead of trying to re-form the ritual, it completely removes the ritual and focuses on functionality. Telve, with its novel product language which does not refer to any traditional background of Turkish coffee making is the first product that makes Turkish coffee in the form of a coffee machine, and it has been widely used and still being used in offices as it aimed to. The public acclaim of Telve is based on the new defined way of coffee making, on the new defined environment of coffee making and the new language of the product which provides the user a perception of both novelties.

## 5 Conclusion

Interpreting the concept of innovation in a socio-cultural context allows one to notice new relationships between subject and object, within this case, user and product. Changes in society lead to novelties in products and, likewise, novelties in products lead to changes in society. The product language as the basic carrier of communication between user and product needs to be re-configured with every novelty. Thus, it not only defines new relationships between user, product, environment etc., but it also serves as a signifier of novelty where it combines or differentiates the 'traditional'.

In all three sample cases, examined in this paper, innovation takes place where new ways of production, use and socio-cultural meanings are described in product design. Thus, different layers of the change in product language are discussed. The innovation in production processes of Iznik tiles, nargile and Turkish coffee pot lead to new product languages which try to combine a traditional essence and a functional daily use, since it becomes hard to find the required time to complete a whole ritual. Thus, they speak of new social lives and the 'new' position of tradition in these lives. While designs related to traditional Iznik tiles

take a public heritage as a starting point and allow to individualize and materially possess it; the novel design of nargile aims to 'dress' the traditional artefact with modernity and still hopes to keep the ritual as well as the traditional essence, and finally, the Turkish coffee machine design changes the whole experience of coffee making where it decides for function rather than tradition. The public acclaim of these products can depend on their functionality, honesty, integrity into daily lifestyle, etc., which actually all depend on product language.

To conclude, it is open to debate whether an innovation in tradition is possible or required, since conceptually, one refers to novelty while the other one refers to antiquity. However, it is a fact that every kind of innovation in a product leads to a new product language which generates new relationships between the user and the product, consequently building new socio-cultural lifestyles.

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# Controlling smart home environments with semantic connections: A Tangible and an AR approach

## Abstract

In the transition from a device-oriented paradigm towards a more task-oriented paradigm with increased interoperability, people are struggling with inappropriate user interfaces, competing standards, technical incompatibilities and other difficulties. The current handles for users to explore, make and break connections between devices seem to disappear in overly complex menu structures displayed on small screens. This paper tackles the problem of establishing connections between devices in a smart home environment, by introducing an interaction model that we call semantic connections. Two prototypes are demonstrated that introduce both a tangible and an augmented reality approach towards exploring, making and breaking connections. In the augmented reality approach, connections between real-world objects are visualised by displaying visible lines and icons from a mobile device containing a pico-projector. In the tangible approach, objects are tagged and can be scanned to explore connection possibilities and manipulate the connections.

## Keywords

Product semantics, interaction design, smart home.

## 1 Introduction

When Weiser wrote his vision of ubiquitous computing about 20 years ago [1], he postulated that we will be surrounded by networked displays of various sizes, and that we will use them to explore and access our information and computerized infrastructure. They would simply be there, around us, like a piece of scrap paper or a blackboard, their use woven into the fabric of everyday life. It would be easy to switch between actively using them and barely noticing their mere existence. People would concentrate on their everyday activities, unaware that they are using possibly more than a hundred computers within their vicinity to carry out these activities.

In today's reality, although there are rooms accumulating almost comparable amounts of computers in the form of smart phones, web tablets, TV screens, netbooks, personal computers and so on, we have not yet achieved seamless operation among them. Each and every one of these devices demands our attention, uses a different user interface and allows access to none of the other components (or only to very few other components within the room). While many of the devices are, or can be networked, the process of making the actual connections and exchanging the information between them is painful without extensive networking knowledge. Configuration details and connectivity settings are hidden, deeply nested within menu structures. Even with the connections in place,

exchanging the actual information is cumbersome, and users have to dig into the file structures to find the files to be exchanged. In contrast, from a user's perspective, the devices should be easy to connect since they are physically close to each other (and can thus be touched or pointed at). The information to be shared might have been on the screens moments ago and could form part of the interaction, depending on the user's intention. Consider a seemingly simple task, like listening to your music stored on your PC or home stereo system from your mobile phone's headphones in the kitchen. It is practically impossible for many users, despite the principal technical ability of the involved devices and available network technologies. Part of the problem may be attributed to the fact that user interfaces are still highly focused on device-oriented operation. Competing standards and technical incompatibilities exist at the service-level, contributing to the problem and making it impossible for non-experts to take full advantage of today's technology.

Some of the irritations that users face today are a consequence of the mechanisms of the market, that imply different goals for the stakeholders. Developers of devices need to have a strong device-oriented view, whereas users' goals are often more easily resolved within a system-oriented view. Developers are concerned about the functionality and usability of the device at hand, possibly harmonizing its usage over the range of products provided by this specific manufacturer. Users, on the other hand, find themselves with a set of devices and services from different manufacturers, or even different industries. As an example: users still have to set the integrated clocks of many devices, even if they are all connected to each other. Although a scanner and a printer make up a nice copier, only selected models offer this combined functionality. If you would want to directly print the image that the video camera is currently sampling, you need a PC and install specific software to do so. Seemingly easy tasks (for an unbiased observer) are not possible, because at development time, nobody thought about it, and only minimal cross-device capabilities have been implemented.

One possible solution to solving the interoperability problem at the infrastructure-level is a software platform developed within the SOFIA[1] (Smart

Objects For Intelligent Applications) project. SOFIA is a European research project within the ARTEMIS framework that attempts to make information in the physical world available for smart services – connecting the physical world with the information world. We aim to enable users to explore and make configurations on a high semantic level without bothering them with low-level details. We believe this can be achieved by making use of Semantic Web technologies and ontologies in an interoperability platform as proposed by the SOFIA project. Such a platform may be used to support semantic interaction in a smart home environment, as is described in [2]. Building on the SOFIA software platform, we propose a user interaction model and two interface solutions. One user interface solution we propose uses a projected augmented reality approach, based on a concept called Spotlight Navigation [3], [4]. Here, a mobile device containing a pico-projector visualizes connection possibilities between devices in the environment. By using direct pointing gestures with the device in the user's hand, users can intuitively explore and manipulate the virtual network connections as if they are part of the user's real world environment. The second user interface solution is a tangible interaction approach, enabling users to physically select devices in their environment and directly view and manipulate the connections in a simple, universal way. In this paper we illustrate both interaction approaches to manipulate semantic connections in a smart home setting, where the tangible UI solution and Spotlight Navigation can be used interchangeably.

## 2 Semantic connections
We defined the term semantic connections [5] to refer to meaningful connections and relationships between entities in an ubiquitous computing environment. These connections are invisible by default, but can be viewed and manipulated on demand, using a special-purpose device or application. We envision these connections as both real "physical" connections (e.g. wired or wireless connections that exist in the real world) and "mental" conceptual connections that seem to be there from a user's perspective. Their context (what things they connect) is pivotal for their meaning. The term "semantics" refers to the meaningfulness of the connections. We consider the type of connection, which often has the emphasis now (e.g. WiFi, Bluetooth

or USB) not to be the most relevant, but that what the connection can do for someone – its functionality – even more. Semantic connections exist in both the physical and the digital world and can exist between objects, people and places.

Semantic connections have properties like directionality, transitivity and modality (i.e. what things they carry). The rationale behind semantic connections is to rely on:
- the meaning of existing objects to provide meaning for the relationships between the objects and the resulting meaning of the networked objects.
- the power of natural mapping and locality, using real objects and locations to provide meaning for the connections that are created between the objects and (object) locations.
- inherent, augmented and functional feedback and feed-forward (using terminology as proposed in [6]) to strengthen the meaning of the connections and the emerging functionality.

Crucial to our approach is to make the gap between user goal and action smaller. If we consider streaming music from one device to another, "streaming" now consists of multiple actions that do not necessarily make sense. In our view, this single high-level goal, should have one (or at least as few as possible) single high-level action(s). That single action should carry the meaning of its goal. By using the physical world as interaction space and using the real location of the objects, we are reducing the need to identify the devices from a list with names or rely on other forms of representation.

## 3  The Connector: A Tangible Approach

As a portal to the semantic connections, we introduce our tangible user interface approach which we called the connector. The Connector can be used to explore and manipulate semantic connections between different devices in the home environment. It is a handheld device that identifies devices, by scanning RFID tags that are located on the devices themselves. By holding the Connector on top of the tag, users can explore the connection possibilities that are visualized with lights on top of the Connector. After holding the device in the RFID field for a moment, the device-ID is locked and the other device to be connected can be selected in a similar fashion. With a push-to-click action a connection between two devices can be established. For removing an existing connection, the ring on the lower part of the device should be pulled until it clicks.



Fig. 1. **The Connector prototype and a smart phone used as a media player.**

### 3.1 Design

The cylindrical shape of the connector (figure 1) is loosely inspired on that of a loupe or hand lens. By moving the connector over a tag, the connection possibilities can be "read" from the top of the cylinder. The display consists of two rings (made up of LEDs), each divided into four segments. The connector supports several actions. You can move it over an object or tag to see whether it is active. A device or object can be selected by holding the connector close to or on a tag until the selection sequence is completed. The connector can be compressed by pushing the top and the lower part together, and it can be pulled, by pulling the lower part and the top part away from one another until it clicks. When the tag is in the range of the Connector's RFID field, it reads the tag and the first (yellow) light segment on top of the Connector will light up, serving as feedback that the Connector recognises the device. After holding the Connector over a device tag for a moment, a sequence starts, lighting up the second, third and fourth segment of the inner ring. This can be seen as feedforward to hold the Connector over the tag until it has been selected and all four segments are lit. After the device is recognized and selected, another device may be selected in a similar fashion. Now, the second ring of lights will start lighting up in sequence and one should wait until both rings are fully lit. Removing the Connector from the tag prematurely cancels the selection process.

When a connection between the selected devices is possible, both rings start flashing green. When no connection is possible, they will turn red. When a connection between the devices you scanned already exists, the rings will turn green. To make the connection, the Connector is compressed by pushing the top and lower part together, or by pushing the Connector down on the device it is touching, until it clicks. To remove an existing connection between two scanned devices, the ring on the lower part of the Connector should be pulled until it clicks. The rings will show a red light to indicate that the connection has been broken. The segments will turn off once the Connector is moved away from the device. Performing the opposite action of what is required to make or break a connection, cancels the procedure.

## 3.2 Prototype

The Connector prototype is made out of four separate pieces that are 3D printed. The lower part and the top part of the Connector can be moved inward and outward serving as a two-way spring-loaded switch. The prototype packages all the necessary components into one integrated device, which is wirelessly connected to a computer using a Bluetooth connection.
The Connector contains the following main components:
- Arduino Stamp 02
- Innovations ID-12 125kHz RFID reader
- SparkFun BluetoothMateGold
- 8 bi-colour LEDs
- Switches
- 3.3v LiPo battery (850 mAh)

## 4  Spotlight Navigation: An Augmented Reality Approach

Spotlight Navigation can be used to explore and manipulate connections between smart devices. With Spotlight Navigation, connection information contained in the smart space is projected into the real world, augmenting the real environment with virtual information, making it intuitively perceivable for users. Spotlight Navigation projects icons close to the actual devices in physical space. It allows for the creation of new connections simply by drawing lines between these icons, using a "pick-and-drop" action with a push-button on the prototype (press and hold the button when pointing at one device, move over the second device and release the button). Additionally the

connection possibilities are projected between devices that allow for a connection, by changing the colour of the projected line (while the connection is being drawn) from yellow to green when the line's end is moved over the frame of the targeted device. When a connection is impossible, the connecting line will turn red and disappear as soon as the button is released.

## 4.1 Design

Spotlight Navigation was invented as an intuitive way of accessing large data spaces through handheld digital projection devices. Rather than directly projecting the equivalent of a small LCD display, Spotlight Navigation continuously projects a small portion of a much larger virtual pane or data space. It is the device's orientation that defines which part of the larger pane is selected for display. This is done in such a way that the virtual data appears to have a fixed location in the real world. By moving the projector's light spot over the wall, users make portions of the data space visible through intuitive, direct pointing gestures. This intuitiveness stems from the fact that the projected content always stays roughly at the same physical place, regardless of the orientation of the device. It becomes visible depending on whether it is in the projector's light cone or not. In other words, users have the impression that they are illuminating a part of a conceptually unbounded virtual data space, just as if they would be looking at hieroglyphs on a huge wall in a tomb with a flashlight. As people are familiar with operating flashlights, the operation needs no or little training. When accessing a data space with the device, users can zoom in and out of the data space by using a scroll wheel control, resulting in a pan-and-zoom user interface. To visualise the semantic connections in physical space, we rely on the symbolic meaning of colour, where green colour means "proceed" and red means the opposite. Using green, yellow and red lines we aim at referring to the "existence" of a connection, the "possibility" of a connection or to indicate that a connection is not possible. Figure 2 shows the projection when connecting two devices together.
With Spotlight Navigation, devices are identified by their physical location, relying strongly on natural mapping. Connections are created simply by drawing lines between the devices. An erasing gesture with the Spotlight Navigation device pointed at an existing connection, breaks the connection.
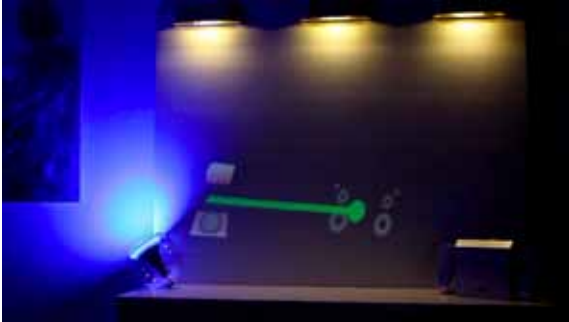
**Fig. 2. Projection when connecting two devices together.**

### 4.2 Prototype

On a technical level, the operation is achieved through continuously measuring the orientation, and optionally also the position, of the device. Our prototype is using an inertial navigation module, also called an inertial measurement unit (IMU), that directly measures the orientation by means of accelerometers, gyroscopes and an electronic compass.



**Fig. 3. Spotlight Navigation prototype.**

The Spotlight Navigation prototype is a fully embedded setup integrated into a 3D printed casing. The design of the casing was targeted at getting the smallest possible setup that could run on the integrated batteries.
A dummy ring was added to the prototype to strengthen the semantics of a mobile projector. Figure 3 shows the prototype. Our current setup consists of the following components:
- OMAP3530 board (IGEP module)
- Pico projector (Microvision SHOWWX)
- Orientation sensor (Sparkfun 9DOF Razor IMU)
- scroll wheel (with button press functionality)
- two additional buttons
- two 3.7v li-ion batteries (Nokia BL5J)

The OMAP3530 processor contains a 3D-graphics core (PowerVR) that is capable of rendering the connection visualizations and device icons in real-time. Our current prototype still requires the object positions to be manually configured in space, as it did not contain a camera. By using a camera, as is planned for future versions, our intention is to recognize the identity and physical location of each device, so that it is no longer necessary to align the projected object icon with the location of its associated device.

## 5  Pilot Evaluation

Both our prototypes were evaluated in a pilot user study. This pilot was composed of demonstrators made by the different partners in the SOFIA project and was conducted with users in a setting that resembles a real home. In order to get enough insights to improve the system, seven groups consisting of three people each were asked to interact with the system, during which their experiences were recorded. The two interaction prototypes presented in this article were part of a larger test setup, which was evaluated during a full week of experiments. In this paper we focus on the results, which are relevant for evaluating the interaction concepts. During the pilot, users experienced a smart space with various automated and interactive appliances and devices, which we refer to as smart objects. The appliances in the smart space are interoperable, sensitive to changes in their environment and exchange information with one another. There exist several explicit and implicit relations between the smart objects, of which some can be explicitly viewed or manipulated with the Spotlight Navigation device (available in the study room of the pilot setup) or the Connector device (available in the living room of the pilot setup).

### 5.1 Participants

Twenty-one participants were recruited in seven groups of three friends. Selection was based on age (between 20 and 35), availability during the week of the pilot and their mutual friendships. Of the recruited 21 participants that successfully completed the trials, 13 were male and eight were female. Their age ranged from 23 to 34, with an average age of 28.5. Nine participants were living alone and 11 were cohabiting. The median score of self-report familiarity with interactive systems was 6 on a 1-through-7 scale.

## 5.2 Materials

Figure 4 shows a brief overview of the different parts of the system. The experiment took place in two rooms, the study and the living room of the Experience Lab on the High Tech Campus in Eindhoven. The facilities and infrastructure of the Experience Lab were used to set up the demonstrator system and to collect observation data (video and audio recordings).
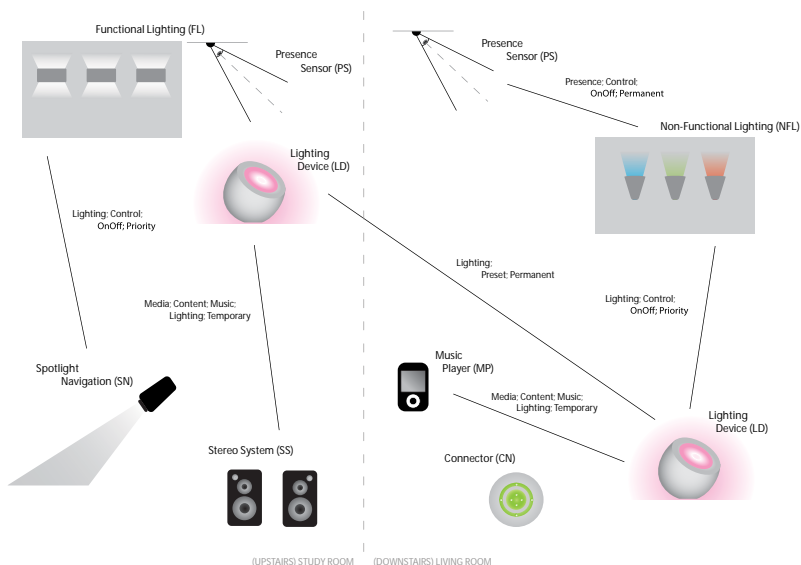


**Fig. 4. The devices and their connections as used in the system.**

## 5.3 Measurements

During the pilot, several measurement instruments were employed. Participants were asked to rate the pilot setup on three different scales; the HED/UT scale [7], the Perceived Control scale [8] and a questionnaire developed by the SOFIA project for internal use. The mental models that users developed during their interaction with the system were recorded using the Teach-Back protocol [9], and the participants' attitudes towards the system were recorded with a semi-structured interview. Because the HED/UT scale and the Perceived Control scale were targeted at the entire system, we do not discuss their results in this paper. Mental models were extracted using the teach-back protocol. Because users' mental models consist of both semantic and procedural knowledge about the system they were interacting with, teach-back questions can be subdivided into "what is?" questions focusing on semantic knowledge, and "how to?" questions focusing

on procedural knowledge [9]. Using such questions, adjusted to our specific situation and research goal, we aimed to extract the semantic and procedural concepts that were relevant for our users. Participants were asked to explain to the researcher what they thought the system was and was for, including listing all the components and the relationships and connections between the components they thought made up the system. By asking for the perceived connections and relationships between the components, we aim to gain a better understanding of how users conceptualize the cause-and-effect relationships between their actions and the responses of the various devices in the smart home. This includes the information that is exchanged between these devices. By asking the participants to explain to the researcher how to perform a specific task with the system, we aim to get insights into how well the participants understood the necessary steps and devices involved to achieve their goal. To support and communicate their answers to both types of questions to the researchers (and for recording purposes), participants were asked to make drawings, schematics or use a textual representation.

*Interview.* In order to gain a deeper insight into the things that occurred during the experiment sessions and record the users' general opinions, a semi-structured interview was conducted. Using a list of open questions as a structure, participants were evoked to share their experiences with the test setup and think along for possible improvements. During the interview, the researchers also asked questions based on specific behaviour or actions of the participants that they observed during the trial.

## 5.4 Procedure

Participants had already received written information about the experiment together with an official invitation by email. After the participants were welcomed in the Experience Lab and were briefed, they received and signed an informed consent form and were asked to fill out a pre-experiment survey. This survey included demographic questions and a self-report scale of familiarity with interactive systems like (tablet) PCs and smart phones.

The groups of 3 participants were split up into two groups of which two participants were led to the livingroom area to perform the role of Mark and Dries,

and one participant was taken to the study to perform the role of Sofia (these names will be used later to identify the different treatment groups). All participants were introduced to the devices, which they had to interact with before the experiment started.

During the experiment, the participants were asked to perform a series of predefined tasks that revealed the functionality of the system. Every participant received these tasks on paper and was asked to think aloud, or for the participants in the living room (Mark and Dries), to share and discuss their thoughts during the whole experiment. After they performed the tasks, they were asked to freely explore the system to deepen their understanding and check their assumptions of its operation. They could continue this free exploration until they thought they understood the system's operation and would notify the researcher that they had finished. The researchers (one in the living room and one in the study) sat down in the back of the room during the entire session and were available in case anything went wrong.

After interacting with the demo, the participants were asked questions to elicit their mental models and were interviewed. The Mark and Dries characters were interviewed together, and they could openly discuss their opinions and mental models. Some of the participants agreed on their answers and agreed on one drawn representation of their shared mental model. Others disagreed, and created their own representation. The duration of each trial was approximately 50-60 minutes, including briefing, instructions, filling out the questionnaires and the closing interview.

## 6 Results

### 6.1 Mental models

Of the 21 participants who participated in the pilot, we collected 18 mental models. The teach-back protocol with the Sofia characters (n=7) resulted in seven unique mental models, while for the Mark (n=7) and Dries (n=7) characters we obtained 11 mental models, of which three were shared. We will first give an overview of the overall results of the mental models, followed by a more detailed description of the mental models recorded from Sofia characters and the Mark and Dries characters (which we treated as one group).

*Completeness.* Out of all the mental models, 15 did not note that presence detection was used; seven out of seven for the Sofia characters and eight out of 11 for the Mark and Dries characters. Of the three that included presence detection in their drawings, one was a shared model and the other two were from the same session. A few other components of the system that were in the study and the living room were occasionally not included in the mental models. This includes the non-functional lighting (NFL) in the living room, the relation between the NFL and the Living Colour (LC) light (the NFL would dim down when the LC was active), the functional lighting (FL) in the study upstairs, and the dimming of the FL when the Spotlight Navigation was in use. The NFL was missing in two mental models, as was the connection between the NFL and the LC. These two mental models were from the same session. For the mental models of the Sofia characters, one out of seven missed the FL and two were missing the connection between the FL and the Spotlight Navigation.

*Semantic Connections Concepts.* During the user experiments some of the participants noticed and discussed interesting networking concepts like transitivity and directionality. These concepts were also considered in the semantic connections inter-action model, but were not implemented in the pilot. Despite the absence of these concepts, participants did intentionally (or sometimes perhaps unintentionally) draw them in their mental models or discuss them. Among the concepts of our interest are directionality, transitivity, priority and the temporary or persistent nature of the connections.
Transitivity was noted in three of the mental models and directionality in nine of them. Two mental models indicated a notion of priority in their mental models, concerning one out of multiple conflicting connections to have priority over the others. Two persons discussed the persistence of connections, wondering when connections would stop existing (for instance when the person would take a mobile device out of the house) or indicating, what they described as a permanent connection, distinctively from the other non-permanent connections.

*Organisational Layout.* We identified three types of organisational layouts in the way people draw their mental models. The majority used a physical/spatial way of describing their mental model, of which we

identified eight as being fully spatial (the main structure of the network is based on the physical location of the components) and another eight mental models have what seems to be an arbitrary mapping, using the physical appearance of the components to identify them in the drawing. Some of these representations include spatial information but it is not used as their main structure. We label these hybrid layouts. There are two mental models that show a logical way of representing the network and its components using blocks and labels to identify the components. Similar ways of organising mental models were found in [10].

*Network Structure.* For the mental models of the Mark and Dries characters, we observed three main trends in the structure of the networks they drew. We distinguished between network structures that define a central entity (which is close to the actual network architecture), network structures that have a mainly peer-to-peer structure, and a mixed infrastructure which both have peer-to-peer connections and connections going through a central entity (the Connector object). All of these mental models of the network are compatible with the actual situation in the pilot. We observed five mental models with a central entity, four with mainly peer-to-peer connections and two with a mixed structure.
For the Sofia characters we mainly observed two different network structures: A daisy-chained one (every component connects to one or two others in a serial manner) found in five mental models, and a parallel structure (where connections had a more parallel nature), which occurred two times. What is interesting to note was that the Spotlight Navigation device was often seen as an entity that was not connected to the network, while the Connector object was in all cases considered part of the network (and in some cases even as being the central entity).

## 6.2 Interviews
From the interviews we observed a few trends. Some of which were to be expected, while others were more surprising. Many participants were disappointed in the limited functionality of the current setup. Although the participants were enthusiastic about the ease of which the connections between devices could be made, they were disappointed that they could only control the connections between two devices,

despite the fact that there were many more devices and appliances available (especially in the livingroom e.g. TV, stereo set, other light sources and luminaries). Most participants were enthusiastic about the "simple way" of making connections. However, they did indicate that they wanted to be more in control of what would actually happen when the connection was made. Some participants indicated that this lack of control was not crucial, because they figured that the connections could be undone in the same fashion when they did not like the effects of the connection. With regard to the overall functionality participants also indicated that they would like to see more "practical applications" that would make their daily life easier. These remarks were mostly in the direction of concepts known from the home automation domain.

Several remarks were made concerning the user inter-action with the Spotlight Navigation and Connector device. For the spotlight navigation, remarks were often made about the icons that were projected. The icon for the Living Colour lamp was not always clear to users. Remarks were also made about the (mis)alignment of the icons and the physical devices, and many participants indicated that the icons could be omitted or be replaced by boxes around the physical objects. Additionally, remarks were made about the inaccuracy of the pointing gesture and difficulties in operating the button on the device. For the connector device, the low speed of the selection procedure was often mentioned. The effort required to physically select a device was often mentioned as a downside, while others mentioned it as a positive point as it was considered playful. Remarks were also made about the limited pairwise selection -participants indicated that they would want to have the possibility to select and connect more devices at the same time.

## 7 Discussion
Spotlight Navigation and the Connector are two alternative user interface approaches to configuring ubiquitous computing infrastructure. Although we cannot directly compare the mental models elicited during the user experiment, which would have asked for a more controlled setting (e.g. having the same setup and having an equal number of participants for both treatments), we did make some interesting observations.

The most striking difference between the way users described the setup was the perception of the users that the Connector was part (if not the central part) of the system, while the Spotlight Navigation was often considered outside of the system. We hypothesise that this is due to the different roles that the Spotlight Navigation and the Connector have in the interaction with the connections. The Connector is used to conceptually "carry" the content between the two devices and in itself represents the relation between these two artefacts. The Spotlight Navigation is, in contrast, perceived as a "remote control" that visualises the connections in physical space. This might lead the users to conclude that the projected lines are the connections, directly between the devices, and leave the Spotlight Navigation itself outside of this network. The results show that devices and appliances that automatically act and react to people's behaviour are often not considered in the mental models, compared to the devices and relations that users interact with explicitly. However, the results also show that some participants noticed these relations, and incorporated them in their mental models. More interestingly, some of the participants expected that they could manipulate these relationships (e.g. between sensor and light) in the same way as they could manipulate the other connections. This result is promising and might indicate that people project their experience with one part of the system to the rest of it. This also became apparent when participants started looking for tags on other devices they thought could also be connected.

An interesting observation is the rather direct impact of the interaction device's design on the mental models. For instance, the design and interaction of the Spotlight Navigation reminded them of a remote control, and consequently they used and described it as such. One participant even thought it was connected to the speaker set because it controlled the music (i.e. making or breaking a connection between the Living Colours lamp and the speaker set started and stopped the music playback).

Another observation was the complicated conceptions the participants had about the connections and their properties. Although there was no explicit directionality on the interactions or the connections, participants conceived the connections that for instance carried

music to have a direction, travelling from its source to a destination. Directionality was also indicated where one device seemed to control the behaviour of the other. By allowing users to use this sense of directionality in their interaction to establish the connection, we could easily give them more control over the connections. Transitivity was another, less obvious, concept that emerged from some of the mental models. Transitivity of a connection is a logical property that emerges when a network node A is connected to B, and in turn B is connected to node C. Transitivity then defines A to be connected to C as well. We observed participants to erase connections they indicated to exist before because they "were no longer needed" because of transitivity. And, in another case, worried about (hypothetically) removing a device from the network when it was in a chain of multiple connected devices, because it would lead to removing the transitive connections as well.

## 8 Conclusion

The SOFIA project provides a platform and therewith the possibilities to improve the interoperability among devices. In this context, two prototypes were developed to experiment with tangible and augmented reality approaches to manage semantic connections. Both show their potential in moving the interaction with devices from a device-oriented paradigm towards a more task-oriented paradigm with increased interoperability. Although we are still exploring the possibilities of our approach, promising results and insights have been achieved already. The results obtained during this evaluation will be used to further define our semantic connections interaction model, and may hopefully help other interaction designers to deal with design opportunities and challenges that emerge when designing for interoperability.

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# An aesthetics of touch: Investigating the language of design relating to form

## Abstract

How well can designers communicate qualities of touch? This paper presents evidence that they have some capability to do so, much of which appears to have been learned, but at present make limited use of such language. Interviews with graduate designer-makers suggest that they are aware of and value the importance of touch and materiality in their work, but lack a vocabulary to fully relate to their detailed explanations of other aspects such as their intent or selection of materials. We believe that more attention should be paid to the verbal dialogue that happens in the design process, particularly as other researchers show that even making-based learning also has a strong verbal element to it. However, verbal language alone does not appear to be adequate for a comprehensive language of touch. Graduate designers-makers' descriptive practices combined non-verbal manipulation within verbal accounts. We thus argue that haptic vocabularies do not simply describe material qualities, but rather are situated competences that physically demonstrate the presence of haptic qualities. Such competencies are more important than groups of verbal vocabularies in isolation. Design support for developing and extending haptic competences must take this wide range of considerations into account to comprehensively improve designers' capabilities.

## 1 Introduction

Are talking and making related? Is it important for designers to be articulate about the haptic qualities of their work? This paper tackles two relevant issues: the role of language in design, and within this, whether and how designers are able to articulate haptic qualities in relation to their work. To investigate this, it reviews relevant literature on design discourse and haptics, cognitive apprenticeship, aesthetic frameworks, and means-end approaches. These theoretical resources are used to critique language use in interviews with graduate designers.

### 1.1 Haptics and Aesthetics

The term haptics [from the Greek haptikos 'pertaining to the sense of touch'] specifically relates to touch and the cutaneous senses. While touch was deemed the most animalistic of the senses by Aristotle, and for long after was deemed mere carnal sensation, more recent philosophers such as Merleau-Ponty have sought to reunite the body and mind, and in the case of Wyschograd, highlight the difference between touch (which can be affective, emotional and metaphorical) and sensation [1].

The term 'haptic qualities' is used here to explain the qualities specific to touch. Unlike fixed features such as form elements, qualities are open to interpretation. In design, there are strong precedents for discussing visual qualities based on the Bauhaus and gestalt psychology [2], but we have not yet made a similarly thorough exploration of haptic qualities and their origins and consequences.

## 2  Relevant Literature

Relevant literature spans language in design, touch in design, intersections of the two through cognitive apprenticeships and criticism, and the role of qualities in designs' consequences.

### 2.1 Languaging Design

While there has been a sustained interest in designers and sketching e.g. [3], what is largely unnoticed is that language underpins much sketching and other design decisions.

A strong provocative comment on language comes from Hodges [4], who believes that the so-called soulless modern buildings of the 20th century are a result of designers being unable to communicate their vision to clients. Lawson [5, p.85] notes that while designers may claim most of their thinking is captured in their sketches "100% is held in the design discussions". He also highlights that the concept of the designer-as-sketcher is a modern one, as masons and other craftsmen as recently as 100 years ago dispensed instructions verbally.

A number of other studies have noted the relevance and importance of language in relation to design. For example, Krippendorf [6] draws attention to the multiple stakeholders involved in design discourse. Also, Cross [7] reported on how words could change the direction of design discussions. Language is also key to design placements [8], and Schön's 'appreciations' [9]. The practical use of language for meaning-making is highlighted in Verganti's study of design-driven innovation in companies [10] He suggests that the designers and the other stakeholders involved in the design process create meanings through language, which are shared amongst the various stakeholders.

If verbal language is so important, why has it received relatively limited attention in design research? In part, this could be due to the challenges in studying verbal language within design processes, relative to the ease with which sketches can be collected and analysed. Design language is often ephemeral: written notes may be regarded as merely aids to back up sketches and prototypes; and critically important design dialogues regularly go unrecorded.

### 2.2 Touch and Language

So how does one talk about touch? We can understand the means with which people understand touch: Lederman and Klatsky's Methods of Haptic Exploration [11] identify six aspects through which we approach objects (lateral motion/texture, pressure/hardness, static control/temperature, unsupported holding/ weight, enclosure/volume, contour following/shape). Akerman et al. [12] suggest three global dimensions of touch (hardness, roughness and weight) with implications such as weight implying qualities such as trustworthiness [1].

Much current research on touch and design language focuses on consumer responses rather than the designers' expertise [13], often through use of simple Semantic Differentials [14]. While this can be useful in terms of understanding the language of experts, e.g. skiing [15], it presumes that users are the best sources for both evaluating and articulating haptic language. Such assumptions need to be tested by comparing consumers' language use with designers' language use. Those that do look at how designers approach touch often collapse it into being able to categorise a product to fit a specific emotion, e.g. a glamorous kettle. This rationalising of the senses can be seen in an extreme form in Kansei Engineering, where emotions are condensed into single words that are next used in matrixes for comparing sensory responses [16]. While this does serve some use in allowing designers to consider some consequences of their actions, it also has the unfortunate effect of ignoring designers' discourse related to the qualities of the product, turning our use of our senses and emotions into something that is to be measured once, rather than explored regularly during the design process.

So why is touch marginalized in relation to design conversations? Semiotics – a school of thought enthusiastically adopted by design – has tended to concentrate on visual language and its associated verbal interpretations [17].

One possible reason is that visual qualities can be critiqued via inspection of images with designers

absent. In contrast, critiques of haptic qualities are more effective when both designers and their designed artefacts are present within the research process.

## 2.3 Apprenticeships: Connecting Language to Making

A notable exception to the lack of attention given to touch and design language can be found in research into communities of practice, notably the concept of 'cognitive apprenticeships'. Collins and Seeley-Brown [18] have studied accounts from practices such as dressmaking, and attempted to both identify the methods with which students are taught to improve their skills. This has been transferred to non-manual methods such as mathematics and reading, but as Collins and Seeley-Brown note, there are gaps in traditional apprenticeship teaching (namely that skills are taught to students to meet business needs, rather than in a way that best supports learning) [18]. The importance of understanding language – and the means with which it can be carefully combined with making – is well described in research on cognitive apprenticeships. Collins and Seeley-Brown's investigation into why traditional apprenticeships work revealed that discourse played a key part in learning: novices picked up their cues for critique through engaging with experts and picking up the language. Ackerman et. al [12, p.1713] suggest that "touch acts as an ontological scaffold, which is reflected in language". This has been similarly noted in wine tasting: when matching words to a specific taste or scent, novices became far more accurate choosing from the words created by experts to choose from [19].

We can conclude from this that novice designers who engage with experts will be exposed to language that will help them to become more advanced at critique of haptic qualities. Such exposure could be direct, via traditional atelier relationships, or indirect, via interactive audiovisual resources. Indirect exposure allows the introduction of innovative approaches to the critiquing of haptic qualities in design, taking novice and experienced designers beyond existing craft practices and expertise.

While designers are not always taught in the way that apprentices used to be, it is worth reconsidering the nature of how materials are used in design education, e.g. making sure that materials are not merely selected because they are close to hand (as noted in Jacucci and

Wagner's research on architecture students and material events) [17]. Innovative and imaginative selection of materials could focus more on exploration and understanding of haptic qualities.

## 2.4 The Importance of an Aesthetic Language

Aesthetic sensitivity through use of language (to reference the Greek aesthetikos), can also be linked to critique. Bardzell [20] has noted that criticism is valuable in design because it not only heightens perception and allows for alternating between the whole and cultural particulars, but also spurs the critic to worthwhile action. Drawing on cultural and literary theory, he suggests that criticism be categorised in terms of the author (creator), text (artifact), context, and audience. Haptic vocabularies can reflect socio-cultural context, direct perception towards qualities of artifacts, and empower both creators and consumers through critical vocabularies that reveal opportunities, meanings and interpretations. A comprehensive haptic vocabulary would thus extend beyond the qualities of artifacts to cover design intents, audience responses, and relations to broader social and cultural contexts.

## 2.5 Qualities, Value Theory and Worth Mapping

Cockton [21] provides a basis for relating product and service qualities to usage outcomes (via consumer experiences) as well as to concrete product attributes (features, materials). Qualities are abstract product or service attributes with a specific role with the means-end chains of product and service consumption. Consumption motivators (the ends of means-end chains) result from the cumulative effects of interactive means (the materials, features, and qualities of products and services, and the user experiences of their consumption). Qualities are therefore the interface between the material product or service and the phenomenology of use and consumption.

Means-end chains can be combined into graphical representations as Worth Maps [22]. Each chain is a path through a network (box and arrow diagram) from a product or service's material attributes, through its features and qualities, via user experiences, to the outcomes of usage and consumption. Such means-ends chains express comprehensiveness and coherence in design reasoning. The extent to which haptic qualities are understood and leveraged in a design is reflected in their explicit roles in means-end chains. Articulate

designers with a strong understanding of haptic qualities can relate these to both the materiality of products and services (features, materials) and phenomenology of usage and goal achievement. For example, as already noted, a material's weight may imply qualities such as trustworthiness [1]. Trustworthiness in turn may lead to confident use of an artifact, leading to valuable outcomes that could not be achieved without confident use. Designers who lack explicit and/or thorough understanding of haptic qualities are less likely to both name and demonstrate haptic qualities, and also less likely to explain how these qualities relate to material causes and phenomenological consequences.

A comprehensive haptic vocabulary would thus be anchored in material qualities, but would associate those with their origins and features on the one hand, and with their consequences for consumer experiences and value realisation on the other. There are structural similarities between Bardzell's [20] aesthetic frameworks and the elements of Cockton's [21] means-end chains. Authored intent [20] relates to intended qualities and actual experiences and outcomes [21]. Audience response [20] relates to perceived qualities and actual experiences and outcomes [21]. Means-end chains as a whole [21] owe their dynamics to the socio-cultural contexts within which they are situated [20]. Such contexts make possible the meanings and motives that transform qualities into outcomes via experiences.

## 2.6 Literature Summary

The existing literature on haptic qualities in design and their relation to verbal and non-verbal expression provides a range of bases for interpreting designers' accounts of the nature and role of haptic qualities in their design work.

The combined perspectives provided a basis for coding and interpreting graduate designers' accounts of their work during interviews at a UK national design exhibition. By comparing graduate designers' accounts with theoretical potentials for haptic vocabularies, we can reveal opportunities for improving designers' capabilities for exploring haptic qualities during design.

## 3 Interviews

In order to investigate the levels of fluency that designers have, in both articulating the qualities of their work, and specifically the haptic qualities, the author conducted short interviews with ten design graduates

at the 2011 NewDesigners Exhibition. The students, from schools throughout Britain, were exhibiting work ranging from furniture to product design to jewellery, but were all designer-makers in that they had all designed and fabricated their work. The designers were also chosen on the basis of work that relied extensively on materials and physical form.

The short interviews were carried out alongside their designed products and audiotaped (videotaping was deemed inappropriate due to the spontaneous nature of the talks). Interviewees were asked to describe:
- **their products and the process that had guided them to the final product,**
- **the qualities that they liked about their final product,**
- **their thoughts about materials and physical form.**

The interviews were conducted on the third and final day of the show. This is relevant for two reasons: firstly the students had had time to get used to talking about their work (or 'refine their pitch'), and secondly as they'd also been able to get audience feedback on their work (some noted that they had only just got the work ready in time for the show).

## 3.1 Results

As in all qualitative research, interview data was coded to reveal emergent themes within it. Initially the analysis focused on specific use of haptic terms, but this proved to be too narrow a focus, due to the broader extent of graduate designers' accounts of their work. Interview data was primarily coded through a phenomenological set of codes that generalized over designers' foci on, and subjective understandings of, their work. Theoretical analyses were secondary, and were focused on themes and evidence within the primary coding. Once a broader view was taken, the following primary codes emerged from analysis of the data:
- *intent*: what the designers intended to achieve; the intended outcome;
- *evaluation*: allowing for reflection, also taking into account the feedback they'd been able to pick up during the show;
- *references*: notes of specific trade and physical terms related to touch (taken from Lawson's observation of design language as being compact and full of references) [5];
- *qualities*: language usages which specifically related to aesthetics and haptics.

While many of the designers initially protested that they weren't able to discuss their products, this did not prove to be the case. The only problematic case came from a student with English as a second language, and even in this situation, the particular student proved to be more nuanced than might be expected. This is in accordance with Krippendorf's [23] and Lawson's [5] assertions that designers are in fact highly articulate and speak in a highly evocative and compact language. However, haptic qualities played only a limited role in the graduate designers' accounts of their work. Through basic coding of the interviews, two themes emerged:
• Challenging Materials, and
• Limited Recognition of Haptic Qualities.

Key observations and evidence for each of the themes is now presented.

*Challenging Materials.* The graduate designers talked more about materials in general than about the qualities that resulted from both materials and features (form). The designers who were interviewed had played with materiality in some respect, and so their work often included some sense of challenging expectations in regards to a material:

Y (wooden steam bent table): I've had a lot of people think that the underneath [the wooden table] is all was really soft and flowing, and they've had to come along and like, touch it, and make sure it's all solid. But yeah, everyone loves it and making sure like, feeling all the curves and everything.

A (metal necklace): I've actually had someone come from up there [the top floor of the exhibition] and go, "is it [the metal necklace] rubber? It looks like rubber". and lots of people have said, what is it actually made of? It's not plastic, but it's usually the sound it creates, you can tell it's metal.

K (acrylic jewellery): If people have knowledge already about the material and the processes, they come in and question more, where's the join, or how it is worked? If it's people who don't and have no idea, they come and approach and question: is it glass?

In Bardzell's [20] terms, the graduate designers' intentions sought to disrupt existing audience expectations about specific materials. However not all

consequences of materials and forms were intentional. One student found that he had created an "accidental illusion" with a stool and table that looked as if both were made of the same materials but were not:

M (stool with metal strap): It wasn't really intentional to bring the strapping through and keep it the same aesthetic, it just sort of ended up that way, without me realizing … I was er, surprised at the number of people saying, "I thought it was fabric, how is it standing up?" which I kinda like really.

These comments emphasise the element of verification prevalent in haptics [24], and are a reminder that the "seeing is believing" is short for "seeing is believing, but feeling's the truth" [1]. Designers' intentions may not be realised until constructed artefacts are critiqued or used, but more importantly, physical realisations and human encounters may reveal unintended consequences. In Bardzell's [20] terms, the designer here extended his understanding of his work through an audience's encounters with it. Within Cockton's [21] means-end chains for design, this graduate designer was mostly focused on relations between materials, features (form) and qualities. There was little focus on experiences, and none on outcomes, which in Bardzell's terms, indicated a limited contextualisation of the design work [20].

*Haptic Qualities: Recognition, to an Extent.* Several students identified materials and their handling during making as a key influence what they did, through their process of making and/or use:

Y I let the wood talk to me, to let it bend the way it wanted to, and then I just wanted to force it a bit more.

E (glass bowl): I'm just so happy that I've found a product, a technique, which really suits me…
I've found, my language as it were, with the glass.

K My work doesn't necessarily have some in-depth deep concept; it's all about the material and the handling of it.

Once again, graduate designers were focused on the initial elements of Cockton's [21] means-end chains, but some could articulate qualities and even outcomes. Interestingly (but perhaps to be expected) the most interesting comparisons in terms of the value of specific materials emerged when designers justified why they'd

chosen one material or process over another (Table 1). One designer who had created a laser cut clock in both acrylic and wood, attempted to describe why the former was more popular:

| Acrylic | Wood |
| --- | --- |
| Weighty, solid, finished (outcome: sold better), lego-like | Lighter, more flimsy (outcome: not as popular) |

Table 1. **Terms comparing wood to acrylic in a laser clock and related success.**

Another graduate designer had tried a number of materials before setting on glass, noting the following properties of all of them (Table 2):

| Glass | Metal | Plastic |
| --- | --- | --- |
| "water-like, touchable" | harsh, "though beautiful polished", didn't flow | "not a material I enjoy working with, it's all wrong" [see below] |

Table 2. **Material comparison for selection.**

The contrasts here were mostly in terms of material qualities, including the way in which glass invited touch. One response was visceral (which is how Aristotle considered touch, i.e. as animalistic): this designer simply did not like working with plastic.
Another graduate designer contrasted the two different materials that met in his work. While the haptic and visual qualities of wood and pewter were directly referenced, form dominated his account of their jointing (Table 3):

| Pewter (cast) | Two Meeting | Wood |
| --- | --- | --- |
| "soft, metal" | Controlling the wood, joints being snug or not strong enough | warm, nice qualities |

Table 3. **Pewter and wood chair.**

Several students had worked with metals (Table 4):

| Metal (vs glass) | Aluminium | Pewter |
| --- | --- | --- |
| "Harsh, didn't flow" | "cool … not warm, but comfortable" | Soft when in thin sheets … but difficult to compress when in large blocks [meant as positive] |

Table 4. **Comparison of terms and materials.**

Several haptic qualities were in evidence here, with the occasional reference to experiential qualities ('comfortable').
Even within single products, they were aware that the value of a haptic quality could change: a necklace was wonderfully 'fragile' and 'delicate', but not so good when 'broken'.
When asked about material qualities most felt that they had made successful choices (sometimes rationalised through why they had not worked with various other materials), there were some terms that attempted to capture haptic aesthetic qualities.

- *Flow* "it just didn't have flow" (E). This was used in a way similar to the concept of harmony in graphic design, in that it represented everything working together (or in this case, not). It could be speculated that this has come from interior or landscape design, as Lehrer [19] notes in wine tasting language that terms can easily move from one domain to another (she relates the concept of a wine having body to the 80s popularity of bodybuilding).
- *Finish*: this was noted by six of the graduate designers as being something they were proud of. This was generally described as sheen, but in one case as patina. These are standard words used in product design language, so it is not surprising to see them used.
- *Comfort* was noted, but used in different ways from furniture to jewellery: in the former, an uncomfortable chair was too angular (M), whereas in jewellery weight, softness, and (to some degree) temperature played a part.
- *Thrown* was used by Y "it's all very organic and thrown" to describe her hand/steam bent wooden table. This was one of the few times a word was clearly taken from another field (here clay working) and shifted into another.

However, it is telling that many other accounts had to rely purely on material and feature (form) references without exploring their consequences, and mostly viscerally, for qualities or experiences:

E plastic was just, was just for me, it's all wrong... not a material I enjoy working with.
J too angular... soft wood, which is really warm and has some nice qualities about it … fluid qualities that were left in it as well, like you can actually see the process

going on, like a little snapshot of what was going on... process, it like, held within the metal.

Other popular terms that came up when explaining design decisions were:

- *Tactility*: "you want to touch and feel it" (E), a rare articulation of an explicit experiential consequence.
- *What it did not have*: "no joins", "no glue" was also common, focused on features.
- *Natural*: there were a number of mentions of this, through the use of both terracotta and wood. In contrast to some graduate designers' challenges to existing contexts of audience interpretations, here others were articulating established semiotic associations and their consumer valuations.

3.2 Comparisons with a Previous Study
In a previous study by the authors of an experienced fashion expert's understanding of textiles' haptic qualities, video recordings revealed how swatches were manipulated to ascertain and demonstrate their tactile qualities. The use of audio recording alone in the current study reported above highlighted the combination of ostension (pointing at), manipulation, and verbal descriptions and interpretations when communicating haptic qualities. When transcribing the recorded interviews, memories of graduates' specific manipulations and ostensions had to be recalled to make sense of some of their language use.
A key insight here is that improved understandings of haptic qualities require more than a simple vocabulary, Ostension and manipulation are integral aspects of haptic understandings. This is also seen in areas such as wine tasting where the glass has to manipulated in a specific way to reveal the 'legs' or 'tears' of a wine, which indicate its alcohol content.

## 4  Discussion
The primary aim of this research is to help tease out the verbal and non-verbal language that designers use to help make meanings out of forming, and be able to present it back to them in a way that they can both be made aware of it, and also be able to improve on it. Such improved vocabularies have to be productive, relating both to the assumed material causes of qualities and also to their expected effects e.g. through situating haptic qualities in means-end chains [21].

Given the broad range of uses for vocabularies of haptic qualities, the interviewed graduates demonstrated only a limited ability to critique the haptic aspects of their designs. Much of the references to haptic qualities were related to the processes of designing and making, and not to their consequences for human experience and outcomes from ownership and/or use of their designs. Their accounts often related viscerally to materials or focused on features (form), with limited extensions beyond these to qualities and experiential consequences. In these graduates' accounts of their designs, few existing theoretical understandings showed through.

The importance of language in design, as established by a range of design researchers [4], [5], [6], [7], [8], [9], & [10], is not well reflected in the graduates' accounts, although most of Lederman and Klatsky's six ways to approach objects haptically were demonstrated in product interactions [11]. This may indicate that the graduate designers' vocabularies had largely been picked up through a cognitive apprenticeship that drew little on existing relevant design research. Existing design education may thus not be preparing students well for articulating their intentions for qualities, experiences, and usage outcomes.
What emerged from student discussions was a disconnect between the language they were able to use to describe their thinking process in concrete terms (references) on the one hand, and their aesthetic decisions relating to touch on the other. While they showed awareness of the haptic qualities and their importance, the language that they used to communicate it was far less specific, except where this was related to processes of making. Few theoretical resources were in evidence.

Graduates' accounts of haptic qualities had a narrow critical range, making limited use of the range of critical possibilities outlined by Bardzell [20]. Similarly, while some graduates occasionally demonstrated an ability to relate haptic qualities to materials or design features, they rarely related qualities to likely or intended experiences or consequences, as made explicit in Cockton's [21] worth maps.
Making designers more aware of the language that they use and their means of communicating and reflecting through it should make designers more aware and more

successful when it comes to both making decisions in relation to touch and therefore being able to communicate it.

There are other disciplines that do not have a strongly established language for discussing aesthetics, but they are anchored by a useful means of replicability. A prime example of this is cooking: Fine notes that the blue-collar staff have to learn to develop an eye and taste for dishes that they've never eaten before, but do so through repetition and not having to be able to discuss it [24]. However, it is not clear that design can rely exclusively on such tacit non-verbal knowledge.

## 5 Future Work

There is an opportunity to investigate the language of designers who have a highly developed appreciation of touch and how their language could be used to improve the design work of novice designers, and perhaps experienced designers too.

Beyond this, design education could be reconsidered in relation to both the cognitive apprenticeship model and design criticism in order to encourage more design dialogue in relation to touch. Similar work has been done by Sonneveld [25] in encouraging design sensitivity in relation to touch, but did not investigate the role of expert discourse.

The current apprenticeship elements of design education could be improved. While some of the aspects of the process are already well formed for learning (e.g. dressmaking students having their knowledge staggered), one of the limitations of the current system is that it often works from practicalities rather than ideals. This is noted with architecture students using materials that are to hand to make prototypes, rather than considering their appropriateness [17].

Understandings of visual qualities are well grounded in gestalt psychology as explotied by Paul Klee and others in the Bauhaus. Such imports from other fields are not uncommon. For example, language used for understanding wine was developed by chemists (and interestingly, later extended by a linguist to be more of a nuanced study [19].

There are clear advantages in developing haptic vocabularies, with accompanying audio-visual demonstrations, augmented where relevant by interactive capabilities. We need to consider allowing students to find ways to enrich their vocabularies, in particular in relation to touch. The reasons for this include:

- **Designers will be empowered to create a wider range** of potential meanings through improved ways of critiquing and interrogating their material choices.
- **If designers want to be able to create brand or** product systems, they similarly need to be given the language to be able to articulate what constitutes the product system. At least one student noted that they were attempting to extend their singular product to a range, but needed to figure out how to do so. Without an understanding of the key ways to manage this, change, any translations risk being diluted in the way that the brown Microsoft Zune changed from a concept model of two-tone brown and green metal to brown plastic described by Gizmodo magazine as "swamp water Jell-O" [26].
- **Designers increasingly work in multi-disciplinary** team settings, where traditional tacit knowledge must be made explicit to communicate with other team members, and to allow discussions of design options [27]. Designers need to be able to articulate and demonstrate haptic qualities.
- **Designers need to be able to reason about the origins** and consequences of haptic qualities, drawing on structures such as the means-end chains of Cockton's Worth Maps [21]. Making the connections within design thinking explicit requires confident broad vocabularies for all elements in design's means-end chains.

We plan to further explore expert, graduate and student use of haptic vocabularies in their accounts of design intentions and opportunities. We will pay particular attention to non-verbal behaviours when accounting for haptic qualities, especially the role of ostension and manipulation. We will use relevant design research as a basis for understanding expert behaviours. Examples and understandings will provide content for an interactive tool for developing designers' haptic vocabularies and understandings. The tool will combine physical and digital resources. Use of this tool by designers will support assessment of the relative value of existing bases for understanding haptic language use and critical behaviours from design research.

## 6 Conclusions

Graduate designers are aware of the importance of touch in their work (both through their work and its importance to their audiences), and are able to point to some decisions that they have made in relation to it, but appear to lack a broad enough lexicon to be able to fully communicate this, and to relate haptic qualities to both their origins and their consequences.

Designers at all stages of development should be empowered by an improved vocabulary, with supporting practices, for the aesthetics of touch. Such a vocabulary is not only key to enable them to communicate, but also to be able to make complex and demanding design decisions such as translating a single product into a product line.

We have identified relevant theoretical perspectives from across a range of design research and have used this to augment bottom-up analyses of graduates' accounts of their design work. Through this, we have identified opportunities for improving the extent, depth and effectiveness of haptic vocabularies and their associated non-verbal resources. We plan to extend the above studies to expand our corpus of examples and understandings. With a suitable corpus in place, we will then transfer examples and understandings into an interactive tool that integrates physical and digital resources we will then evaluate the effectiveness of this tool.

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# Learn to make, make to learn: Reflections from sketching haptics workshops

## Abstract

This paper presents results, observations and insights from four workshops on the design of haptic interfaces. The workshop series was called Sketching Haptics, and the primary objective was to explore how the fields of Haptics and Design can come together for educational purposes during 4-5 days. The current haptic advances tend to favor technological refinements over other forms of inquiries. The initial premise is that designers, with their creativity and user-centered perspective, can contribute, along roboticists and engineers, to evolve the next generation of haptic interfaces. Designers might not have the technical affinity to develop cutting edge haptic technology, but they possess skills, processes and expertise that can definitely bring new perspectives, applications and considerations for haptics. The main takeaway from the workshops reveals that quick, creative, explorative works is not only possible but can be valuable and rewarding. The observations also stress the necessity of making, prototyping, materializing ideas and sketching in hardware when dealing with our sense of touch. By communicating the structure, activities and outcomes from the workshops, I hope to inspire educators and designers to survey and embrace the nascent field of haptic design, help develop our haptic design toolbox, and ultimately democratize haptic interfaces.

## 1 Introduction

Despite decades of research and advances in our understanding of the sense of touch, designers are generally unfamiliar with haptics. As new technology, tools and approaches are reshaping our design activities, I believe that designers and particularly design students are now in a position to learn and develop a heightened sensitivity to haptics. Designers, with their creativity and user-centered perspective, can now join roboticists and engineers to help evolve new haptic interfaces that are ultimately more humane, valuable and meaningful to us. As the haptic, design and Human-Computer Interaction (HCI) communities are constantly expanding and reaching out into new territories, new areas naturally overlap and provide new grounds for collaboration and fresh inquiries. The amalgam of Haptics and Design is fairly new and poses interesting challenges for designers, HCI professionals and researchers.

Traditionally, haptic advances tend to favor and recognize technological refinements over other forms of inquiries. As Design and Haptics are coming together, what are the activities, challenges and friction points that underpin this new field of inquiry? How can designers play an active role in this collaboration? And more fundamentally, why designers and other creative professionals know so little about haptics, our sense of touch and how to go about designing for that modality? The workshop series is my quest to answer some of these questions.

In this paper I present the background motives, workshop series characteristics, the structure of the activities, some results and outcomes, and conclude with observations and insights.

## 2  Background

The workshops build on previous works by numerous researchers [1], [2], [3]. MacLean explicitly advocates approaches and inquiries from Interaction Design for haptic design [4].

This workshop series is the result of my professional interest in haptics, both from a PhD student in design perspective [5] and from an educator point of view.

## 3  Workshop Series Characteristics

Creating a rich, dynamic and creative atmosphere, for any workshop, is a very challenging task in itself. Naturally, the art and science of planning an educational workshop and adjusting its activities with the participants' progress is well beyond the scope of this article. The considerations and details put forward in this section are restricted to what seems particularly relevant or significant.

The workshops under consideration were realized between October 2010 and October 2011. They were part regular educational activities for the university students, and part a practical form of research and inquiries for my doctoral studies. The characteristics of the workshops are presented in table 1.

| Work-shops | Host program, level | Group size |
|---|---|---|
| A | Interaction Design, MA level | 9 participants |
| B | Computer Science, MA level | 16 participants |
| C | Computer Science, MA, PhD and Post-Doc levels | 9 participants |
| D | Interaction Design, MA level | 11 participants |

**Table** 1**. Host programs, levels and group sizes of the workshops.**

Workshops A and D were realized at Umeå Institute of Design in Umeå, Sweden. The participants were design students generally familiar with the design process and model making activities, but novices in programming and electronics. The participants had access to various workshops and facilities at the design school for building their realizations.

Workshop B took place at Chalmers University in Gothenburg, Sweden. Workshop C was hosted at the University of British Columbia, Vancouver in Canada. These two workshops welcomed students who were more acquainted with computer science and HCI, and less with design. Both workshops took place in class-room-like environments with limited access to tools, materials and equipment for model making and proto-typing. It is worth noting also that workshop C had an interesting mix of participants, ranging from first year Masters students to post doctoral researchers already experts in Haptics.

## 4  Schedule and Activities

The four workshops had similar programs in their structure despite varying time constraints. The schedules ranged from continuous 5-day period full time to 3-5 days spread over a longer period or a weekend, and sometimes running in parallel with other courses. Table 2 presents a schedule used in one of the workshops.

|  | AM | PM |
|---|---|---|
| Day 1 | kick-off presentation + what is haptics + intro to movement, mechanisms and actuation | assignment #1 no technology (cardboard, glue, tape, rubber band, etc.) |
| Day 2 | review of assignments #1 + design process lecture + presentation of various actuators + assignment #2 (3 different scales of actuation) | work on assignment #2 + recap Arduino |
| Day 3 | review of assignments #2 + lecture about motors and actuators with Arduino | rework assignment #1 or #2 with Arduino control |
| Day 4 | assignment #3 (significant challenge) + code/hardware clinics | collective literature review/discussion + work on assignment #3 |
| Day 5 | work on assignment #3 | final presentations, video documentation and debrief |

**Table 2. Schedule of one workshop.**

The activities have been deliberately developed with a progression in the use of technology. The first assignment involves no technology, where actuation is human powered and controlled. This first step is also where the use deception, fakery or other Wizard of Oz inspired techniques is usually advocated. The second exploration introduces electricity, motors, switches and other simple building blocks to expand on speed, responsiveness, range and power. These new additions are meant to broaden the range of possibilities, but also directly highlight challenges in controllability and durability. The third and subsequent assignments bring in microcontroller, sensors and simple programming (via the Arduino platform) to explore the link between sensor and actuator, input and output, and complexity to a certain extent. At this stage, the participants are encouraged to build something that can be run with minimal intervention of the creator(s). The emphasis is put on felt sensation and variability. Figure 1 shows an example of a standalone project that directly reacts to the user.

The four workshops were composed of lectures, demonstrations, impromptu and short clinics on specific topics and team tutoring sessions. Participants were strongly encouraged to work in teams of two or three, and change teammates during the week. Various design constraints and small work briefs were defined, but participants were invited to interpret the assignment very openly.

## 5 Outcomes

This section showcases some of the realizations made during the workshops (figure 2). The various images depict also, although very partially, some of the tools and processes from the sessions. Additional materials, presentation slides, photos and videos are available online at http://www.guchmu.com/sketching-haptics-workshops.

## 6 Reflections and Insights

The initial goal of conducting Sketching Haptics workshops was to explore how the fields of Design and Haptics could come together during a few days, with a strong focus on prototyping and tangible outcomes. Although the activities were generally appreciated from the participants and the hosting educators, many challenges remain in the pursuit of bridging Haptics and



Fig. 1. **Project running in standalone mode, without the intervention of its creator.**



Fig. 2. **Various hardware sketches made during the workshops.**

Design. My observations and reflections are presented under the following two themes: Make to Learn and Learn to Make.

## 7  Make to Learn

Our sense of touch has various characteristics and capabilities that we have grown accustomed to. In our everyday activities, we barely notice how our perceptual processes work and the different psychophysic mechanisms involved. To tackle and learn more about our sense of touch, it is often necessary to build some sort of apparatus that can sense the world and/or produce stimuli, so we can isolate and recreate a sensation 'on-demand'. Discussing and drawing haptics isn't satisfactory to develop a complete understanding or to ground design decisions. Ideas, concepts and proposals have to be felt or experienced in some way.

This reliance on hardware translates into considerable challenges for building and making things rapidly. The haptic explorations are as good as your hardware implementations. Various haptic devices are commercially available, and could be used to explore various haptic concepts quickly. Unfortunately, these products are often expensive and have a very steep learning curve, putting them out of reach for most workshop settings. For specific haptic teaching activities, Shaver and MacLean built a specific actuated platform to ease the development of haptic design explorations [6]. Despite a simplified platform and proper documentation, it requires advanced low-level programming and a few days of work to get up to speed with the device, at a cost of a few hundred dollars.

## 8  Exhilarating Simplicity

The Sketching Haptics workshops favored a rough introduction of haptics, starting with general construction and craft materials (paper, cardboard, foamcore, hot glue, rubber bands, etc.) and mechanical kits (LEGO, Meccano, etc). The priority is to first get acquainted with our touch sense, and start discussing and verbalizing haptic sensations. Realizations can be seen as rather trivial and simple, but it is surprising to what extent simple contraptions or pieced-together rigs can trigger and initiate very rich discussions between the participants.

As motors and other actuators are added to the mix, a new world of haptic stimuli can be explored and experienced, i.e. vibration, friction, pull and push

forces, etc. At the same time, evolving haptic sketches or embryos of haptic interfaces where physical forces and movement are present tend to result quickly into miniature wreckages and ruined constructions. Quick, non-committal and explorative constructions are generally not compatible with controlled actuation and repetitive movement.

grow, explode, shrink, scale, rotate, pulse, flick, rest, disappear, clutch, release, hold, capture, pin, prompt, confirm, repeat, stable, glide, slide, stop, hit, kick, cancel, ease in/out, ramp, augment, increase, decrease, agitate, shake, twist, transform, cycle, ricochet follow, guide, grab, screw, implode, circulate, constrain, channel, force, lead, invite, smooth, hard, harsh, solid, soft, compliant, bounce, spring, break, stop, collide, permute, accelerate, react, bob

**Fig. 3. Actuation keywords used as a starting point for design.**

One line of explorations that has been helpful as a point of departure for haptic exploration was to start creating interface ideas that are inspired by actuation keywords like shrink, bounce, and slide (figure 3) or prepositions that involve movement or time (between, around, with, etc.). These terms can be interpreted very openly, and often have visual or auditory references to build upon directly. It is equally inspiring to learn about the numerous haptic illusions [7] and try to build an apparatus to experience one of them.

## 9  Haptic Qualities versus Available
##    Resources

One main observation from the workshops was that the selection of available actuators and materials greatly regulate what is being built and explored by the students. In the first two workshops (A and B), I provided solenoids, vibrotactile and servo motors as the main building blocks. Vibrotactile stimulus was very common in the projects being developed, most probably because vibrotactile motors are the easiest items to use and control.  A few participants used servo motors to build haptic sketches, but those projects had a tendency to be unreliable (difficulties securing the servos

properly) and difficult to calibrate over multiple runs. In workshop A, the vast majority of hardware sketches were built out of wood. Students had limited issues with solidity and stability, in contrast to the workshops B and C where sketches were ruined or unusable fairly rapidly. This could be derived by the fact that all students from workshop A had quick access to a wood workshop nearby and a plentiful source of free scrap pieces to work with.

During the last two workshops, I presented other types of haptic actuators (voice-coil and piezo) and their adoption rate seemed to match their ease of use. For some of the more complicated actuators, I prepared code samples and special wiring connections so students could get going fairly rapidly. Ultimately, students only used the actuators I simplified, no one ventured into uncharted grounds during these intense days. In the end, participants were enthusiastic about exploring any kind of actuation and stimuli, as long as they could manage to build and control it reliably. More complicated force-feedback mechanisms and kinetic elements seemed out of scope for these workshops.
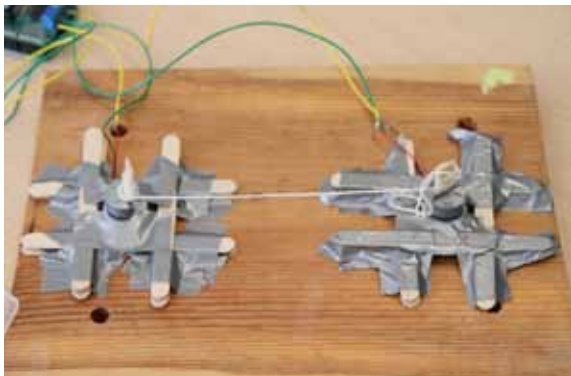


**Fig. 4. Actuated project without haptic feedback.**

There is one difficulty that appeared during each of the workshops: participants had a tendency to build actuated projects with no direct haptic qualities. The apparatus would be moving, spinning or doing something without any direct action on the human body or skin (figure 4). After the debriefing sessions, students mentioned that the challenges of just making something work was often overwhelming, and that they forgot the apparatus needed to interface with humans ultimately. After mentioning the concern, all groups were able to quickly rectify their activities and focus on haptic output in the realizations.

Despite a large selection of materials, easier toolkits and lower barrier to entry in actuation technology, it remains challenging to successfully experience a large variety of stimulus and sensations over a period of a few hours or days. One has to not only develop the haptic concept, but often has to build the platform to support it. It would be comparable to having to physically build a screen or monitor every time you develop a new visual interface idea.

In conclusion, the workshops highlighted that design explorations in haptics are definitely possible and fruitful to some extent. Participants engaged quickly with the topic and found ways to build interesting apparatus and sketches that embed haptic ideas. They could express various details and considerations that were grounded in their felt experiences, and have other relations to those sensations too. Although very demanding, building haptics to learn haptics seems like a beneficial way to get acquainted and develop a sensitivity of the haptic domain.

## 10 Learn to Make

Prototyping activities, outside the haptic realm, are challenging in their own way. Going from idea to materialization can serve many purposes and goals [8], [9]. It is up to the designer to identify and govern which filters, shortcuts and perspectives are valuable and worth pursuing or building [10].

The workshops' activities were an opportunity to learn about haptics, but it was equally a lesson in prototyping and sketching in hardware [11]. As mentioned in the previous section, the material qualities are known to influence how things feel, for both motionless and actuated artifacts. What made the workshops particularly challenging was the strong time constraint imposed on the making endeavors. Generally, participants had more or less one day (4-6 work hours + overnight) to fully realize a particular assignment or hardware sketch. This strong limitation made sure that participants were focusing on explorative and non-committal works, and that they could investigate numerous tracks, iterations or alternatives over the course of a few days.

## 11 Prototyping Skills, from Model Making to Programming

The participants had varying levels of expertise pertaining to model making, prototyping, mechanical engineering, electronics, programming and haptics.

Roughly half of the participants were design students, with considerable exposure and experience in creative processes and model making skills. The other participants had a background in computer science, and were generally at ease with programming and sensing/control systems. Each group was able to leverage their current expertise, and work towards the areas unknown to them. Haptic researchers got to learn about design process, user-centered methods and creative explorations. Design students were able to explore actuation control and psychophysics, for example. All participants were able to find a relevant and stimulating challenge, and tap into their teammates' expertise to advance their learning.

The workshops emphasized a progressive use of technology, starting with only analog and non-tech materials on the first day, using "humanware" or Wizard of Oz technique with simple motors the following day, building towards a complete hardware and software assignment for the last day. This approach doesn't aim to imply that more or advanced technology is better. On the contrary, the activities are purposely structured to veer away, as much as possible, from complex and intricate technology often associated with haptic interfaces. From a pure haptic perspective, it is impossible to do without actuation and technical devices, but I believe design inquiries and creative explorations can help contribute fresh and relevant perspectives to the haptic field. Designers' views of technology and computation are different, not better or worse than any other engineering professionals.

**Fig. 5. Virtual ball-in-a-box haptic interface built in one day.**

Naturally, the different groups were able to realize different kinds of haptic interfaces based on their skills and interests. For example, one group comprising

a post-doc haptic researcher implemented a virtual ball-in-a-box haptic interface (fig. 5) just within hours, using a cardboard box, clever embedded electronics and programming.

**Fig. 6. Haptic jewelry responding to proximity of nearby humans.**

On the other side of the spectrum, a design student was able to produce actuated jewelry pieces made from actuators, beads and felt, which responded to proximity with other human beings (figure 6). In most cases, the integration of simple actuation and responsiveness framed in relevant context/situation resulted in ingenious haptic interface ideas.

The balance between quality and quantity of models or sketches is particularly difficult to manage when time and tools are limited. Participants tend to make do with the available materials, access to tools and combined expertise from the group's members. During the workshops, participants had the opportunity to learn about prototyping, assimilate new making skills and bring new ideas to life. In today's knowledge economy, the ability to make or build stuff has decreasing value. For exploring, understanding and advancing haptics, making skills are very valuable if not essential.

## 12 Conclusion

This paper presents results, observations and insights from four workshops on the design of haptic interfaces. The workshops "Sketching Haptics" set out to explore how the fields of Haptics and Design can come together for educational purposes. The current state of haptic development tends to promote technological refinements over other forms of inquiries. The initial premise behind the workshop series is that designers, with their creativity and user-centered perspective, can contribute and drive, along roboticists and engineers,

in the development of haptic interfaces. Designers might not have the technical know-how to develop new haptic technology per se, but designers have instrumental skills, processes and expertise in how people interact with technology. Haptic design activities present numerous challenges for designers and other professionals not familiar with haptics. The exercises and assignments were developed in order to maximize exposure to felt sensations and circumvent common technological constraints.

The overall results from the workshops reveal that quick, creative, explorative works are not only possible but can be valuable and rewarding. The various realizations and projects were diverse and inspiring, but most importantly they act as catalyst and platforms for tangibly engaging with haptic notions and concepts. That new medium makes it possible for newcomers to relate, feel and develop a heightened sensitivity.

In closing, I hope that by relating and exposing those workshop endeavors and realizations, other design students, practitioners, educators and haptic experts will be intrigued and stimulated to initiate similar activities in their own community. The field of haptic design is young but developing rapidly. I foresee a bright future where designers and haptic experts will collectively expand our haptic design toolbox, vocabulary and library, and help develop the next generation of haptic interfaces that are more humane, valuable and meaningful to us.

## Acknowledgments

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# A study on a tangible interaction approach to managing wireless connections in a smart home environment

## Abstract

Technological advances in computational, networking and sensing abilities are leading towards a future in which our daily lives are immersed with interactive devices that are networked and interoperable. Design has an important role in facilitating users to make sense of the many connections between devices in a networked environment. Two design solutions based on a tangible interaction approach have been developed, that allow users to manage wireless connections between devices in a smart living room context. One design (Interaction Tiles) is a centralized approach based on a high level of semantic abstraction. The second design (Nodes) employs a distributed and localized approach, building upon laws of grouping from Gestalt psychology. A user experiment (n=15) was conducted, comparing both design solutions in the form of video prototypes, to gain insights into the mental models users construct when using the methods. Findings suggest that users' mental models of the Nodes design are more accurate representations of the actual structure of the network and that it allows for the projection of different mental models. Furthermore, findings also suggest that this does not necessarily lead to increased usability or increased perceived value.

## Keywords

Gestalt, Product Semantics, Interaction Design, Smart Home

## 1 Introduction

Technological advances in computational, networking and sensing abilities are changing the domain of interactive product design. Visions of the future, such as Ambient Intelligence [1], Pervasive Computing [2] and Ubiquitous Computing [3] predict a future in which our daily lives are immersed with devices that are networked and interoperable. Other discourses on the future of technology, such as the "Internet of Things" [4] and "Shaping Things" [5] predict all devices to be connected to, or to form a new, Internet of Things. This allows individual products and their location in space and time to be identified.

In such worlds, interactive products no longer function, or are interacted with, in isolation. Rather, they become part of a larger network of products. This changes the field of design from a "one person - one product" paradigm into that of a world in which many products and systems form complex networks [6].

For these highly interactive and intelligent systems to have any merit, it is imperative that users are able to understand and manage their content. Design plays an important role in allowing users to make sense of this content – the devices and connections within the network – and to help bridge the gap between virtual and physical worlds.

Various approaches have been developed that aim to bridge this gap. One example is Tangible Interaction [7], which builds upon perceptual motor-skills by presenting

users with physical entities that can be manipulated to interact with virtual data. The European research project SOFIA targets to "make information in the physical world available for smart services – connecting the physical world with the information world" [8]. In the context of this project, we have previously designed the Interaction Tile [9]. The Interaction Tile is a design based on tangible interaction that allows users to explore and manage wireless connections between devices in a smart living room context. The design employs a centralized approach and builds on high-level semantic abstractions.

We created the Nodes design to explore an alternative design direction in the same setting. The Nodes design employs a distributed and localized approach and builds on Gestalt psychology's laws of perception. These hypothetical laws dictate expected perception of visual information in an organized way. In this design they are employed to visualize the otherwise invisible wireless network. In order to gain insights into the use of Gestalt laws to aid in designs that bridge the virtual and real, a user experiment was conducted. The two designs were compared in order to answer the following research question: Is there a difference in the user constructed mental models between the Interaction Tile and the Nodes design? And if so, what is this difference?

It was expected that the Nodes design would provide users with a mental model that more accurately resembles the underlying structure of the network, compared to the Interaction Tile. The Nodes design places physical objects that suggest the real architecture of the system directly in the environment. This allows users to perceive the network, as it exists within the context, without requiring users to take a large step in semantic abstraction.

## 2 Design

Both designs presented in the research are designed to allow users to explore, make and break wireless connections between media devices in a smart home environment.

### 2.1 Interaction Tile

The Interaction Tile [10] allows users to explore, make and break connections between devices in the smart home environment. It revolves around a high level of semantic abstraction, based on icons that represent

the devices in the environment. The design (see Fig. 1) is based around a central, cube-like object – the Interaction Tile. The Interaction Tile features 4 LED lights that provide feedback to the user about possible as well as active connections. Smaller, cube-like objects each represent a device in the living room. An icon on top of the small cubes communicates what device they represent.
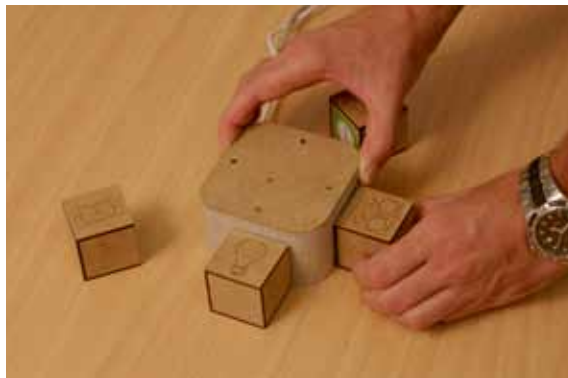


**Fig. 1. Interaction Tile.**

When an object is placed next to the tile, the lights give immediate feedback when the object is recognized (Fig. 2c). When multiple objects are placed near the interaction tile, it immediately shows the connection possibilities (feed forward) through lighting colour and dynamics. The lights' colour coding is simple and straightforward. Red colour means no connection and no connection possibility (Fig. 2d); green colour means there is an existing connection between the devices present (Fig. 2a/e) and green pulsing means that a connection is possible (Fig. 2b). To indicate that the interaction tile did sense the first object a user places near, it shows a red colour at the side the object was detected (Fig. 2c). By placing a second, third and fourth object, the interaction tile shows the lighting effect corresponding to their connection capabilities. By simply picking up the tile and shaking it, the user can make or break the connection between the devices present at the interaction tile. The result of this action depends on the connection's current state, and the devices present; if the tile shows a connection possibility, the action will result in a connection event. The same action performed when the tile shows an existing connection will break the connection.

We rely on the symbolic meaning of colour – green colour meaning "proceed" and red meaning the
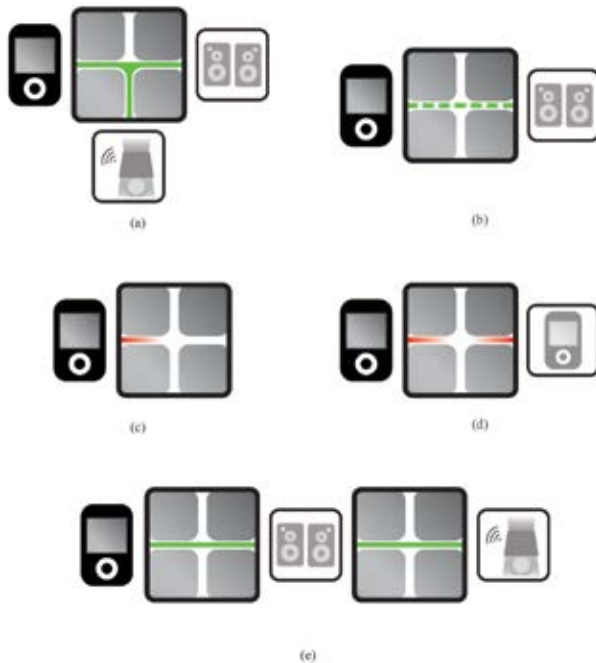
**Fig. 2. Meanings of lighting colour and dynamics.**

opposite. Using the association of solid colour and pulsing colour (indicated with solid and dashed lines) we aim to refer to the "existence" of something and the "possibility" of something. This something is a connection, being invisible but with noticeable results (functional feedback; i.e. the sound of music out of a loudspeaker that you just connected to your MP3 player). We rely on iconic representation for the cube-like objects representing a stationary non-mobile device, and on meaning resulting from direct manipulation of these objects we just described (representing other objects). People seem to be able to work with all these

different (in fact rather complex) relationships at the same time, and our expectation is that we need the richness of all these mechanisms to successfully interact with our complex environments and the envisioned smart environments of the future.

## 2.2 Nodes

While the Interaction Tile is a centralized design – the connections are made by interacting with a central device, irrespective of the location of the actual devices being connected – the rationale with the Nodes design was to explore a different approach to allow users to understand and manage connections between devices in the same context. As opposed to a centralized solution such as the Interaction Tile, which abstracts the net-work and takes the connections out of their context, the Nodes design is distributed and localized.

The Nodes design revolves around physical objects that represent nodes within the virtual network. The physical nodes are small circular platforms that are distributed in the environment, meaning they are placed close to or onto the actual devices a user wants to connect. Placing the nodes near devices does not yet establish the connections between the devices. To establish connections, users need to determine the start and end points of connections between the nodes. These are determined by placing flat shapes that resemble an arrow (start point) or negative arrow (end point) vertically onto the nodes. (Fig. 3) By aiming a start point on one node directly at the end point of another node, the connection between two nodes is visualized and established (Fig. 4).



**Fig. 3. Placing a Node on a device (left), placing a network start point on a Node (middle) and placing a network end point on a Node (right).**
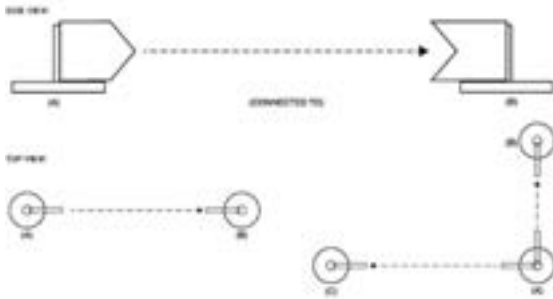
**Fig. 4.** The side view shows how to aim the Nodes to connect device A to device B. The top view shows two networks: one in which device A is connected to device B, and another in which A is connected to both devices B and C.

The Nodes design is based on laws of prägnanz, the main principle in Gestalt psychology. Gestalt psychology revolves around the principle that the human mind is holistic and that it has self-organizing tendencies in its perception [11]. The laws of prägnanz (Fig. 5) are a set of hypothetical laws that allow for prediction as to how visual information is grouped according to certain characteristics. Specifically, the Nodes design builds upon the Law of Closure: The mind has a tendency to complete incomplete forms, effectively seeing something for which it does not receive stimuli. In this design, this principle is used to visualize something that is invisible (the virtual network) through physical objects that represent parts of it (the nodes and start/end points). The design also employs other prägnanz laws:

– The Law of Proximity – objects that are close to one another are perceived to belong together. Used in the design to communicate a node belonging to a specific device.
– The Law of Similarity – objects that are similar in form are perceived to belong together. Used in the design to communicate the nodes belonging to each other and form networks.
– Law of Good Continuation – the mind continues visual patterns. Used in the design to communicate connections that cross one another.

## 3 Evaluation

A user experiment was designed to answer the research question proposed earlier in this article. The experiment was set up to collect data about differences in participants' mental models, when presented with two design
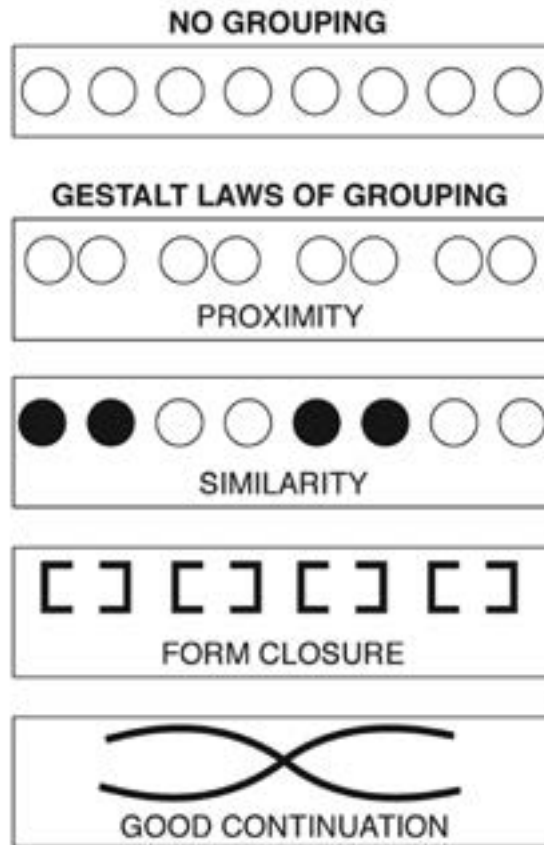


**Fig. 5.** Examples of the Gestalt laws of prägnanz.

solutions to create networks of devices in a smart living room environment. Two pilot tests were conducted to identify and repair problems concerning the set-up of the experiment.

### 3.1 Participants

Fifteen participants in the target demographic of 45+ were recruited. This demographic was used in order to gain insights into the mental models of users that are expected to be less familiar with the networking of interactive products than generations that grew up with such technologies emerging. In total, eight females and seven males were recruited. All participants indicated that they use multiple electronic products with varying regularity. The educational background for the participants ranged from low to high.

### 3.2 Experiment Design

A within-subjects design was used. We employed the Teach-Back Protocol [12], an established technique that allows researchers to gain insights into the mental

models constructed by users. Because users' mental models consist of both semantic and procedural knowledge about the system they are interacting with, teach-back questions can be subdivided into "what is?" questions focusing on semantic knowledge, and "how to?" questions focusing on procedural knowledge [12]. Using such questions, adjusted to our specific situation and research goal, we aimed to extract the semantic and procedural concepts that are relevant for our users. Participants were asked to explain to an imaginary peer what they thought the system was and was for, including listing all the components and the relationships and connections between the components they thought made up the system. By asking the participants to explain to an imaginary peer how to perform a specific task with the system, we aimed to get insights into how well the participants understood the necessary steps and devices involved to achieve their goal.

To support and communicate their answers to both types of questions to the researchers and for recording purposes, participants were asked to make drawings, schematics or use a textual representation. The data was collected by examining the drawings and descriptions made by participants, as well as from observations and recordings made by the moderator. In the post-test discussion, participants were asked for their feedback and preferences for the two designs.

Video prototypes [13] were used to convey the inter-action and functionality of both designs to participants, using the exact same usage scenario. Video prototypes allow the researcher to have much more control over the behaviour of the system, minimizing the interference of prototyping design flaws or technical instability of the networked devices and networks formed.

The use of video prototypes instead of real prototypes influences the construction of mental models by the participants, as humans learn differently when seeing as opposed to doing. To minimize this difference, an adaptation to the Teach-Back Protocol was implemented: Users interacted with cardboard models of the designs to act out their use of the systems within context and were asked to vocalize their thoughts and ideas during this step. This stimulates users to form their own mental models despite the lack of functionality in the cardboard prototypes.

## 3.3 Materials
The following materials were used in the experiment:

- video prototype of the Interaction Tile design
- video prototype of the Nodes design
- laptop computer to present the video prototypes to participants
- non-functioning model of the Interaction Tile design
- non-functioning model of the Nodes design
- digital camera mounted on a tripod to record the experiment
- six non-functioning devices that represented the devices in the scenario (a VCR, a TV, an ambient light that reacts to sound, a set of speakers, a CD-player and a small radio)
- a voice recorder to record audio during the experiment.

## 3.4 Procedure
The experiment was conducted in a controlled environment. An entertainment room at a residence was furnished to resemble a living room, the context in which both designs would be used. Participants were presented with a video prototype of the design and asked to complete a number of task scenarios (see next section) using cardboard models as well as writing and drawing. To emulate the spatial dimension of the Nodes design, the six devices used in the task descriptions were positioned in the environment. The devices were turned off and to avoid unnecessary confusion they were clearly marked. The moderator sat next to the participants while conducting the session. The moderator welcomed the participants, introduced them to the experiment, supported the video prototypes with an explanation and led the participant through the two test cycles. The moderator took notes on the behaviour and comments of participants, answered participants' questions and asked follow-up questions relating to observations and problems that arose during the test. Every session was recorded from a wide angle using a video camera and the audio was recorded using a separate audio recorder. The moderator led the session and made notes.

*Tasks.* Eight different tasks were created for the experiment:
- Connect the CD player and the speakers: The music from the CD plays back on the speakers.
- Connect the radio and the speakers: The music from the radio plays back on the speakers.
- Connect the CD player, the speakers and the ambient light: The music from the CD-player plays back on the

speakers and the ambient light responds to the music.

- Connect the CD player, the speakers, the TV and the ambient light: The music from the CD player plays back on the speakers, and the TV screen and the ambient light respond to the music.
- Connect the CD player, the speakers and the TV: The music from the CD player plays back on the speakers and the TV screen responds to the music.
- Connect the TV and VCR. Also connect the CD player and the speakers: The VCR plays back on the TV. The music from the CD player plays back on the speakers.
- Connect the TV, the VCR, the speakers and the ambient light: The VCR plays back on the TV, the sound from the VCR plays back on the speakers, and the ambient light responds to the sound.
- Connect the radio, the speakers and the ambient light: The sound from the radio plays back on the speakers, and the ambient light responds to the sound.

Every participant was asked to perform all of the tasks in an order that was randomized for each participant. Each task was presented on a card, allowing users to review the task if necessary. In addition to a simple description of the devices to be connected, the card also communicated the connections in context (i.e. the music from the CD player plays back on the speakers), in order to facilitate the participants' understanding of the type of connections needed and their purpose. Participants were divided into two groups. One group started the test using the Interaction Tile design, after which they repeated the cycle for the Nodes design. The other group went through the procedure in the reversed order. After an introduction to the experiment, participants were asked to read and sign an informed consent form, and to fill in a short pre-test questionnaire. The pre-test questionnaire aimed to gain general demographic and background data from the participant, including some general insights into their use of electronic products.

Participants were first presented with a video prototype of the design. This video prototype showed a user making and breaking connections between devices using the respective designs. In the videos, the designs appear to be fully functional. Both video prototypes involved the same person, in the same context and managing the same connections. The participant was then asked to use cardboard models of the design to manage connections for two of the task scenarios. The

participant was asked to think out loud and explain what they were doing and why, including how they expected the system to respond to their actions.

Then, employing the Teach-Back Protocol, participants were asked to write down a short general description of the design they were using, as well as to explain to an invisible friend how they conceptualized the connections in two of the tasks, using drawings. This procedure was repeated for the other design. Finally, the participants were asked for anything they would like to share about either of the designs and their preferences, and the moderator followed up on problems or observations. This post-test discussion ended with a short debriefing by the moderator.

## 4 Results

The collected data was transferred to small cards and analyzed using the Affinity Diagram method. Cards were clustered based on their relation to each other, resulting in three categories of interest, presented in the Discussion. The results of each technique are described in the following sections.

### 4.1 Acting Out

While using the Interaction Tile, three users forgot to shake the tile, a required action to establish a connection between the devices which icons have been aligned with the tile. Instead, they assumed that simply placing the icons next to the tile would establish a connection. This had no substantial influence on the mental models of the participants, as they still perceived a network to be formed, and were able to explain how they viewed the network. The meaning of the icons also confused some participants while they were using the tile. This did not influence their mental models of the network, as their perception of the network and the devices in it remained the same.

Using the Nodes design, five out of the 15 users made mistakes in their use of sender/receiver combinations (e.g. making a connection by pointing two senders at each other, as opposed to a sender and receiver). Ten participants succeeded in using the right combination of senders and receivers consistently. Two participants quickly recovered from this initial mistake. One participant realized his mistake as he attempted to describe the system. Two participants did not realize their mistake of not using the sender/receiver forms. One of them only used senders to connect devices.

All participants understood the importance of aiming two senders or receivers at different nodes towards each other. One participant placed two nodes at the same device to establish connection to two other devices, but this did not influence her perception of the network and connected devices. The 14 other participants placed the correct number of nodes at the correct devices (one for each device). About half of the participants required a few moments to decide what nodes were required to send and what nodes were required to receive. The other half was able to decide instantly.

Two participants were unsure about the placement of nodes relative to the device, i.e. whether they should be on top of the device or whether they could also be in front of the device. Most participants placed the nodes in front of the device, while some mixed nodes on top of and in front of the devices. None of the participants expressed worries about height difference in placement of the nodes.

Participants were observed to create similar networks in different ways. For example, when performing a task scenario that involved connecting an ambient light that reacted to music, some participants connected the light to the source of the audio (CD player, radio), but most connected it to the speakers that made the audio from the source audible.

## 4.2 Description

Roughly half of the participants expressed that they found it difficult to write down a short general description of the designs. Two participants were only able to describe one system (the one only Nodes, the one only Interaction Tile) and two participants were unable to write a description at all. When participants were observed to become uncomfortable by their inability to describe the system, the moderator skipped this step. For the Interaction Tile, almost all participants described a central entity that is used to connect everything, and which automates the establishing of connections. For the Nodes, almost all participants referenced the existence of two elements: a sender and a receiver.

## 4.3 Teach-back Protocol

All participants were able to use a drawing to explain how they perceive the connections in a certain scenario using a particular design.

Concerning the Interaction Tile design, almost all participants clearly indicated all connections to be mediated by the central entity. They perceived all devices as being connected to the central unit, and that this central unit managed the connections for them. Two participants thought the central unit managed the connections through instructing the main device in the network to form connections to other devices by itself. One participant described the connections as moving around the central unit; i.e. every device connecting directly to another, unmediated by the central unit. This participant did not realize the underlying necessity for some kind of connection to exist between the devices and the Interaction Tile in order for it to be able to instruct devices to form connections. Despite some participants making mistakes in their use of sender/receiver elements in the acting out tasks, all participants implemented this differentiation correctly and consistently in their drawn explanations of connections in the Nodes design.

## 4.4 Post-test Discussion

During the post-test discussion, some participants expressed that they wondered what was happening inside the Interaction Tile. They perceived it as being automated. One participant explained that he found it difficult to understand the system because he was unaware of what happened inside the Interaction Tile.

## 5 Discussion

The study aimed to determine whether users' mental models differ between the Interaction Tile and Nodes design, and what exactly this difference is. It was expected that the Nodes design provides users with a mental model that is more accurate towards the actual architecture of the system than that of the mental model created when using the Interaction Tile. Analyzing the data using Affinity Diagrams, three categories of results emerged from the data. The three categories mirrored each other across the two designs, and were merged to contrast the differences between the two designs:

## 5.1 On Mental Models

For the Interaction Tile, almost all written descriptions of the system by the participants revolved around a central device that is connected to all devices and manages the connections automatically. Participants

often referred to the Interaction Tile as the "central unit", "the interface to all devices" or "a magic box". Almost all participants also indicated in their drawings (see Fig. 6) that they perceived all connections to go through the Interaction Tile, where the Interaction Tile "did something" to the signals and created the network. This leads to the conclusion that the Interaction Tile system creates a mental model with a centralized hierarchy; all devices are connected to and controlled by a central object, the Interaction Tile.

For the Nodes design, almost all participants wrote about "senders and receivers" to make connections, and placement of nodes near devices that need to be connected to determine the content of the network. In their drawings, all participants created hierarchical connections between devices, where some devices send data and others receive it (see Fig. 7). Participants created different mental models of the same type of networks, and were able to adapt the use of the system to fit their mental model without compromising the functionality of the network. For example, in a network of three devices, music from a CD player plays on the speakers and an ambient light responds to the music. Most participants directed the signal from the CD player to a receiver on the speakers, and relayed the signal from the speakers to a receiver on the light. Some participants sent two signals from the CD player, one towards the speakers and one towards the light. This shows a powerful characteristic of the Nodes design: it supports users in projecting different mental models on the system.

It can be concluded that the results of our study support our hypothesis that the Nodes design provides users with a more accurate mental model towards the actual configuration of the network in the sense that devices are directly connected to each other without the network being mediated by a central unit. However, as the design allows for different mental models to be projected onto it, not every mental model of the Nodes design is exactly the same as the network's real architecture.

## 5.2 On Symbolism and Interaction
For the Interaction Tile, some participants were confused about the meaning of the graphical icons on top of the blocks (i.e. which device was being represented by which icon). Also, participants wondered whether the location of the icons relative to each other
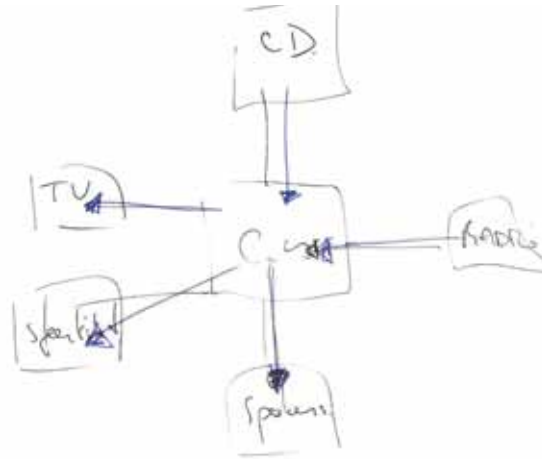


**Fig. 6. A typical mental model drawing of the network when using the Interaction Tile: all connections go through a central unit.**



**Fig. 7. A mental model drawing of the perceived network when using the Nodes design: Data is sent from the radio towards the speaker-set, which acts as a relay to an ambient light.**

was important, although they assumed it was not. For the Nodes design, similar problems surfaced. It was difficult for some participants to immediately apply the sending/receiving concept in their acting out tasks, and some did not realize the importance of using the right arrow-shape to send or receive a signal. In their drawings, however, all participants used the sending/receiving principle correctly in explaining connections. This indicates that the system could benefit from a better form design to allow differentiation between the sending and receiving shapes. Furthermore, two participants wondered about whether the location of the nodes relative to the device was important, although they assumed that it only had to be in close proximity. These issues for both the Interaction Tile and Nodes designs are similar and occurred (roughly) equally often and for a minority of the participants. They did not influence the mental models, as these were observed from the Teach-Back Protocol to be consistent for all participants, whether they identified these issues or not. They do however point out important design issues that can be limitations to both systems. This suggests that

further research into the semantics of sign and form in both designs could lead to a better understanding of the interaction required for the device, as well as increased usability.

### 5.3 On Value Judgment

From the observations and post-test discussions, some data concerning the participant's preference for either method surfaced as well. When asked about their opinions on both designs, almost all participants indicated they preferred the Interaction Tile method over the Nodes method.

They described the Interaction Tile method as being very easy to use, as they only had to add icons of the devices and did not need to determine what the role of each device was. The system was perceived as being automated and therefore experienced as the most user-friendly. Furthermore, they liked the fact that they were able to manage the connections without getting up and moving about the space.

Most participants indicated they found the Nodes design easy to understand, but that it required too many actions. Furthermore, some participants indicated that they would not like having to place additional objects in their living room, for which they did not see specific merit. This suggests that although the Nodes design provides a more accurate mental model of the network, this does not necessarily lead to better usability. Further research could explore design directions that merge the merits of the Nodes design (accuracy and clarity of the mental model, flexibility towards different mental models) with those of the Interaction Tile design (ease of use, perceived value).

## 6  Conclusion

The study compared the mental models created by users when using both a centralized and a distributed approach as a tangible interface for configuring networks of devices. A clear difference has been found in the way users perceive the network and suggests some speculation as to how this could impact understanding and usability of such networks.

The success of the Nodes design in allowing users to create and apply mental models to networks suggests that Gestalt laws of prägnanz can be powerful tools in the way in which physical artefacts can acquire meaning in an ecology of objects, and how they can help to bridge the gap between real and virtual worlds.

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# Yeti: Designing geometric tools with interactive programming

## Abstract

Designers scripting geometric tools have had two options: either use an interactive visual script, or forgo interactivity to use a text-based script. Within this paper we consider a third option: interactively writing text-based scripts. Described is an interactive scripting environment created for this purpose, which manages geometry with a Directed Acyclic Graph generated from the text-based relational markup language, YAML. The environment is compared to the two existing scripting options by using them to draw three geometric compositions. We argue it is possible to interactively script geometric tools, and that interactivity is a vital component in making scripting intuitive.

## Keywords

Interactive programming; End-user programming; Design computation; Parametric modelling.

## 1  Introduction

Since Sutherland's digital Sketchpad, designers have aspired to make coding more like sketching. Prior to Sutherland, computer programs were manually executed in 'batches'. The designer would compile the code, define inputs and parameters, run the program and wait – often a long time – for the result. When Sutherland developed Sketchpad in 1963 he sought to overcome the delays in batch processing and allow "man and a computer to converse rapidly." [1]. Sketchpad was one of the first interactive computer programs. It displayed the results of the designer's actions immediately, which facilitated feedback and reflection in a conversation between designer and computer. Almost 50 years after Sketchpad, interactive graphics programs have all but replaced the drawing boards they once imitated. These design programs each offer a prescribed palette of design tools and often afford designers the ability to script their own customised tools. A script defines a list of operations for the computer to carry out. Yet when designers attempt to design their own design tools with scripts, they must once again design using a batch-processed system. This is because scripting in its current form involves writing out a procedural script, pressing compile, setting the inputs for the script, and waiting for the computer to draw the result – like the programs prior to Sutherland. Unlike sketching, or even digital drafting, with scripting there is a pronounced delay between the action of the user (changing the code) and the reaction of the system (redrawing the geometry). Such a delay can slow the pace of iteration in the design process and hinder feedback reaching the designer in a timely manner. Recently a number of scripting languages have emerged for musicians that enable the interactive modification of text-based scripts. Using these interactive programming languages the musician can immediately hear how changes to a script driving a musical performance will sound. These languages appear to be a viable method

for achieving a similar level of interactivity in geometric design. However, as will be outlined in this paper, the emphasis musicians place on tempo and timing makes their techniques unsuitable for the computationally intensive task of generating geometry.

With no existing interactive scripting tools for describing geometry, this research seeks to better understand the technical and cultural limits of designing geometry with interactive scripts. This paper begins with an outline of an interactive scripting technique that overcomes some of the computational impediments associated with the interactive scripting of geometric tools. 'Yeti' is an interactive scripting environment developed to utilise this technique, the implementation details of which are explained in this paper. Using a reflective practice methodology, Yeti is tested in a pilot study by applying it to three geometric design problems and comparing its performance to that of non-interactive text-based scripts and interactive visual scripts. The three design problems are taken from an architectural context, although it is anticipated this research will be of interest to designers outside the field of architecture, particularly those describing geometry with their own scripted design tools or parametric models. The paper begins by describing some of the existing scripting environments designers utilise.

## 2 Existing Design Scripting Methods

A script defines a list of actions for the computer to carry out. In contemporary usage, scripting is essentially synonymous with programming. As such a script can automate tasks that would otherwise be performed through the user interface and it can also define entirely new actions. For designers the primary motivations to script are: productivity (doing tasks that would take too long otherwise), and control (linking various actions together to create customised tools) [2]. Design software packages often encourage scripting through inbuilt scripting interfaces, and there are also applications (like Processing) that are created explicitly as standalone scripting interfaces for designers. With design increasingly being conducted on computers, so too scripting has increasingly become a way for designers to automate and control the design process. To run a script, the computer generally has to interpret (or compile) the script into a machine-readable set of instructions. This is supported in scripting interfaces through an 'Edit-Interpret-Run' loop, whereby the

designer edits the text of the script, presses a button to activate the script, and waits first as the computer validates the script, then waits as the computer interprets the script into a machine-readable set of instructions and finally waits as the computer runs this set of instructions. The notable exception is some visual programming languages, like Max-MSP, which will be discussed in the subsequent section. As a consequence of the Edit-Interpret-Run loop, there is a pronounced delay between the action of the user (editing the script) and the reaction of the system (redrawing the geometry). This delay impacts the rate of iteration since each variation of the script the designer tests goes through the Edit-Interpret-Run loop, often with the designer manually deleting the geometry of the previous loop between iterations.

## 3 Interactive Scripting

Interactive programming (also known as live-programming) is a method for editing and interpreting scripts while they run. To the end user there appears to be no Edit-Interpret-Run loop because any edit they make is automatically incorporated with the already running instance of the script. Behind the scenes there is still an Edit-Interpret-Run loop, where the computer automatically interprets an edit and in real-time invisibly transitions the running instance of the script to the new edited version. The net effect is that the end-user can experience in real-time the consequences of editing a script – closing the gap between action and reaction. The crux of creating an interactive programming environment is smoothly transitioning a running script between different versions of the script. The most obvious method is to abandon the currently running script whenever it is edited, and automatically interpret and run the updated version of the script. For certain applications, such as SimpleLiveCoding for Processing [3], this is effective. However for the computationally taxing task of drawing geometry this is less desirable since it involves abandoning all the previous calculations and recalculating the geometry every-time the script is modified, even if the modification only changed a small and discrete part of the geometry. The method typically employed in interactive debugging is to maintain the state of the code – through a call stack – allowing the code to be rewound to the site of the edit [4], however all subsequent code still needs to be recalculated, even if it is not affected by the modification.

Perhaps one of the most developed systems for transitioning scripts has been developed by musicians, for whom interactive programming allows modification of scripts driving a musical composition while immediately experiencing the sonic implications. The first performance with an interactive script was by Ron Kuivila at STEIM in 1985 [5]. In 2000, Supercollider led a revival of text-based interactive programming for musicians, and was followed by a number of similar languages like ClanK and Impromptu. All of these languages share in common the need from musicians to invoke actions relative to an underlying time signature. Typically this occurs through scheduling a reoccurring sequence of actions to be performed, and whenever the script is modified, adding the modified actions to the queue [6]. These musical environments have been adapted to generate geometry but the repetitive cycling of actions makes it unsuitable for generating anything other than basic geometry [7].

Therefore despite the scattered implementations of interactive programming, few – if any – are suitable for the unique challenges designers face when shaping geometry with scripts. Designers desiring the interactive feedback of sketching while they script currently have to make do with Edit-Interpret-Run loops. This is primarily due to the difficulty of editing and updating an already running script while handling the computational intensity of geometric calculations.

## 4 Introducing Yeti

The problem of editing a script while it runs geometric calculations has been elegantly overcome by the interactive visual scripting environments GrasshopperTM, HoudiniTM and Generative ComponentsTM. These three environments use Directed Acyclic Graphs (DAG) to represent relationships between geometry [8]. A relationship may be that a line is tangent to a circle (the circle is a parent of the line) and whenever the circle is adjusted, the line moves to satisfy the tangential relationship. From these geometric relationships the dependencies of the geometry can be extracted. Thus when part of the DAG is edited, the only recalculation required is to the geometry dependent (and therefore affected) by the edited part of the DAG [8]. Since a node within the DAG is directly associated with the geometry it creates, the node can manage the creation and deletion of geometry without the designer needing to remove old instances of the geometry. The DAG

is defined through visual interfaces in Grasshopper, Houdini and Generative Components. Text-based scripts within these environments cannot not be interactively edited and still use the Edit-Interpret-Run loop. Yeti is a text-based interactive scripting environment developed for the interactive creation of geometric tools. Yeti uses a DAG to manage the editing and calculation of geometry, but the DAG is defined through a text-based script rather than the visual interfaces used by Grasshopper, Houdini and Generative Components. The language of Yeti's script is based on the relational mark-up language YAML [9]. The syntax consists of 'key: value' pairs, where the key is assigned the value to the right (the 'x:' in Table 1, has a value of −10). More complex values can be assigned through a list of 'key: value' pairs, separated from the parent key with indentation (the 'point:' in Table 1, has been assigned 'key: value' pairs for x, y & z). Relationships are defined by naming keys (names start with the '&') and referencing them as a value (references start with the '*').
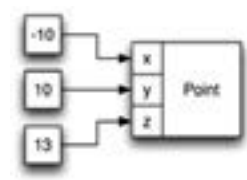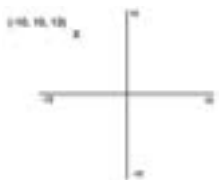
| Yeti (YAML) | Directed Acyclic Graph | Geometry |
|---|---|---|
| point:<br>››x: −10<br>››y: 10<br>››z: 13 |  |  |

Table 1. **A simple Yeti script in YAML (left) and the corresponding DAG (centre) with the geometry it produces (right). Note all keys in the Yeti script map directly to nodes in the DAG.**

The advantage of using YAML is that the 'key: value' pairs map directly into a Directed Acyclic Graph, where the key defines a node and the value defines either: the property of the node, or its relationship to other nodes (see Table 1). Whenever a script is modified in Yeti, the underlying DAG is automatically updated in the following process:

1. The edited script is tokenised into keys and values.
2. For every key, a corresponding node is generated in the DAG.
3. The node is assigned properties and related to other nodes based on the values assigned to the corresponding key.

4. Once the DAG is created, all nodes dependent upon deleted, added or modified nodes are recalculated, creating a new instance of the geometry.

In addition to interactive editing of running scripts, the YAML language and underlying DAG enable a number of unique features in Yeti:

- *Error handling*: The interpretation of code while it is being written frequently causes errors because the computer is often unable to resolve the ambiguity of partly written code. Yeti interprets and run scripts with errors by ignoring 'key: value' pairs with errors in them. Typically errors cannot be ignored in other languages because it interrupts the top-to-bottom progression of logic.
- *Interactive debugging*: Clicking a key in the code highlights the geometry controlled by the key. This helps clarify the often-enigmatic connection between code and geometry that characterises scripting. Yeti is able to do this because keys in the script are directly associated with parts of the model's geometry via nodes in the DAG.
- *Instancing of objects:* The YAML language can be extended to include new keys. The user does this by creating a prototype object for the key through a list of 'key: value' pairs. When the new key is used in the script, a new instance of the prototype object is created and modified for the unique properties of that object instance. This is a common feature in text-based scripts but one that visual scripts often do not support.

| Python | Yeti (YAML) |
|---|---|
| P1 = Rhino.Geometry.Point3d(0,10,13)<br>P2 = Rhino.Geometry.Point3d(P1.X, P1.Y+20,0)<br>myLine = Rhino.Geometry.Line(P1,p2)<br>doc = Rhino.RhinoDoc.ActiveDoc<br>doc.Objects.AddLine(myLine) | line: &myLine<br>start: &p1<br>x: 0<br>y: 10<br>z: 13<br>end: &p2<br>x: *p1.x<br>y: (*p1.y + 20) |

**Table 2. Comparison of scripts to draw the same constrained line in Rhino Python and Yeti.**

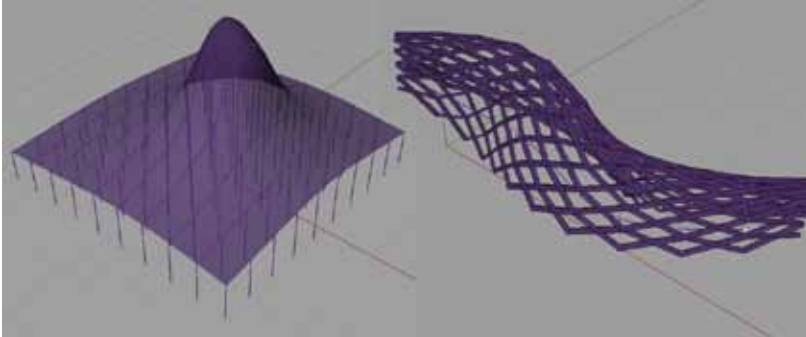YAML also has its drawbacks. The definition of geometric properties and relationships in YAML is a significantly different method of scripting compared to the ordered list of procedural actions familiar to many scripters (the two paradigms are compared in Table 2). Similarly the recursion offered in procedural languages is not yet possible in Yeti due to the difficulty of representing recursion in a DAG. For this reason Yeti is not Turing-complete, and therefore unsuitable for certain operations like L-systems and cellular automata. Despite these quirks and limitations, YAML and the underlying DAG is fundamental to empowering the interactive scripting of geometric calculations, along with a number of other advantages like interactive debugging and error handling.

## 5 Designing Geometry with Interactive Scripts

### 5.1 Method
To explore the viability of interactively generating geometric tools with text-based scripts, we carried out three design projects with the iterative scripting environment Yeti (version 0.3). As a benchmark we repeated the work with two established methods of scripting: interactive visual scripting in Grasshopper (version 0.8.0052), and text-based scripting with Rhino Python (In Rhino5, version 2011-11-08). The three design problems have an architectural bias but the focus of the analysis is towards the shaping of geometry and designers who do so already through scripting or parametric modelling. Since this is the first time interactive scripting has applied in this context, the investigation is a pilot study designed to identify the major issues with interactive scripting in anticipation of refining Yeti further. The three projects used in the study are:

*Project 1 & 2: Axel Kilian's Roofs*
Axel Kilian developed a pair of tutorials in 2005 to teach the then highly experiential visual scripting software, Generative Components. The tutorials demonstrate how to developed a customised geometric tool with scripting and introduce "several key parametric modelling concepts," such as: geometric constraints, data arrays, modularity, and aggregate difference from topological similarity [10]. These two roofs form an interesting benchmark, both because they employ essential scripting techniques, and because they hold some historic credence with which it is possible to track the development of parametric modelling.

**Fig. 2. Project one in Yeti (left) the more complicated project two in Yeti (right).**
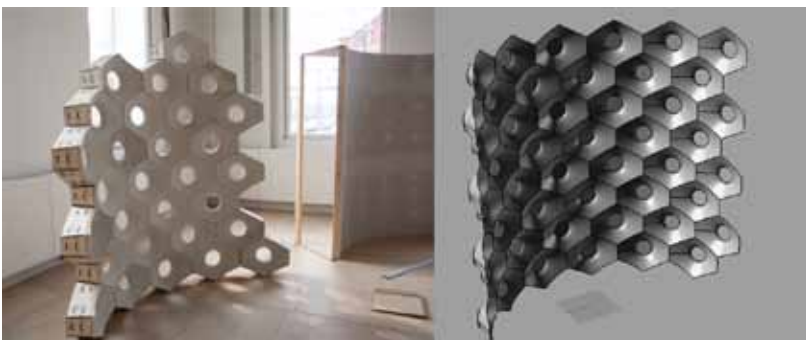


**Fig. 3. Full-scale prototype at Smart Geometry (left) and associated digital model (right).**

*Project 3: Smart Geometry 2011*

As part of the Responsive Acoustic Surfaces workshop at Smart Geometry 2011, two acoustic walls were developed to test the sound scattering of various plaster hyperboloid tile configurations [11]. Originally the wall was designed with the interactive visual scripting environment Grasshopper, used alongside Digital Project and Open Cascade. From the workshop it is known the project pushes the limits of interactive design through the computationally expensive calculation of the hyperboloid intersections, where very subtle nuances in the planarity of the intersections determine the project's viability.

5.2 Differences between scripting environments

The following section broadly describes the main differences between the three scripting environments, with a focus on the technical capacity of each environment.

*Geometric output.* The geometric library for Yeti is still being developed but it was capable of creating the geometry of the Kilian Roofs and creating the geometry of the hyperboloid wall, as was Grasshopper and Python. In all the environments the most challenging geometric task was to encode the reasoning for which side of the hyperboloid intersection to keep in project three. The difficulty of expressing this indicates that

certain types of architecture are more amenable than others to the logic of scripting, a logic Yeti follows.

*Script length.* The number of lines of code in the Yeti scripts were essentially identical to the Python scripts, although the lines of the Yeti scripts tended to be sparser containing just ten characters on average, whereas the lines in Python contained 25 characters on average. The Grasshopper schemas are not directly comparable to text-based scripts, but it should be noted that the interface for Grasshopper did many of the tasks that needed to be explicitly defined in the Python and Yeti scripts, such as making geometry visible. In the Python scripts, significantly more of the script was involved with managing arrays of data, but in Grasshopper and Yeti arrays of data were resolved by the software rather than the user [12].

*Speed of execution.* Yeti remained responsive throughout the two roof projects. On the more complex roof an update cycle typically took 100ms, which was faster than one can type. This is comparable to Grasshopper and faster than the Python script, which took 2 seconds to execute (Python's biggest hindrance seems to be the way it draws geometry). The intersections in the geometry of the hyperboloid wall were too complex to calculate in real-time with either Grasshopper or Yeti. It was only possible to complete the project by disabling the interactivity and reverting back to the manual Edit-

Interpret-Run loop employed by scripts like Python. While interactive programming is useful on simple projects, batch-processing is still a useful paradigm to grind out computationally expensive geometry and a useful paradigm for Yeti to fall back on.

### 5.3 Discussion: Intuition and Interactivity

In creating Sketchpad, Sutherland not only created the first interactive CAD tool but also one of the first programs to "eliminate typed statements (except for legends) in favor of line drawings" [1]. Sutherland described controlling a computer with text as "writing letters to rather than conferring with our computers" [1]. It is an argument about whether designers find interactive drawing more intuitive than writing code. In the past 50 years, despite the increasing prevalence of scripting, overwhelmingly CAD software consists of interactive visual interfaces activated with mouse and keyboard shortcuts.

However for certain types of geometry, like the geometry in the three projects above, scripting is the only method of productively generating and controlling the geometry. For these projects designers have no option but to 'write letters' to the computer sent via the Edit-Interpret-Run loop. In writing these letters, some of the intuitiveness is bound to the language it is written in. The scripts from Python and Yeti, while of a similar length, are strikingly different in approach (See Table 2) the Python scripts methodically working through a list of actions while the Yeti scripts begin with the outcome and describe the necessary parameters. For this reason Yeti may seem unintuitive to designers already conversant with procedural scripting languages like Python [12]. Whether users new to scripting experience this difference in intuition remains to be studied. Another factor in the intuitiveness of letters written to the computer is the speed they are returned. In carrying out the three projects above, it is clear intuition and interactivity are tightly coupled. Being able to click on words in the Yeti script and see the geometry they control highlighted, helps clarify their purpose. Similarly being able to edit a parameter and instantly see the geometry respond, makes manipulating the parameters feel more intuitive.

While writing code often feels like 'writing letters', the three projects above begin to uncover how interactivity can make scripting a more conversant and therefore intuitive experience. It remains to be seen if the advantages interactivity brings are enough to overcome the hindrances of needing to use a language like YAML. The cultural implications of such a change could be profound, particularly if scripting became intuitive enough to use on projects other than those that can only be productively generated and controlled with scripts.

## 6 Conclusion

Sutherland's digital Sketchpad placed interactivity at the foundation of digital design. When scripting designers have had two options: either use an interactive visual script, or forgo interactivity in favour of writing the script with text. This paper has articulated a third option: writing a text-based script in an interactive programming environment. Significantly this research has demonstrated it is possible to interactively program computationally-intensive geometric tools. This can be achieved by managing the geometry with a Directed Acyclic Graph, which can be generated from a text-based relational markup language like YAML. The mark-up language used to attain the performance necessary for interactive scripting may seem unusual compared to the conventions of established methods of design scripting, however there is a real benefit to being able to instantly see how a change to the script will affect the model's geometry. In the future interactive programming may make the act of writing code as responsive for designers as the act of sketching in a Sketchpad.

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# Towards a responsive architectural morphing skin

## Abstract

The typical application of responsive architecture is in the facade or skin of a building with mechanical joints actuating the kinetic transformation. This paper investigates the unexplored 'soft' approach using lightweight elastic form-changing materials provides an opportunity for designing responsive Architectural Morphing Skin (AMS). This idea is inspired by the current morphing technologies of aerospace engineering especially in the area of morphing wing research. The research aims to develop a method for designing an AMS with a passive and active design strategy to minimise mechanical operation and reduce weight. Using a practice-based methodology, an AMS prototype is generated through a development process namely soft kinetic system (SKS). AMS serves as a 'second skin' brise-soleil in the form of a canopy to an existing courtyard space. It responds in real-time to environmental stimuli to address two fundamental criteria: comfort and visual.

## Keywords

Kinetic, responsive, elastic, form-changing materials, morphing skin.

## 1  Introduction

Architecture has typically resisted kinetic motions, however, the technological advancement for designing dynamic screens and animated surfaces are new opportunities for designers and architects [1]. Precedents in these architectural approaches often involve the design of kinetic skins that are transformable. These architectural skins also provide a screen between people and the natural environment, offer rich possibilities for visual expression and new architectural vocabulary [2]. This design approach has been explored since the 1960s, with one of the first examples being the responsive brise-soleil of LA County Hall of Records designed by Richard Neutra in 1962 [3]. However, the design of such kinetic skins often includes complicated, intricate and heavy mechanistic elements such as joints, actuators and control system for dynamic responsiveness. The kinetic skin of L'Institut du Monde Arabe in Paris designed by French architect Jean Nouvel in 1987 is a salient example of this approach [4]. These solutions involving conventional mechanical components like multiple pistons to actuate transformation require designers to deal with high energy costs and complex mechanisms. Those piston components were found to be prone to fatigue-failure, causing gasket leakage from the piston [5]. This approach often produces brittle and vulnerable kinetic systems. Thus, the reliability and longevity of the system is the main hindrance for kinetic architectural skin to be a mainstream approach in architectural design. In this paper we investigate how to design kinetic architectural skins with fewer mechanical operations and explore the potential for elastic and form-changing materials to be used as an alternative

approach to designing responsive kinetic skins. This research investigates beyond the conventional mechanical kinetic skin approach by exploring the 'soft', lightweight, flexible and form-changing materials for responsive kinetic architectural skins.

Current projects intend to investigate the 'softness' of the kinetic architectural skin in various attempts. The recently completed Media-ICT building designed by Cloud 9 Architects in Barcelona demonstrated the energy efficiency and implementation of the 'soft' approach to kinetic architectural skin. The complex façade made of ETFE is responsive to user necessity. The ETFE skin protects the interior when there is too much direct sunlight. When light is needed it opens itself to let the daylight in [6]. This pneumatic kinetic shading device sets an early inspiration to conduct this research work; however, further investigation is needed especially in terms of air ventilation and shadow casting. Other relevant projects such as 'Kukkia' and 'Vilkas' designed by Joanna Berzowska and Marcelo Coelho, investigated the 'soft' approach of kinetic electronic garments that integrate the Nitinol and custom control electronics to move and change on the body in slow, organic motion [7]. Coelho further explores this idea in the project namely 'Shutter' as a permeable surface for environment control and communication [8]. Although these projects provided an insightful knowledge of using active form-changing materials to design 'soft' kinetic textile skins, further investigation is needed especially in terms of responsiveness, adaptability and scalability of these systems. Although the 'Living Glass' project by David Benjamin and Soo-in Yang integrated the Nitinol actuator and sensor to form a responsive kinetic skin, it focuses on the transformation within the local 'openings' for ventilation purposes [9]. There is an unexplored area for global topological transformation on the entire surface of this project.

This research intends to expend the repertoire of current responsive kinetic skin design by developing an alternative method to integrate form-changing materials with computational processes to design Architectural Morphing Skin (AMS). This project explores the passive and active design strategies for AMS with minimised mechanical actuations. In this context, the proposed concept of Soft Kinetic System (SKS) embodied through a design experiment, called Blind, serves as a second

skin brise-soleil in the form of a canopy to an existing courtyard space that responds in real-time environmental conditions to serve two fundamental purposes: comfort and visual. The main idea behind deploying SKS as a development process for designing AMS is the integration of an exoskeleton structure, and the surface to act as the actual actuator. As an early hypothesis, the elastic nature of these structures is able to accommodate responsive mechanisms with passive elastic memory while minimising the energy and weight required for actuation. This paper aims to explore the passive and active design strategies for responsive AMS through soft kinetic system integrated with parametric design tools. This study describes a new repertoire of responsive architectural morphing skin ideas using accessible 'soft' components such as elastic form-changing materials embedded with contemporary sensor devices. This approach intended to provide alternative methods for designers and architects to design responsive architectural skins.

## 2 Soft Kinetic System

The concept of soft kinetic system (SKS) is inspired by the soft mechanical approaches in aerospace engineering especially morphing wing technology [10]. In the field of engineering, the word morphing is used when referring to continuous shape change that is, no discrete parts are moved relative to each other but one entity deforms upon actuation [11]. For example, on an aircraft wing this could mean that a hinged flap would be replaced by a structure that could transform its surface area and camber without opening gaps in and between itself and the main wing [12]. This concept of morphing skin is an emerging aerospace technology that has influenced aircraft wing design. It has remains unexplored territory in terms of designing responsive kinetic architectural skins.

Soft kinetic system (SKS) does not require mechanical joints, hinges, or motors. The kinetic actuation also takes place in the overall system with the use of form-changing materials and little use of mechanical components. SKS served as the proposed method of inquiry for designing Blind. Table 1 shows SKS included four focus areas, Elasticity, Tensegrity, Form-changing materials and Adaptability for individual component implementation and goal:

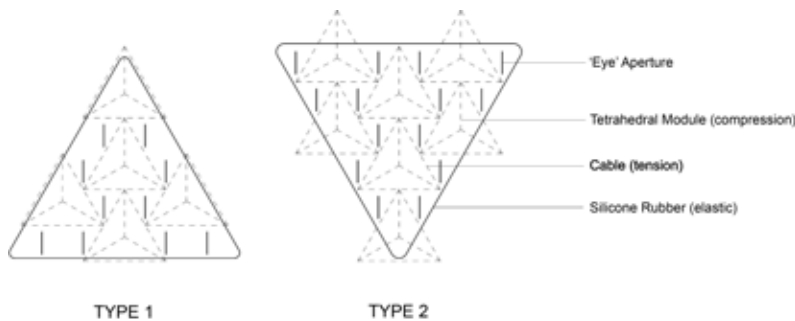| Focus areas | Components | Goal |
|---|---|---|
| Elasticity | Architectural skin | Flexibility |
| Tensegrity | Skeleton | Transformation |
| Form-changing materials | Actuator | Actuation |
| Adaptability | Sensor | Sensing |

Table 1. **Focus areas, components and goal of SKS.**



TYPE 1  TYPE 2

'Eye' Aperture

Tetrahedral Module (compression)

Cable (tension)

Silicone Rubber (elastic)

Fig. 1. **Two different types of triangular skin modules embedded with tensegrity tetrahedral components.**

The first area used elasticity as a design strategy to explore the new possibilities of the flexibility of architectural skin. The most common elastic materials deform when force is applied to them and that deformation is reversed to return to the same state once that force is removed. There is potential energy stored within the material itself that can be harnessed to activate the acceleration back to its original state. This offers potential new forms of flexibility, adaptability and deformation using the memory effect in architectural skins. The second area focused on the tensegrity structural approach that reduces the friction between mechanical joints and achieves a lightweight structure. Due to the interdependent nature of all the elements, a slight change in any of their parameters can result in a significant form transformation [13]. For these reasons the tensegrity skeleton was chosen as part of the SKS and for its flexibility and lightweight components. The third area discussed form-changing materials that by nature dynamic and deformation occur under electrical stimuli to produce expansion and contraction which can harnesses for actuation of the SKS. We proposed shape memory alloys (SMAs) as the active form-changing materials to investigate

the alternative of actuation. The last area explores the adaptability of SKS in order to achieve morphing skins that display elastic properties, able to respond to digital and physical stimuli. This idea is developed using parametric design tools discussed in subsection 3.4.

## 3 Designing a Prototype for Architectural Morphing Skin

In order to implement the soft kinetic system (SKS), this section discusses the design experiment, called Blind, to investigate AMS to exhibit comfort and visual applications. Blind is the multilayer AMS that included four components: Skin, Skeleton, Actuator and Sensor formed by two basic types of triangular modules (Fig.1). Each of the components works to test the implementation of Blind as a responsive AMS. The four-pronged developmental process of SKS: Elasticity, Tensegrity, Form-changing materials and Adaptability as the methods of inquiry for designing Blind, will be discussed in subsections 3.1-3.4.

### 3.1 Elasticity
We explored the flexible performance to the skin of Blind using lightweight elastic material. The elastic material used for this experiment was silicone rubber and it forms the basic non-load bearing membrane surface for the architectural envelope. The elastic nature of this skin is able to accommodate responsive mechanism with passive elastic memory while minimising the energy and weight for actuation [14]. The skin surface of Blind is fabricated using silicone rubber because of its heat resistance and elastic capacity (Fig. 2). In general, silicone rubber offers good resistance to extreme temperatures from -55 to 300 degrees Celsius. Under these extreme temperatures, the properties in terms of the elongation, compression, tear and tensile strength are far superior to conventional soft and elastic materials. Conventional organic rubber has a carbon to carbon backbone which can make it susceptible to UV, heat, ozone and other ageing factors that silicone rubber can withstand [15]. Thus, this heat tolerant material property makes silicone rubber a suitable material to integrate with active form-changing materials (SMAs) to form morphing skin, addressing elasticity and actuation respectively. In addition, the skin itself serves as part of the actuation as well as structural component of the overall modular tensegrity system of Blind (Fig. 3).

**Fig. 2.** Silicone rubber in the mould (left). Laser cutting the openings of 'eye' apertures with embedded SMA wires (middle). RModular silicone skin (right).
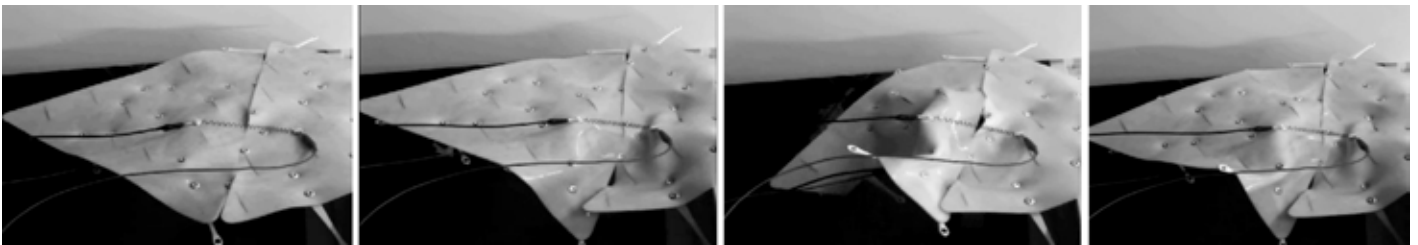


**Fig. 3.** Initial experimentation for elastic silicone rubber skins set as the structural components as well as actuators.
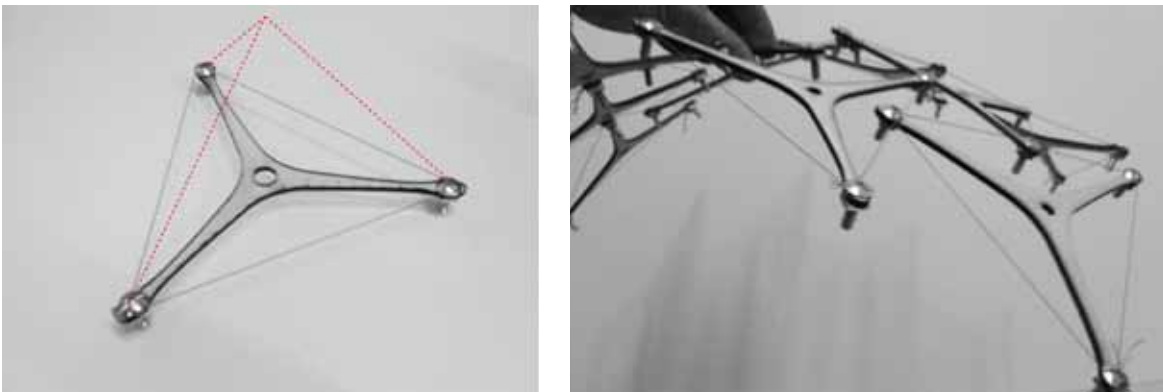


**Fig. 4.** 'Reduced' version of tetrahedral module to minimise weight (left). Tetrahedral modules formed the elastic tensegrity skeleton of Blind (right).
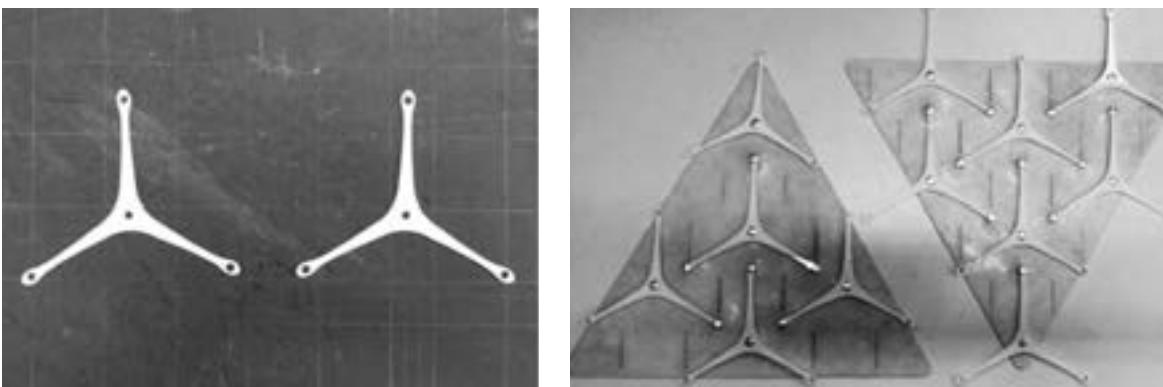


**Fig. 5.** Physical fabrication of Type 1 and 2 tensegrity skin modules.

## 3.2 Tensegrity

The term tensegrity coined by Buckminster Fuller by combining the words tensional and integrity is a structural principle based on the use of isolated components in compression inside a net of continuous tension, in such a way that the compressed members do not touch each other and the pre-stressed tensioned members delineate the system spatiality [16]. This approach provides the structural flexibility that is suitable to implement for the skeleton of Blind. The materials used for assembling this skeleton included using accessible ABS (Acrylonitrile Butadiene Styrene) as a primary lightweight and strong explicit material for a 'reduced' version of tetrahedron. It integrated with stainless steel wire as tension component to fabricate the tensegrity tetrahedral module with reduced components used as exoskeleton structure (Fig. 4).

The elastic silicone rubber embedded with tensegrity tetrahedral modules formed two different types of larger scale modules (Fig. 5). They served as the basic components to fabricate Blind for structural integrity as well as actuation purposes. The integration of the modular tetrahedral skeleton and elastic silicone skin that fabricate the overall continuous surface of Blind in order for transformation to take place.

## 3.3 Form-changing Materials

As a result of comparing multiple form-changing materials, we found that shape memory alloy (SMA) is the most suitable material for designing soft kinetic system (SKS). Although EAPs (Electro Active Polymers) have been used widely in robotic research, EAPs-based actuators are still exhibiting low force below their efficiency limits, are not robust, and are not available as commercial materials for practical application considerations [17]. Furthermore, they require high activation field (>150V/um) close to the breakdown level. Since the 1960s, SMAs have been the most accessible form-changing materials in the present market, and there are many applications in the aerospace and automobile sector [10]. They are commonly used in a wire or spring form that contracts in length when heat is applied. The heating can be done directly via electricity to give electrical actuation. SMAs expand by as much 8% when heated and cooled. When the SMA is below the 'transform' temperature (60 degrees) the material takes on an 'elongated' and

neutral form, but if heated it contracts and returns to the 'memorised' form. This process creates a dynamic range in the way that the SMA wire expands and contracts for various state changes (Fig. 6).



**Fig. 6. Deformation of SMA wire occurred when heated by electric stimuli.**

Ordinary metal alloys have an internal structure that is not altered by small temperature or electric current changes. Electrical stimuli create heat causing the atoms of the metal to vibrate faster and this makes it easier to bend when an external force is applied. The molecular form of the metal is not normally altered by heating. However, form-changing materials such as SMAs are, by nature, dynamic and deformation occurs under electrical stimuli in this experiment, using: 5V for a 3 amp current. There are two stable crystalline states in their structures that are triggered when a temperature change occurs. Thus, SMAs are selected to implement in this research and develop further because of their accessibility, reliability and low electric current usage. This form-changing process produces expansion and contraction that can be harnessed for actuation of the whole kinetic system.

Figure 7 shows four potential profiles for 'Soft' actuation based on the process of expansion and contraction in specific parts of the SMA wire (Fig. 7). While profile one and two show the potential for the pull and push actuation, profile three and four functioned as the spring system that can actuate greater distance and force. They demonstrate that an alternative actuation system can be embedded in the overall tensegrity structure discussed in subsection 3.2. for various transformation purposes. Profile one and four are selected to use the form of actuation to Blind in terms of transformation for their robustness and stronger pulling force (Fig. 8).
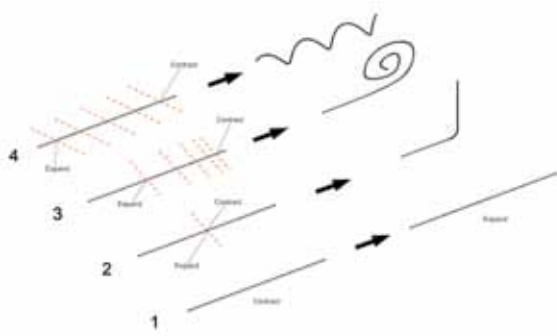
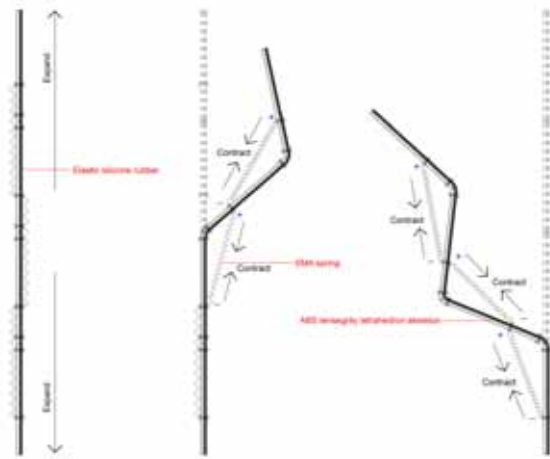Fig. 7. Four potential profiles for 'soft' actuations of SMA wire.



Fig. 8. SMA springs embedded with tetrahedral skeleton and silicone rubbers for actuation through electrical stimuli.

### 3.4 Adaptability

The application of the adaptability of Blind is as a prototypical active shading device that to regulate shading and shadow control to improve the comfort level of existing spatial conditions. Blind can also be responsive to ambient conditions or live data streaming that addresses two applications termed comfort and visual. The comfort application of Blind in the form of a semi-ellipsoid canopy creates a 'transition' space in-between Blind and the existing courtyard space (Fig. 9). This application is embodied in two experimental processes. The first process used design tools such as Grasshopper and Firefly parametric software together with Arduino microcontroller and photo resistor for initial digital simulation (Fig. 10). Full-scale digital simulations demonstrated the shadows cast into the existing courtyard space under the Blind

screen provide a morphing patterned atmosphere that suggests a continued relationship between exterior and interior by shadow casting and modulation of the direct sunlight (Fig. 11). Blind is an alternative approach to the conventional inert brise-soleil, the design of which generally lacks the consideration of its effect on the interior condition especially in different timezones and seasons.



Fig. 9. Blind in the form of a semi-ellipsoid canopy performed morphological transformation for optimal sunlight manipulation.
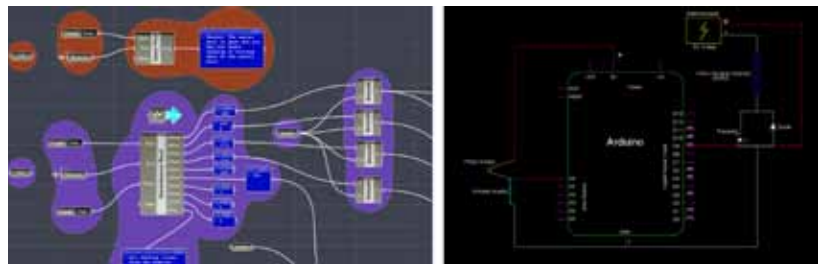


Fig. 10. Grasshopper and FireFly schema (left). Responsive process of Arduino microcontroller for digital simulation (right).
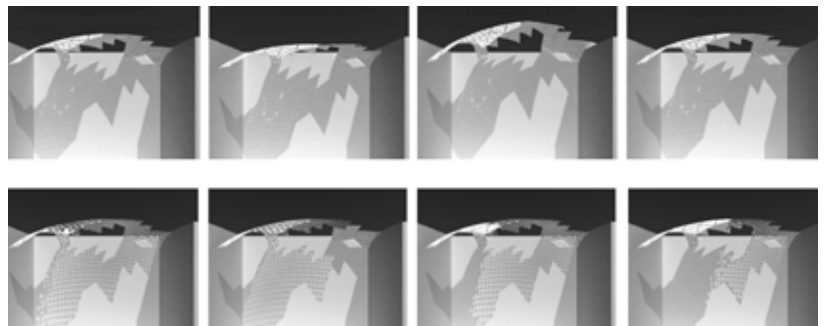


Fig. 11. Shadow casting of morphological transformation (top). Morphing shadow patterns of porosity transformation (bottom).

The second process is a physical experiment involved through the use of SMAs spring that serve as the actuators to reduce mechanistic components to test the initial physical transformations of Blind (Fig. 12). This experiment also using a photo resistor as light

sensor and the torchlight mimicking the path of sunlight to embody the initial essence of comfort: a digital and physical responsive skin model in various morphological states for optimal performance as a sunlight modulator (Fig. 13).
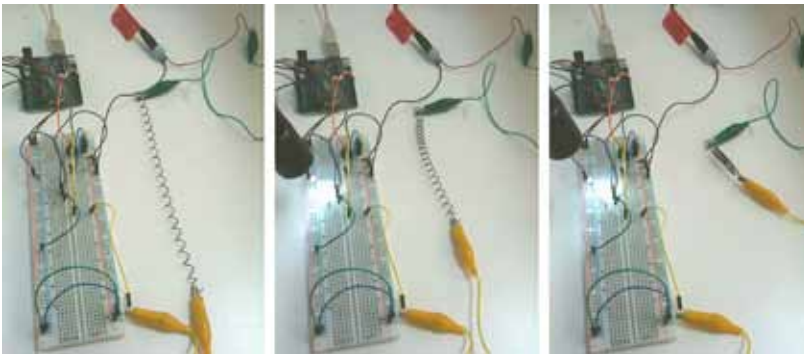


**Fig.** 12. **The expansion and contraction of the SMA spring responding to direct light through a photo resistor.**

Blind allows transformation to take place in the exoskeleton structure and skin. It develops the skin surface transformation in two different types: morphological and porosity transformation. Morphological transformation explores the global surface curvature of Blind to be modifiable. It allows contraction and expansion while maintaining the continuous topology of any undulating or flat surface. It can respond to various functional drivers.



**Fig.** 13. **Morphological transformation of the triangular modules of Blind responding to direct light for optimal performance.**

Porosity transformation, on the other hand, focuses on the visual application through permeability of Blind that is generated by the individual 'soft' aperture to cast shadows in response to sunlight penetration. This transformation manipulates the spatial conditions of the interior and exterior spaces through the dynamic patterns of the skin surface. The initial geometry of the membrane aperture is inspired by the performance of the eye. The 'eye-like' apertures in the geometry are determined by their relative curvature on the

responsive undulating silicone rubber surfaces and actuated by SMA wires and springs. This analogy of an 'eye-like' permeable aperture functioned as a skin muscle mechanism in the eye which allows various changing porous patterns in binary form on the skin (Fig. 14). This perforation process created a potential application for the surface of blind as the 'analogue media screen', to display binary images or even motion graphics. It is also adding a new layer of aesthetic for visual communication between existing courtyard space and external surrounding environment.
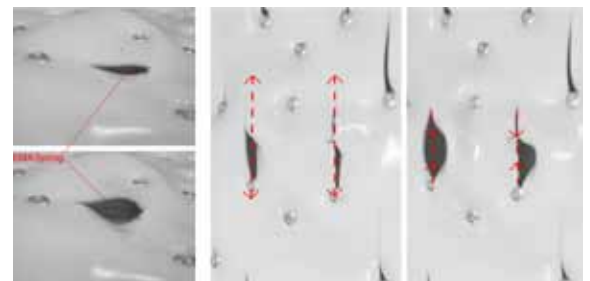


**Fig.** 14. **'Eye-like' apertures open and close actuated by SMA wires to perform porosity transformation.**

## 4 Conclusion and Future Work

Architectural skins are part of the crucial components for architecture in terms of climatic control and visual appearance. In general, the materials used to construct these components (steel and glass) have not changed for a century. Their 'hardness' is literally true from the standpoint of both system and materials. Current advancement of material technology provides the alternatives especially the 'soft' textile and form-changing materials such as Aramid and electro active polymer. They became increasingly relevant to architecture as well as responsive architectural skins design for lightweight and flexibility purposes. The study provided in this paper initiated the investigation towards this direction using scaled physical prototypes, digital simulation and physical computing set as the methods of inquiry. The design experiments explored in this paper through the passive and active form-changing materials embedded in the elastic tensegrity structural components. It is an alternative method for less energy and simpler actuation to control, and regulate the behaviour of responsive morphing skins in terms of the comfort and visual. The form-changing material that operates inside the tensegrity system becomes the new kind of 'structures'. It can actuate the elastic

component exposed to the ambient environment to be functionally adaptable. This alternative approach for actuation can create multiple states of stability in terms of transformation for architectural skins. It has potential, and is more economical and silent than conventional mechanical approaches. The research in this paper demonstrated the new possibilities of implementation for responsive architectural morphing skins evaluated through the small-scale design experiments. The design method developed through Blind provides designers with a mix of passive and active design strategies for responsive architectural morphing skins. This experiment while in an early stage, evaluated through the criteria of comfort and visual, point to the potentials, and identified the challenges, for full-scale architectural applications,

AMS revealed the new territory of responsiveness from mechanical components operation towards a 'solid-state' kinetic matter for actuation and transformation. Future work will focus on this 'solid-state' approach to further investigate the potential of the harness, elasticity, thermal, magnetic and sensing properties of the form-changing and kinetic matter embedded with physical computation for AMS application. The full-scale physical experimentations also included explore the possibilities of AMS for feasible implementation in architecture.

## Acknowledgments

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# Digital-physical hybrid design: Harmonizing the real world and the virtual world

## Abstract

Embodied interaction technologies make it possible to enhance our real artifacts. Various displays and projectors are already embedded into the artifacts, which makes it possible to create virtual forms into them. The virtual forms present dynamically generated visual expressions containing information that ascribes some additional values to the artifacts, and enables users to consider them as being more attractive. Using virtual forms is a very promising way to enhance artifacts surrounding us, and to make our daily life and business richer and more enjoyable. Recently, many people are anxious about the future that is why increasing daily pleasure is one of the most important social issues to be considered. In this paper, after presenting an overview of three case studies that enhance traditional artifacts with virtual forms, we extract five values that define a frame how a user feels about them. We describe the values and explain how they are used in the case studies. Then, we propose a framework to design digitally enhanced artifacts with these five values. Moreover, we show that the values are of significant importance in order to make a user's activities with them richer and more enjoyable by adding virtual forms or changing values dynamically with virtual forms.

## Keywords

Embodied interaction, semiotics, empathetic value, persuasive value, informative value, economical value, ideological value, gamification, digital-physical hybrid design.

## 1 Introduction

Embodied interaction technologies make it possible to enhance our real artifacts and the various displays and projectors that are already embedded into the artifacts, allow us to attach virtual forms to them [1]. The virtual forms show dynamically generated visual expressions containing information that provokes a user to feel some additional values of the artifacts, and enables him/ her to consider the artifacts as more attractive. Technologies have become mature enough to realize the virtual forms. Sensors retrieve various information about the real world, and the virtual forms reflect what happens in the real world and offer more value to a user. Using virtual forms is a very promising way to enhance the artifacts that surround us, and make our daily life and business richer and more enjoyable, since increasing daily pleasure is one of the most important social issues to be considered. Traditional artifacts enhanced with virtual forms bring an augmented reality features to them and from now on in this paper we call them "AR artifacts", where "AR" stands for Augmented Reality. Computation becomes a primary method to realize AR artifacts. The virtualization of the real world

through computational materials makes the distance between artifacts disappear, and the communication within a community more asynchronous. In addition, information reflecting the current situation is embodied in AR artifacts. There are many advantages in using virtual forms to design AR artifacts. The virtualization makes our real world more flexible, and there is a possibility to incorporate more trading and gamification aspects, which will encourage a user's motivation in his/her daily life.

However, how to "successfully" and "harmoniously" design the virtualized real world with AR artifacts remains an important and challenging issue. In order to suggest some clues for solving this problem, in this paper, we describe three case studies and based on the experiences with them we are able to extract five values, which allow us to discuss and consider some good design implications for the design of AR artifacts. The proposed five values are significant in order not to lose the reality in traditional activities by adding virtual forms.

A frame in social theory consists of a schema of interpretation, which is a collection of anecdotes and stereotypes. People construct a set of mental filters through biological, emotional, economic and cultural influences. The choices they make are influenced by their creation of a frame. Framing can affect the outcome of a choice problem. The framing effect, one of the cognitive biases, describes that presenting the same option in different formats can alter people's decisions [2]. The values discussed in this paper are very useful for defining a frame to characterize activities with AR artifacts. We can recognize how each of the proposed values is defined depending on the current frame associated with the current AR artifact. The values could be changed by incrementally adding virtual forms to some AR artifacts. Thus, this approach offers the possibility to apply and design gamification elements and mechanisms for the current activities with AR artifacts in a more systematic way without modifying the infrastructure heavily.

The main contribution of this paper is to propose five values that can be used to change the frames in which people use artifacts explicitly. The values are useful as a design tool to make the artifact more attractive.

The paper is organized as follows. Three case studies that use virtual forms to enhance our real world are presented in Section 2. In Section 3, five values are

extracted from our experiences with the case studies and we show how these values are used in the case studies. Section 4 shows how to consider maintaining the reality even when virtuality is introduced in the real world. Finally, we conclude the paper in Section 5.

## 2  Three Case Studies

### 2.1 Persuasive Ambient Mirror

Virtual Aquarium is an AR artifact called a persuasive ambient mirror [3] that has been developed and has the objective of improving users' dental hygiene by promoting correct toothbrushing habits. It is set up in the lavatory where it turns a mirror into a simulated aquarium as shown in Figure 1. A virtual form in Virtual Aquarium represents an aquarium located in the lavatory, and the form reflects a user's toothbrushing behavior. Fish living in the aquarium are affected by the users' toothbrushing activity. If users brush their teeth properly, the fish prosper and procreate. If not, the fish become unhealthy and may even perish.

In this AR artifact, we use a 3-axis accelerometer sensor that is attached to each toothbrush in a household and a user brushes his teeth in front of Virtual Aquarium using such a brush. Since toothbrushes are usually not shared and each sensor has a unique identification number, we are able to infer which user is using the artifact at a given time. Toothbrushing patterns are recognized by analyzing the acceleration data. The toothbrush is able "to observe" passively how the user brushes his/her teeth and this is the only interaction needed to use this AR artifact.

In this AR artifact's case, the ideal user's behavior model is defined as follows: 1) a user brushes his/her teeth at least twice a day; 2) one session involves at least three minutes of brushing; and 3) brushing involves patterns that ensure the teeth are properly cleaned. Each user's behavior is compared to the ideal one and translated into a feedback as described below.

As shown in Figure 2, when a user begins to brush his/her teeth, a scrub inside the aquarium starts cleaning the algae off the aquarium's wall. At the same time, a set of fish associated with the user starts moving in the aquarium in a playful manner. When the user has brushed his/her teeth for a sufficient period of time, the scrub finishes cleaning and the fish dance becomes even more elegant. When the user finishes brushing,
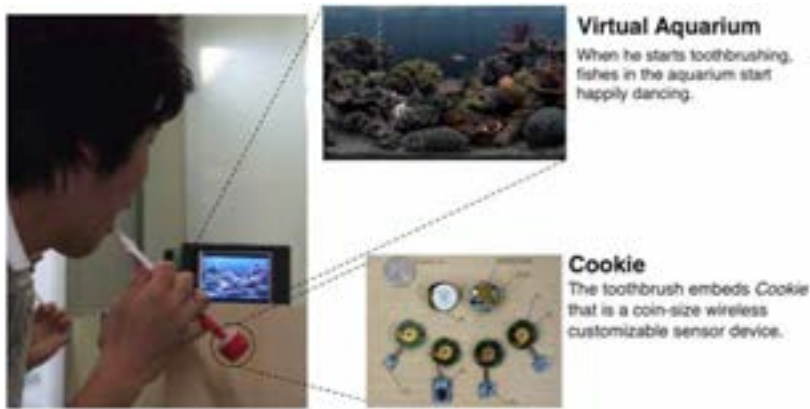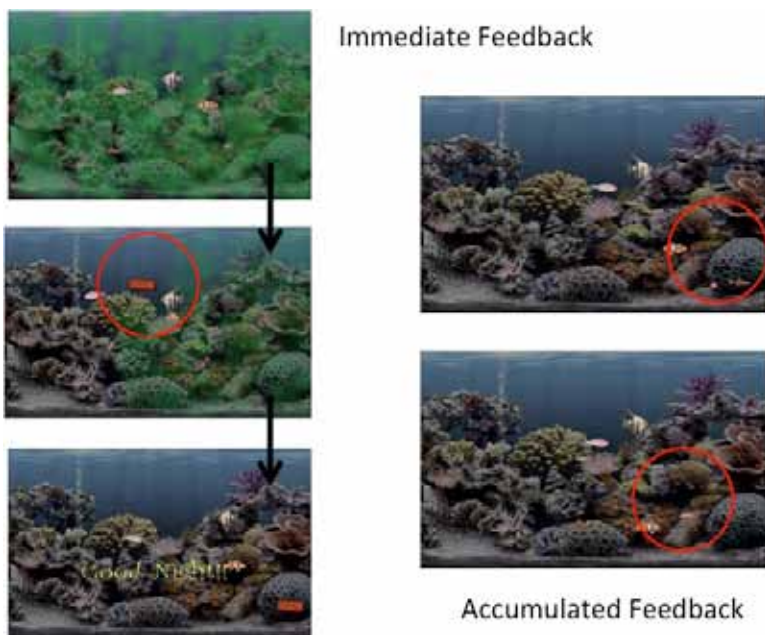
**Fig. 1. Virtual Aquarium.**



**Fig. 2. Proactive Information Feedback in Virtual Aquarium.**

the fish end their dance and resume their normal activities. Both the activities of the fish and the movement of the scrub are designed in such a way as to give the user hints regarding the correct method of toothbrushing. However, if a user does not brush his/her teeth sufficiently, the aquarium becomes dirty, and the fish in the aquarium become sick. The feedback information is returned immediately according to the movement of the user's toothbrush. We call this feedback immediate feedback.

The health of the fish is visibly affected by how clean the aquarium is. If the user neglects to brush his/

her teeth properly, fish health worsens. In contrast, faithful brushing may result in the fish laying eggs as shown in the right pictures of Figure 2. At first, the eggs are not very likely to hatch. If the user continues to brush consistently for a number of days in a row, the incubation ratio increases. This way, the long-term feedback gives clues to the correct behavior and attempts to maintain motivation over a period of time. The long-term feedback is called accumulated feedback. While designing this AR artifact, we consider the association between a user's healthy lifestyle and the cleanliness of the aquarium. Our design takes into account the fact that the user feels empathy for the virtual fish.

In our daily life, a mirror reflects our appearance and allows us to know whether we look well or not, whether our makeup and clothes fit or not and so on, and has the power to make what is invisible from us visible. We believe that mirrors are adequate devices to reflect our current behavior that return immediate feedback on the current situation. Virtual Aquarium is a new type of mirror that reflects a user's current state, encourages him/her to change his/her behavior and motivates desirable lifestyle.

### 2.2 Augmented Board Gaming

Go is a traditional board game for two players, where the goal is to occupy a larger portion on the board than the other player. Black and white stones are used to control the territory and a board with a grid of 19x19 lines is used as the game field. The rules of Go are relatively simple, but the underlying strategies are extremely complex and rich. As in chess and reversi, a numerous set of strategies have been invented to reduce the complexity, but studying them requires the player to actually understand the strategic concepts. Thus, it takes a long time for a beginner to play well with an experienced player and to feel pleasure during the play. Augmented Go [4] supports several gaming modes to play a game. The basic idea is to offer useful information to beginners without extra interactions and intrusive devices as shown in Figure 3. A virtual form in Augmented Go is superimposed onto the real Go board. Proactive feedback information is offered visually by superimposing guidance information onto the Go board by a projector. A web camera connected to a personal computer is used to detect the position of each Go stone. The OpenCV library is used for
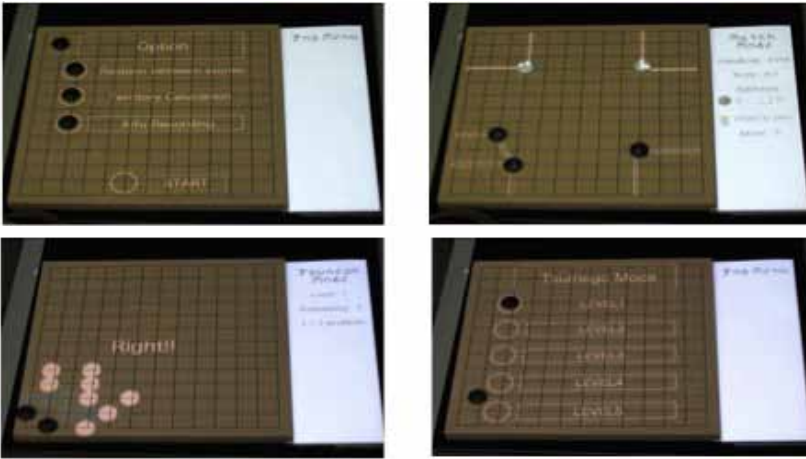
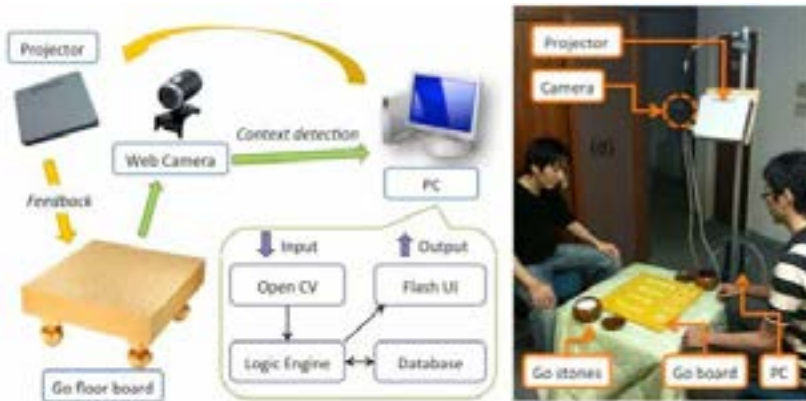**Fig. 3. Augmented Go System.**



**Fig. 4. Proactive Information Feedback in the Augmented Go System.**

visual analysis and the core logic of the enhanced artifact generates information presented to the players according to the current game situation.

The AR artifact supports several gaming modes. As shown in Figure 4(a), players can interact with the AR artifact by placing Go stones on a menu that is projected onto a board. Here, we explain briefly some of the modes and how players interact with Augmented Go.

Normal Play mode. The normal play mode is the basic form of the Go augmentation. In this mode, two players play Go as usual, but useful information is projected on the board to help beginners recognize the situation and make better decisions. The rules of Go are simple, but the vast number of possible moves in each turn makes it hard for beginners to make decisions. Moreover, on the large 19x19 board, beginners tend to concentrate on localized fighting in a narrow region and lose the big picture. It is difficult to recognize invaded areas, since an invasion process gradually progresses as new

stones are put on the board. For choosing good offense and defense strategies, recognizing the links between the Go stones is important, but it requires some skill. Moreover, the normal play mode visualizes the strength of links between the Go stones. As shown in Figure 4(b), same-colored stones are connected with lines. If a dangerous situation occurs somewhere on the board, a warning message appears for the players to avoid losing the area. The sequence of stone moves is also recorded into the database, which facilitates replaying the game for self-training. Replaying allows us to review and analyze the play by projecting the stones on the board later.

Tsumego mode. Tsumego is a type of exercise where the player is given a game board situation. The aim is to find the best sequence of stones' placement in a given board situation. In this mode, the positions of the stones are visualized on the board. Players can try different moves by placing stones on the board, with the results and comments explaining key important points
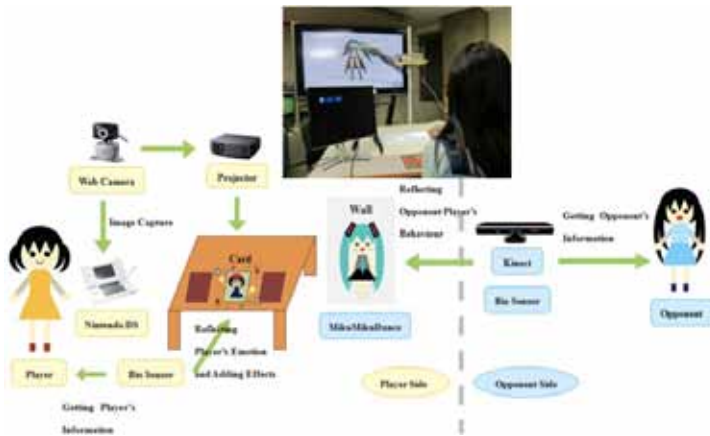
**Fig. 5. Augmented Trading Card Game.**

displayed as visual feedback (Figure 4(c)). The Tsumego mode prepares questions for a player with different skill levels, and the level of difficulty can be selected in the menu (Figure 4(d)).

The advantage of our approach is to allow players to receive information through the normal interaction with the Go board and the stones. By superimposing information onto the board, players can concentrate on the normal play or self-training without fragmenting their attention by taking an instructional book and so on into their hands. This is important to make it possible for the players to allocate enough cognitive resources for understanding the current situations in the game.

### 2.3 Augmented Trading Card Game

A trading card game is also commonly referred to as a collectible card game, a customizable card game, or CCG. For our purposes here, we will use trading card game (TCG) to refer to all the three varieties of games. In a nutshell, a TCG combines the collectability of trading cards with a strategic game play. Typically a player purchases a starter set, containing a playable deck of cards and a manual that includes an explanation of the rules and the mechanics of the game in an intro- ductory fashion. One of the biggest problems faced by any new TCG player is the need for an opponent to truly engage in the game play, as it is extremely unusual for any TCG to support a solitaire mode. Players usually begin playing with a friend, at a particular location such as a hobby game store that offers organized gaming opportunities and includes a tutorial component, or via an online portal.

Computer-based TCG is also becoming popular, and in our project we make a comparison between the real TCG and its virtual one running on Nintendo DS [5]. An important conclusion resulting from that comparison is that the computer-based TCG loses a lot of realities offered by the real TCG. For example, the sense of real cards is essential for many TCG players since making and completing collections of cards is a significant source of pleasure for them. Also, the computer-based TCG implies some communication limitations, as it allows a player neither to have an eye-to-eye contact, nor to look at or chat with the opponent player. As described above, although most of the current computer-based TCGs lose the realities of the real TCG, we claim that ubiquitous computing technologies may help to recover these lost realities and encourage and attract players to enjoy the computer-based TCG in a very similar way to the real TCG. Moreover, adding special effects and virtual forms to the computer-based game might even increase the excitement and the enjoyment of the game more than the real one.

Figure 5 shows Augmented Trading Card Game (Augmented TCG) that we are currently developing. This system extends the trading card game running on Nintendo DS, where two players are usually located in different places while playing the game.
In Augmented TCG, the opponent player is represented as a virtual character. The movement of the character is synchronized with the movement of the real opponent player by using MS Kinect, and the behavior of the character is determined by the information retrieved from a biosensor attached to the opponent player, i.e. the virtual character's behavior reflects the real player's behavior and emotions to some extent. In Augmented TCG, two virtual forms are used. The first form is superimposed onto the playing table to show the virtual trading cards and some special effects during the play. The second virtual form is installed on the wall and represents the virtual character of the opponent player.

The trading card itself is also enhanced in the AR artifact. Cards presented on the display of the Nintendo DS are retrieved by Web cameras and projected on a real table. Then, these cards can be enhanced by adding effects reflecting the player's emotions, enjoyable battle effects or empathetic effects to the characters shown on the cards.

In the original computer-based game, a player usually cannot see the opponent player. However, the proposed Augmented TCG enables us to recover this lost reality by adding a virtual character whose movement and behavior are synchronized with the movement and behavior of the real opponent. In addition, the virtual trading cards carry some special effects that increase the sense and the excitement of the game. Similarly, if the character drawn on a trading card shows some empathic expressions, a player feels more empathy for the character on the card, and feels more enthusiastic and committed to the game. We believe that such special effects would help to compensate the lost realities of the real trading cards. Moreover, virtually attached rarity to the virtual trading cards would also bring a feeling of reality and would encourage a will to collect virtual trading cards.

## 3 Design Implications

In this section, we extract five values based on our experiences with the design of the case studies described in the previous section. We mainly focus on the experiences that provide us some clues as to how to integrate virtual forms into the real artifacts by increasing their values without losing the reality for a user. The virtual forms offer the possibility to enhance a user's experience beyond the original artifacts. The values presented in this section are a useful tool to analyze the current artifacts and to develop AR artifacts with virtual forms. As shown in the next section, designing AR artifacts incorporating the five values described here enables us to consider which frame is chosen that corresponds to the current AR artifact. The approach provides the possibility to change the current frame explicitly in order to gamify the usage of the AR artifacts according to a user's personality by changing or adding the five values.

### 3.1 Semiotics of Virtual Forms

The meaning of the visual forms should be easily understood by the user [6]. When instructions on the use of the virtual forms are needed, they should be simple so that the user can understand them completely with ease. It is not a good idea to assume that the user will read a manual. One of the solutions to this problem is to use metaphors. Understanding a metaphor relies on the user's prior knowledge. If the user has been

acquainted with similar information in the past, the user can learn the meaning of new virtual forms through the use of an appropriate metaphor. A metaphor does not require too much information for making a better decision. For example, as described before, in Virtual Aquarium, the cleanliness of the aquarium is a metaphor of the cleanliness of the user's teeth. Also, Augmented TCG's special effects surrounding the battlefield become metaphors to show the will and strength of the virtual characters drawn on the trading cards. Another solution is to use affordance. In Augmented Go, a player chooses a command to the system by putting a Go stone on a circle projected on the Go board. In this case, the accuracy to identify commands is important because a user cannot distinguish the misunderstanding of the offered affordance and the inaccuracy to recognize commands.

However, users sometimes misunderstand the meaning of the visual forms, and this is one of the dangers of relying on metaphors and affordance. Users may find unintended meanings in a visual form. For example, if a supposedly unattractive picture is used to discourage undesirable behavior, that picture may actually have the opposite effect on an avant-garde or ironic art consumer. Moreover, the way a picture is understood by a user strongly depends on the cultures and personalities of the users. It is not easy for a designer to attach a single meaning to a specific expression for all people. The interpretation of the expression could be left to the user. This open interpretation [7] allows the user to feel pleasure or good surprise on one hand, but on the other hand it is not easy to predict the effect of the interpretation by the user in a controllable way. The presentation of the information according to a user's current attitude is a key issue for representing the values described in this section. The information may appear in an ambient way. For example, as shown in this section, a metaphor is a useful tool for that purpose. However, visual information representing a metaphor should be tangibly manipulated to present more detailed information [8]. One of the solutions is to offer a visual expression that offers an affordance presenting more detailed information by opening the visual expression. After a user can choose one of the visual expressions, detailed and concrete information appears on a visual form for the user to make a better decision. This style of information design is effective

to show enough information when designing AR arti-
facts. A skillful user chooses several necessary abstract
pieces of information and opens the information to
show more detailed information. Choosing how much
information is necessary depends on the user's current
attitude. Virtual forms attaching a value require us to
choose an appropriate feedback strategy according to
a user's current attitude, but it is not easy to detect
the user's current attitude with the current sensing
technologies. The interaction design enables the users
to explicitly retrieve necessary information according
to their current stage because a more skillful user has
a strong incentive to know more detailed information
for raising up his/her current level to the next level.

## 3.2 Five Values Extracted From Our Case Studies
*Empathic Value and Virtual Characters.* Using an
empathetic form is an effective way to evoke the user's
emotions. Empathy is a strong social incentive to feel
values on a virtual form. Empathy engages the user to
feel close to the empathetic form. Virtual pets are a
typical example of an empathic form and they are very
popular in many online services. Social robot pets also
make our daily life happier. The pets evoke the user's
empathetic emotion and encourage him/her to change
undesirable behavior as a consequence of negative
emotions. The emotional impact is very effective in
making the user keep desirable habits. One interesting
theoretical result is the media equation [9]. A user
feels empathy for even non-living things like a personal
computer. The result indicates that there is a possibility
to use various expressions or products that do not
represent living or animated characters. On the other
hand, if the form showing a pet is too realistic, a user
may feel uncomfortable although he/she feels empathy
for unrealistic characters. The phenomenon is called
the uncanny valley [10]. When the user considers that
something expressed by information services has a
personality, the user feels empathy. If the personality fits
the user's personality or he/she feels altruism towards
the personality, he/she feels a close relationship.
Therefore, designing a good and appropriate personality
is an important topic when designing AR artifacts. In
Virtual Aquarium, fish in the virtual aquarium evoke
emotion to the user. In this case, one of the important
design issues is to synchronize the current situation of
the virtual fish with the user's toothbrushing practice.
In Augmented TCG the virtual character representing

the opponent player has a strong impact on the player's
feelings during the game play. If a player has a good
feeling about the virtual character, the player tends to
satisfy the game play sincerely even if he/she does not
know the real opponent player well.

Media tend to be used by a user for a longer time
if the user feels empathy for it. However, it is not
easy to offer empathetic experiences to users. One
promising way to solve the problem is to make
it possible for a user to customize his/her own
experiences. For example, decorating a mobile phone
is very typical for Japanese people, which makes it
unique and differentiates it from others. It is also very
typical for people to customize their avatars in online
games by changing their avatars' accessories, clothes,
shoes, and hairstyles even if doing so involves paying
extra money. The product attachment theory [11]
explains why people like customized things more than
uncustomized things. According to that theory, people
prefer a product whose personality matches their own
personality. The customization is a process to make the
products more preferable to a user.

*Persuasive Value and Feedback Information.* An effective
and easy way to change a user's behavior is to offer
feedback information to the user [12]. When a user
behavior is desirable, a positive expression is returned
as a feedback, while if he/she behaves in a bad manner,
a negative expression is returned as a feedback.
Designing emotional incentives is one of the important
aspects to offer the persuasive value on the virtual
form. However, the approach requires that the stimulus
continues forever in order to maintain better habits.
A user may get bored after the same stimulus is
received over a period of time and the stimulus itself
can not be strengthened infinitely. Also, the feedback
information should not reflect the real effect if the
effect does not appear soon. If users do not receive the
appropriate feedback information according to their
efforts, they will lose interest and motivation. Moreover,
the feedback information needs to be synchronized with
the real situation of the users to make them feel the
sense of the reality.
The transtheoretical model defines a five-stage process
involving the progress to change the user's undesirable
behavior [13]. The returned information needs to be
changed according to the current stage of the user's

attitude, skills and knowledge. In earlier stages, the user prefers emotional reinforcement not to give up his/her current efforts. On the other hand, for the user who is in a nearly final stage, enough information for making a better decision through rational thinking is more suitable. Virtual Aquarium offers emotional stimulus to a user to continue to wash his/her teeth. Also, Augmented TCG offers special effects on the trading cards to encourage more plays. The design of the case studies is suitable for encouraging users to play the corresponding game continuously. On the other hand, in Augmented Go, the projected information on the real Go board is useful to make a better decision, but the AR artifact does not offer emotional stimulus to encourage a beginner to play the game.

A beginner may not have an interest to continue using the applications described in the case studies over a period of time. Especially, if the activity to use the AR artifact requires some additional efforts, it is not easy to continue the activity since the curiosity does not motivate more than the exertion of extra effort demotivates. This is one of the reasons why most people give up many interesting activities quickly. It is important to offer extrinsic motivation like joy, comfort or reward in the early stage.

In the next stage, self-efficacy is the key to raise the stage. A user feels self-efficacy when he/she has a confidence to continue the target activity. The confidence comes from the evidence that he/she has the ability to do the activity well and the user needs to be offered enough information showing such evidence. In order to move to the later stage, the user needs to perceive self-efficacy. Since a positive attitude is necessary to grow the user's self-efficacy, it is essential to use positive feedback, and the user should be aware of his ability to change his/her current lifestyle.

The feeling as information theory [14] is useful to consider how AR artifacts with virtual forms evoke the user's emotions. The theory indicates that it is difficult to think rationally while in a positive mood and users tend to think more rationally when they are in a negative mood. The results indicate that positive stimuli are effective in early stages, but in later stages, negative stimuli are desirable under the transtheoretical model. Virtual Aquarium provides positive stimulus when the user's current behavior is desirable, but negative stimulus is returned when he/she behaves undesirably. One of the important findings is that negative stimulus

alone is not effective, because the user becomes rational, and he/she considers the effectiveness of his/her behavior. He/she needs enough information to think about the importance of the activity in a rational way. When rational decision-making is important, it is desirable not to evoke a user's positive emotion too much. It may lead heuristic thinking to make a wrong decision. The fact is important when designing an AR artifact for a game. A game usually evokes a user's deep emotion, but it may not be better to win the game without rational thinking.

*Informative Value and Decision Making.* The informative value is useful to offer information to a user in order for him/her to make a better decision. When using the persuasive value, a user usually makes his/her choice unconsciously, but the informative value enables a user to feel his/her decision explicitly. If users believe that they make a decision by themselves, they usually do not try to change their decisions, and the effect is useful to increase intrinsic motivation.

We believe that proper supports of decision-making are very important and the informative value should be incorporated in various future AR artifacts using virtual forms [15]. We hope the experiences described in this paper are useful to design future AR artifacts. In Augmented Go, extra information is projected on the physical GO board. The user can still use normal stones and a board without attaching any artificial objects like visual tags. Also, the user does not need to be equipped with special devices like a head mounted display. Projecting information directly on the GO board is useful not to fragment a user's attention. While doing Tsumego, a user needs to look at a book. This forces a user to look at the GO board and a book alternately, and this prevents them from concentrating on learning the strategies of a GO play.

For designing informative value, it is important to consider how much information is necessary to make better decisions [16]. If hidden information becomes explicitly visible for a user, his/her decision-making will become more rational, counteracting the biases that may creep into their or his/her decision-making processes. For attaching informative value, how to offer the nudge proposed by Richard Thaler to make rational decisions is an important design decision [17]. However, if proper information is not given, a user may get more confused, and in such case it is hard to make a rational decision.

For example, if there are too many choices, a user tends to not choose at all [18]. A large amount of information also requires heavy cognitive efforts, so it is important not to give too much information when asking for a decision. Also, too much information is neither effective nor helpful for helping a user think rationally. In some cases, heuristics are dangerous and lead to mistakes in decision-making [2], and the bias in heuristic thinking may cause the user to make a wrong decision. However, heuristics are necessary to make better decisions from many choices within a reasonable time. The amount of information should be carefully designed for better decision-making.

*Economic Value and Virtual Items.* Not surprisingly, we also found that economic values are a powerful technique to motivate people to change their behavior. An economic value is a tangible reward that the users consider valuable, yet not necessarily actual money or goods. In online games, millions of players work hard to obtain rare and valuable virtual goods, and even trade these goods for real money at a rate of three billion dollars per year [19].

In [20], Lendonvirta proposed three attributes that make virtual items valuable in the game. The first attribute is the functional attribute consisting of two categories: performance and functionalities. The performance is the skill to play a game well and the functionality of the equipment increases the possibility of winning the game. The second attribute is the hedonic attribute. The attribute consists of six categories: visual appearance and sounds, background fiction, provenance, customizability, cultural references and branding. The hedonic attribute offers the value to satisfy a user's emotional desire. The third attribute is the social attribute. This attribute consists of one category: rarity. The value is strongly associated with the ability to distinguish a group of owners from non-owners. The above attributes are effective to provide economic value to virtual forms by making the items with the attributes shown in the forms exchangeable with other people.

Adding economic values in our case studies is a very important issue. In Virtual Aquarium, we can buy fish and plants for the aquarium. If a user becomes sick, he/she may not wash his/her teeth properly and it may make fish ill. The user may feel helplessness and hopelessness about using Virtual Aquarium if there is

no way to solve such problems. If a user can use virtual currency and buy medicines, it motivates him/her to continue using Virtual Aquarium. In Augmented Go, it is useful for a user to buy more Tsumego patterns in order to improve his/her skills or to buy new software to analyze his/her current play in details and advise better ways to play in the future Go games. In Augmented TCG, a player can buy a new trading card and strengthen his/her current card deck. It is also possible to buy a new virtual character and a new pattern to add special effects on the virtual trading cards.

There are different virtual money systems in many online services. In each service, a different virtual currency is defined. One of the most interesting issues is the exchange of virtual and real currencies. The rate to exchange the virtual currency and the real currency may be changed according to the value of the virtual currency. This means that the value of the virtual currency is decreased if the trust of the virtual currency is decreased. We believe that the economic value will change the understanding and attitude to virtual and real money and will be useful for the design of a money system that uses the virtual currency in a more effective way. Although the economic value is a powerful tool to motivate behavior, it may lead to unpredictable results if not used carefully [15]. One additional effect that could be utilized is reciprocity, or the desire to reciprocate gifts and favors received from others. Virtual gifts are frequently exchanged in online environments, strengthening the relationships between users. Another example of economic incentives in persuasive technology is the activity-based billing system [22], which uses automatic micropayments and microrewards to coax users towards desired behaviors. The approach utilizes the heuristics to make a decision to change a user's behavior and to make the economic incentive more effective.

*Ideological Value and Aesthetics.* What is here referred to as an ideological value is the notion of influencing users' behaviors through influencing their attitudes and values; in other words, educating the users on a deeper level. Attitudes and values influence the users' behavior in the long term. The ideological value makes it possible to motivate the user by himself/herself. The user raising the ideological value has a belief called self-efficacy that makes him/her believe he is able to achieve his/her goal. In our current case studies, we

choose simple metaphors that could be understood by the user easily, but the metaphors have shallow impact on the understanding of the importance of maintaining a desirable lifestyle.

The virtual form that has the ideological value may also include a user's dreams or expectations for the future. Especially, an art form is a useful style to express future human's dream or expectation in an ambient way. A virtual character may speak some words reminding a player's future dream or expectation. This may be useful to help a player mature through the game play. Also, virtual forms can be drawn surrounding virtual trading cards or a virtual character and they may include the importance of recent serious social problems such as sustainability and human wellbeing. This makes it possible to learn these important issues during game play by incorporating these social problems in the game design. Also, a special effect in Augmented TCG can represent the wish of a character in a trading card, and the effect can heavily influence a player's current motivation. Using an art form is a useful tool to give meaning to virtual forms. We believe that artistic ways of thinking will help for digital-physical hybrid design that offers more stimulative experiences to consider the importance of a desirable future. For example, contemporary conceptual art uses complex metaphors to provoke deep reflections on issues like sustainability and peace in the world.

The ideological value is brought by intellectual stimulation. For maintaining desirable behavior, it is important that the user is aware of the importance of the desirable behavior. The association between the effect of desirable behavior and the virtual form offered to the user as feedback is an effective intellectual stimulation. Other values described in the previous subsections cause an extrinsic motivation that makes it difficult to maintain the user's desirable behavior for a long time. On the other hand, the ideological incentive may cause an intrinsic motivation, and thus the changed behavior to be maintained for a long time [23]. Aesthetics is an important concept to design the ideological value. Especially, in Japan, incorporating the ideological value in Japanese digital products is a promising way to sustain the Japanese economy [24]. Of course, Japanese traditional folk craft represents the aesthetic value, and we need to investigate how to incorporate the esthetic value into AR artifacts as a next step.

## 4 Achieving the Reality in the Virtualized World

In this section, we show a brief and ongoing framework to design a new AR artifact with the proposed five values. It is important to note again that the values are very closely related to each other, which can be seen from the descriptions in the previous sections. For example, the rarity in the economic value strongly depends on the feeling of how important it is to a user. Therefore, how to orchestrate the extracted values defines different frames for the different users. Although it is not easy to change the value attached to the real form, the virtual form allows the value to be changed by replacing the values attached to the virtual form. This means that the currently attached values can be changed according to the situation, which on the other hand offers the possibility to gamify the AR artifact successfully.

The framework consists of the following two steps. The first step is to consider which values are used to design a target AR artifact. The second step is how to orchestrate the five values and design an AR artifact to change the current frame by changing the association of the values and the virtual forms without losing the reality of the artifact. In the remainder of the section, we describe the two steps briefly.

As a first step, we consider how to use virtual forms to offer additional values to a user. In our framework, there are five core values: empathic value, persuasive value, informative value, economic value, and ideological value. For using the values, we first choose a virtual form that can offer the target value. The value should offer a feeling of materials to the virtual form as in the real artifact because the newly attached values may change the meanings of the original artifact.

As a second step, we need to consider how to obtain and keep the reality in the AR artifacts. The virtual forms should convey some realities to users. For example, in Augmented TCG, if there is no real feeling for the opponent player, then the player is more likely to cheat. Also, it is hard to feel empathy for the virtual trading card. Rarity is an important economic value to make a user feel empathy for virtual items [20]. The value makes it meaningful to collect trading cards because the owner of the rare card has a feeling that the card is unique. Recently, many Japanese animations include scenes that can be manipulated from real photo scenes. Realistic scenes are important for making a

viewer feel the reality in fictional stories. Also, in a game, when the season in the game is synchronized with the season in the real world, a user feels more reality. If a virtual character in a game uses humorous words or jokes, the reality of the character is significantly increased. Recently, Apple iPhone 4s offer an assistant application called Siri. The application offers a new way to control a user's phone with the user's voice. Since Siri sometimes answers very humorous words, it increases the reality of the answers. Also, if a user can customize his/her virtual room with furniture that represents some realistic items, a user feels the reality better. One of the most important design issues is that the virtual form should be natural like traditional real materials. However, the virtual form may exaggerate the effect in the real world, which might make the AR artifact with the virtual form even more exciting and attractive to the user than the original one. A feeling of the reality is important so that a user continues to use an AR artifact for a long time. However, it is hard to say and define, when and how a user feels the reality on an expression presented in a virtual form. It is not just enough to make the virtual form as close as possible to the realistic expression because a user may not feel the reality and may not be satisfied or attracted by extremely realistic expression. A user sometimes feels the reality to unrealistic exaggerated expressions or to expressions that include reality elements partially. It is an important issue to investigate the question of how a user feels the reality in a next step of our research.

## 5 Conclusion

Based on the experiences with the three case studies, we draw some important conclusions for the design of AR artifacts. The most important issue is how to define the meaning of the virtual forms. The forms need to offer some values to users and to include empathetic, persuasive, economic, informative and ideological values that wield influence over users. Attaching the meanings to forms of products is necessary to design the user's experience. Baudrillard proposed that the consumption becomes more symbolized and additional values become more important than the products as materials [25]. For example, a brand offers significant additional values to fashion items, and a consumer feels the value on their virtual properties. On the other hand, adding values to virtual items makes a user feel the realities into them [20].

This means that real products are becoming more virtual, and virtual products are becoming more real. Maintaining the reality in our real world is extremely important to make our daily life meaningful, and keeps us interested in the real world without escaping in the virtual world [26].

Digital-physical hybrid design causes real forms and virtual forms to be seamlessly integrated. In the next step, we are interested in using our concept to gamify our daily and business environments. Gamification recently became a popular concept for making daily and business activities more enjoyable [27]. The basic idea is to use a game mechanism to control activities in daily life and business. Our framework can be used to successfully design AR artifacts and is also very useful for realizing the gamification of daily and business activities. We believe that Digital-physical hybrid design offers additional values to an AR artifact, and these values are used to define a new frame to make our daily and business activities more exciting and enjoyable.

In this paper, we assume that traditional displays and projectors are used to realize virtual forms, and we do not consider the tangible aspects of the virtual forms. We found that the sense of physical touch is important for a TCG player [5], and we will consider the issue in the near future. Future tangible technologies will help to discuss the possible solutions [28] to this issue.

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# Digital craft in digital space: A paradigm shift in the making

## Abstract

With every technological innovation in Industrial Design there is an accompanying conceptual change about how materials are used, how forms are put together, what they symbolize and how their existence changes the way we reflect upon the design and the design process. We are currently in the midst of such a change. Digital technologies offer designers a new context to challenge the methods of mass production with inventive and very different means of making, forms of manufacture, and avenues of distribution within the broader context of virtual systems, services and networks.

This paper documents an ongoing sequence of projects by both design academics and students from Victoria University of Wellington seeking to explore these issues. Through the process of practice-based research we demonstrate that digital technologies are capable of both expressing and expanding traditional notions of workmanship and craftsmanship – to revive and embody its emotive and meaningful qualities within these new emerging social contexts and systems of making.

## Keywords

Digital craft, industrial design, digital guilds, co-design, digital manufacture.

## 1 Introduction

Over recent decades we have seen vast changes occurring in many areas of our existence. With the birth of computing came numerous new opportunities in the development of technologies, completely changing the way we function in everyday life and bringing a resounding transformation to the domain of Industrial Design. Here we believe lies an exceptional chance for design to help shape the future of our world. As creators of many of the objects and systems that proliferate in our lives, design is in a unique position to explore the possibilities of these new technologies.

What is important, however, is that we should not overlook the role of design in facilitating the absorption of the technological within human consciousness. For it is precisely design that facilitates the connectivity that lies at the heart of machinic processes, and lubricates the processes themselves. And it is design that fosters the 'sensuous correspondence' with the world, that flares up at that vital moment of assimilation afforded through visual expression [1, p. 12].

In starting to facilitate this absorption of technology, not only do we have the chance for more agile, flexible and sustainable forms of production, we also are at a point to investigate the changing role of the designer as facilitator rather than design dictator [2], redefining the machine to consider the social machine as a conduit of desire [8], and digital communities such as virtual guilds [3].

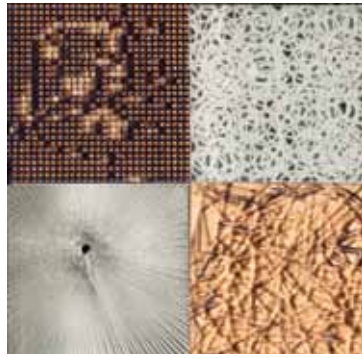**Fig. 1. Beyond the Smooth group (2002), Beyond the Smooth: CNC Machining with Meaning © Maxe Fisher.**



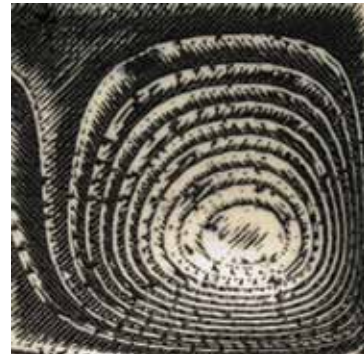**Fig. 2. Dan Emery (2005), Craft without Hands © Dan Emery.**



**Fig. 3. Ross Stevens (2006), Worn Out or Worn In © Ross Stevens.**

A starting point for such investigations is the notion of digital craft and the shift from mass-production to more customised, individualised methods of designing and making. An initial theoretical framework for such investigations is provided by David Pye's eloquent critique of mass-production in the age of the machine. In The Nature and Art of Workmanship he argues that the failure of mass-production is not that it is incapable of producing quality products, but that it has created a system of undifferentiated, uniform and characterless products; a material culture which gives little value to workmanship and craft, and the potential of both. Pye noted that since mass-production is a designed system of our own making, and, to an extent, that it is no longer producing something we desire, then we should construct another [4].

The workmanship of the motorcar is something to marvel at, but a street full of parked cars is jejeune and depressing; as if the same short tune of clear un-modulated notes were being endlessly repeated. A harbour full of fishing boats is another matter. Why do we accept this as inevitable? We made it so and we can unmake it. Unless workmanship comes to be understood and appreciated as the art it is, our environment will lose much of the quality it still retains [4, pp. 2-3].

In his lament, Pye was attempting to raise the consciousness of not only the designer and/or the maker, but also that of the intended market, to the world that we have produced through mass-production. Unfortunately, Pye died in 1993 and was unable to see the unfolding of a new revolution in design and making, and the potential for a new material culture; a revolution grounded in the burgeoning landscape of new tools of digital design and manufacturing. To understand the potential of our new material culture of digital design and fabrication, we must understand the fundamental background of the technology and its inherent potentials. The field of digital fabrication is composed of two general types of fabrication technologies; subtractive and additive. Subtractive technologies fall in the line of CNC routers and associated fabricators, which work by eliminating material from a larger form, until it matches a computer model. One such example would be taking a large plaster block and using a CNC router to remove bits of plaster at increasing depth levels until the desired pre-determined shape is achieved. The second group of technologies are those that fall into the additive camp. This includes the machines often referred to as 3D printers; machines where materials are added until a final desired form is obtained. This can be achieved through the hardening of material through a liquid bath, or through the additive layering of a material. The significant impact of both technologies is the relief for the designer or the maker of some of the restrictions of previous manufacturing technologies. In the mass-production model, economy and viability were only achieved through repeatability and restriction of variation. The goal of which was quality control of similar objects, through which economy of scale was achieved. The new digital fabrication technologies require no such repetition. They are as capable of producing two completely different products in a row as they are two completely identical products in a row. In both cases there is no need for retooling, no expensive set up; it is similar to printing two separate documents from your computer. It is easy to see how such flexible technology can provide a transformative opportunity, however, when we consider the rapid innovations and reductions in price which are making these machines available to the general public, the potential is all that much greater.

In 2000, the Industrial Design programme at Victoria University of Wellington began extensive practice-based research within this emerging field of new technologies. Our interest in this subject was twofold. Firstly out of a sense of necessity; the decline of mass-production was already more than evident in our industrial neigh-bourhoods with the migration of manufacturing to
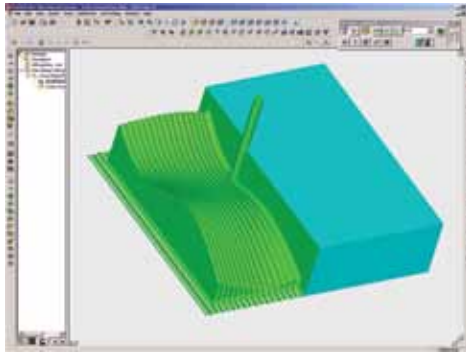
**Fig. 4. Beyond the Smooth group (2002), Beyond the Smooth: CNC Machining with Meaning © Paul Hillier.**
**Fig. 5. Beyond the Smooth group (2002), Beyond the Smooth: CNC Machining with Meaning © Paul Hillier.**
**Fig. 6. Beyond the Smooth group (2002), Beyond the Smooth: CNC Machining with Meaning © Paul Hillier.**

China. Seeking alternatives, we changed focus to the potential of digital manufacturing technologies as a more agile, flexible and sustainable form of manufacturing, more suited to our geographical isolation. Secondly; it presented an opportunity to discover, test and create innovative new ways in which the digital and physical worlds may begin to merge and how this may effect on-going changes in the discipline of design. By using the digital to push beyond our known ideas of craft as a degree of workmanship and as a social practice, it raises the question, is digital craft an opportunity to explore new forms of production and social practice while recapturing all the richness and diversity we value in traditional forms of craft?

## 2 Projects

This paper documents a sequence of projects undertaken at the school, by both academics and students, seeking answers to this question. Our first explorations into digital craft started with a project called 'Beyond the smooth; CNC machining with meaning'. The project was a collaborative study undertaken by academic Tim Miller with undergraduate students. Their task was to explore issues of surface, texture, form and meaning through the direct manipulation of digital milling data. Digital milling generally leaves the surface with a series of fine concave grooves or tracks. The technician or engineer will probably regard such a surface as unfinished and will do everything possible to eliminate these traces of the making process to achieve a perfectly smooth surface. However Miller identified a design opportunity in these irregularities and encouraged the students to take control of the software and to prescribe every cut taken by the tool.

Each student was asked to investigate an architectural project that has added to the ideas and theories of surface and structure, and to use it as a starting point to engage the computer as a generative tool to produce a series of models, transforming cast plaster blanks with increasing complexity from 3D surface through to 3D

form and space. The project engages a form of digital technology which Pye was certainly aware of, but it had not yet revealed its true potential at the time of writing The Nature and Art of Craftsmanship, when he noted that diversity in shapes and surfaces could also, no doubt, be achieved fairly crudely by numerically controlled machine tools, and perhaps something more can be hoped for there in the course of time [4, p. 73].

Close on the heels of this project the School acquired its first laser cutter. This initiated a journey of discovery for one of our students, Dan Emery who threw himself into an intensive sequence of experiments, to explore and exhaust the limits of this new device. His thesis 'Craft without Hands' challenged precisely that monotony and sameness achieved as a by-product of mass-production while seeking to engage digital craft. In a self-imposed challenge he restricted his experiments to materials like MDF and extruded plastic sheet; industrial materials which have been processed to the point of lifelessness in the name of technical consistency and uniformity. In a process reminiscent of the apprentice gaining an intimate understanding of his tools, Emery explored not only the effects of the speed, intensity and pathway of the laser on the surface and structure of his samples, he also took the investigation a step further by exploring the effects of subverting the settings, or corrupting the digital process with deliberate hand interventions such as mounting the work askew. His prolific output of samples revealed remarkable visual and tactile richness in what are otherwise dull and banal materials.

To further emphasize his point Emery identified the table as an everyday object with a long tradition of being both hand crafted and mass produced – as a kind of datum, a suitable reference point against which he could further test his thesis. This resulted in an exploration of new structures, new forms of construction as well as the visual expression of the digital processes involved. As if to acknowledge the expressive success of his approach it

Fig. 7. Dan Emery (2005),
Craft without Hands © Dan Emery.



Fig. 8. Dan Emery (2005),
Craft without Hands © Dan Emery.

very quickly became known in the faculty as 'pixel' table. Similar opportunities exist with 3D printing or additive manufacturing technologies as demonstrated by a series of experiments from academic Ross Stevens' thesis 'Worn out or Worn In' exploring variations in build topography from a fused deposition (FDM) printer [5].



Fig. 9. Ross Stevens (2006), 0.5° build angle.
Worn Out or Worn In © Ross Stevens.
Fig. 10. Ross Stevens (2006), 1.0° build angle.
Worn Out or Worn In © Ross Stevens.
Fig. 11. Ross Stevens (2006), 10° build angle.
Worn Out or Worn In © Ross Stevens.

The variations in surface textures are derived from the printing process which builds 3D forms from very fine (0.3mm) layers deposited by the printer. The digital file used to create these samples was identical in each experiment. However, intervening with the digital process and building the samples on minutely different angles causes the layers to create different surface textures as an individualized and seemingly decorative pattern over the surface of the product. The pattern is inherent in the process and not a superficially applied decoration.

Such interventions introduce an element of unpredictability or serendipity to the digital process and we see a new understanding of a machine aesthetic emerging that is not unlike the irregular structure and growth patterns or natural diversity and variegation we find in organic objects such as plants and shells. To what extent the algorithm will be able to mimic these manual interventions remains to be seen. In any event, these projects demonstrate that engaging the digital in this way, whether CNC machining, laser cutting or 3D

printing, is an opportunity for industrial design to draw on the traditions of craft and recapture all the depth, subtlety, overtones, variegation and diversity which Pye celebrates as being fundamental to design. Diversity on the small scale is particularly delightful in regulated workmanship because there it maintains a kind of pleasantly disrespectful opposition to the regulation and precision of the piece seen in the large: as when, for instance, the wild figure of the wood sets off the precision of the cabinet-work. Diversity imports into our man-made environment something which is akin to the natural environment we have abandoned; and something which begins to tell, moreover, at those short distances at which we most often see the things we use [4, p. 72].

In terms of design education, the principles behind digital craft – the flexibility of digital control combined with the freedom from commitment to tooling – also make it fertile ground for students to experiment in ways which were never previously possible with traditional processes of mass-production, such as injection moulding or metal pressing. For that reason we regard it as critical to offer these digital technologies in-house where we can encourage students to do what the instruction book, or external service providers, might say cannot be done, and let them test the technologies to their limits. By customising their tools, the designer harks back to the evolutionary role as homo-faber or tool maker using a medium to affect the medium, comes to know how the tool works to open up new possibilities in the virtual stage of digital design [where] a new level of control and exploration is exposed [6, p. 1].

Having expanded the accepted boundaries of our proprietary equipment as far as possible, Ross Stevens then challenged our undergraduate students with the impossible; to design and build a fully functioning 3D printer in four and a half weeks.
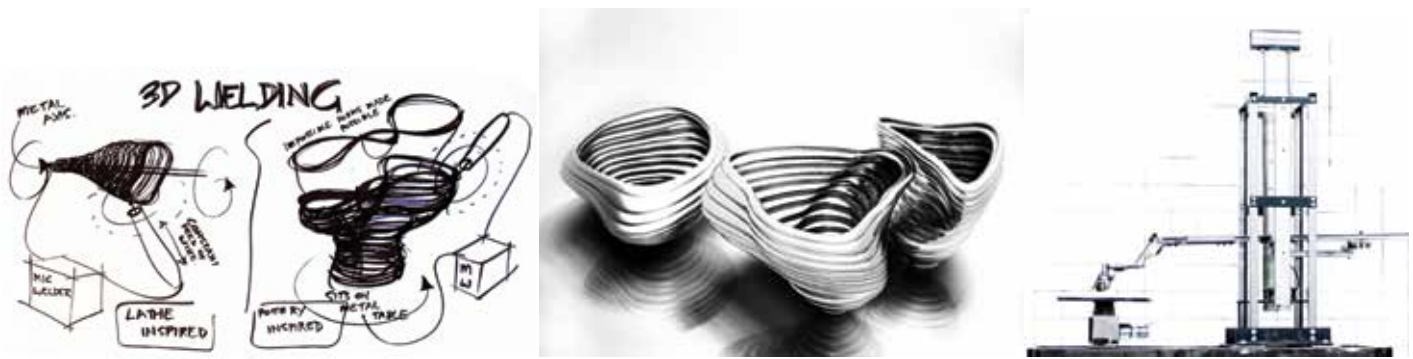MIG-me is an investigation of 3D welding as an additive

Fig. 12, 13, 14. MIG-me group (2007), MIG-me © MIG-me group.

process, or building thin walled vessels on a digitally controlled rotating bed with a continuous bead of stainless steel MIG welding wire feeding through an electrode gun mounted on two axes. Curiously, the build process lies in principle somewhere between hand-coiled and wheel thrown ceramic vessels, capturing the advantages of both; asymmetry and vertical fluidity.
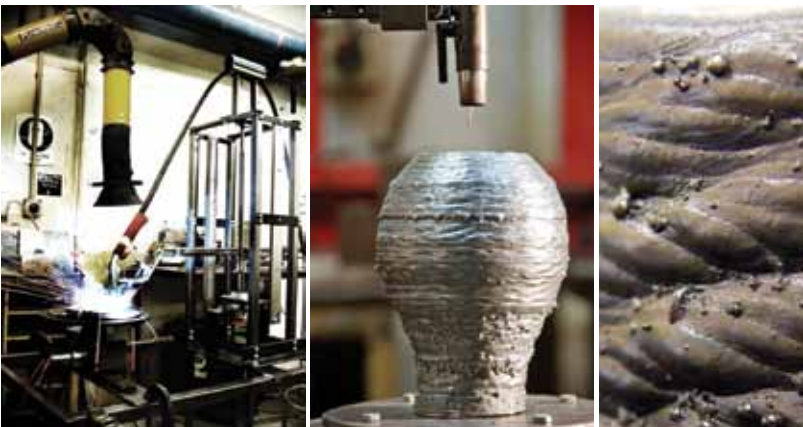


Fig. 15, 16, 17. MIG-me group (2007), MIG-me © MIG-me group.

While the form is digitally controlled the physical process of making, or the 'tectonic' forces of welding and the fluid quality of the molten steel, are very evident in the build quality and surface structure of the vessel. It is a form of mass-production, but one where no two vessels are the same – in either form or surface quality. The point of this exercise is not so much the design of the machine, it is what the machine produces that is of interest to us, in both cases new and unexpected material qualities, original and infinitely variable surfaces, forms and structures that, with some engineering assistance, may ultimately lead to new forms of production. But therein lies the design challenge; to make an aesthetic judgement in refining these processes without losing the expressive quality of making. Or in Pye's terms, maintaining 'the contrast

and tension between regulation and freedom, uniformity and diversity' [4] in the pursuit of richer and more poetic manufacturing processes.

This project questions our established uses of digital tools and starts to look at how the digital can create things that were imperfect yet perhaps more creative than with the existing systems. It seems that it was more interesting to look at what didn't follow the exacting standards of the digital and how the digital and physical responded to and translated information. Or as Masterton puts it in Deconstructing the Digital: "Perhaps it will be more appropriate to learn how to abuse, rather than use, these systems in order to develop a creative niche" [7, p. 24].

However we are only just beginning to scratch the surface of digital craft and the next group of students suggest that there is very definitely more to come. Calling themselves NEXUS, their project was inspired by forms and structures found in nature such as slugs' eggs and frog spawn. They identified the bubble as a unit capable of generating complex 3D forms and additive structures and explored possibilities with an experimental approach best described as research by 'making'.

They started with the obvious; materials such as hot glue or wax, followed by plaster and resin. There were many others, including snap frozen water droplets, corn starch and blown glass, as well as the ultimate material of choice – gelatine – a water soluble, colorless, nearly tasteless solid substance derived from collagen in animals' skin and bones. Being translucent it allowed them to explore transparency as a quality of bubbles they wanted to celebrate and thereby supported the aesthetic intent underlying all of their explorations.

A further advantage is that gelatine sets almost instantly in contact with air. It also proved to be versatile in terms of scale, accommodating a wide range of bubble sizes, thereby suggesting it may serve as a model for a more natural process of making, not unlike cell biology with applications ranging in scale from the micro to macro.
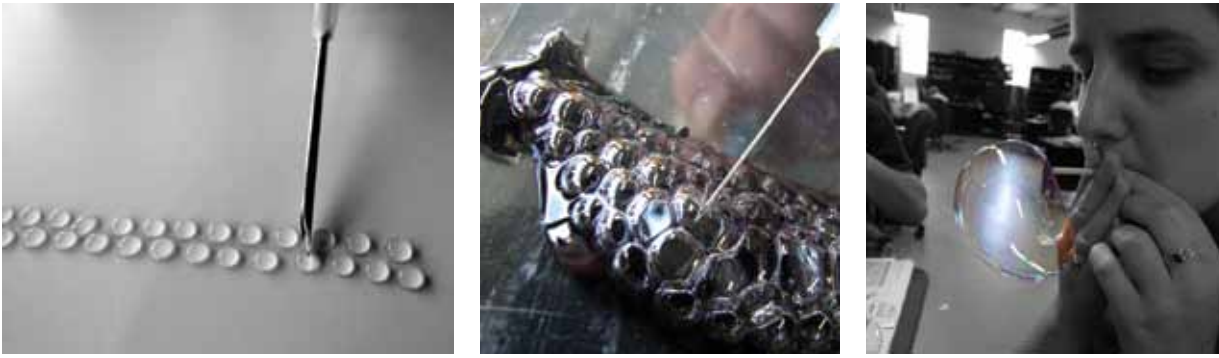
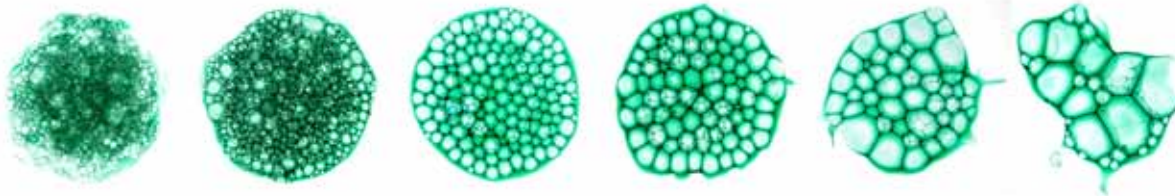**Fig. 1**8, 1**9, 20. Nexus group (2008), Nexus © Nexus group.**



**Fig. 2**1. **Nexus group (2008), Nexus © Nexus group.**

Experimentation with additives – initially with natural food colouring to achieve different colours suggested that the gelatine could also be used as a carrier for other substances. This later proved to be an important insight.

Material experiments slowly gave way to experimenting with the machine itself. Bubble size was controlled with a miniature peristaltic pump while a three axis build platform completed the exercise and allowed the students to generate complex 3D forms.





**Fig. 25. Nexus group (2008), Nexus © Nexus group.**
**Fig. 26. Nexus group (2008), Nexus © Nexus group.**

The resulting structural forms combined with their unusual expressive and material qualities invite and inspire new and very different interpretations of what the ultimate physical product might be. The opportunity to individualize the form along with ability to suspend nutrients or medication in the gelatine offers potential in unexpected areas.
The NEXUS group suggested applications as diverse as architecture, horticulture or health and well-being. It is shown here as a medicinal mask or skin wrap which

**Fig. 22, 23, 24. Nexus group (2008), Nexus © Nexus group.**

can be customized to individual scanned anatomies and infused with patient specific medication or regeneration agents that leach out as the gelatin softens in contact with body moisture. The customization takes place on two levels, the physical form of the mask and the chemical configuration of the medication. So this open ended form of exploration without preconceived ideas as to what the ultimate product might be, not only suggests new and very different types of products, it also takes the notion of digital craft beyond the crafting of objects to include the crafting of new forms of product services and systems.

As a form of exploration it also engages Pye's workmanship of risk by engaging unconventional materials for unforeseen purposes. Or as Patrick H. Harrop reflects upon Pye's proposition in his paper 'Agents of Risk' by writing,

When we make, instead of predetermining action, we discover a map of engagement. We play by challenging and resisting material. It in turn reveals an intentional resistance that provokes another challenge, and on and on. In fact, craft excels in the less-than-ideal situations. When challenged by aberrant materials, geometry and craft are forced onto innovative discovery [8, p. 1].

However, as time and methods of making progressed, a new challenge for students arose – the challenge to put these new forms of making into the broader context of virtual systems, services and networks.

Or, to make full use of these new digital technologies, not just developing new ways of making but to take it a step further, to put these technologies into context and develop new social and cultural scenarios of making, in the so called 'digital space'.

This introduces the idea of virtual guilds and the potential for a massive shift in the way products are designed, manufactured and distributed. With the opportunity for learning and communicating across time and space via the internet, it is quickly becoming apparent that the role of the designer is changing. Already we see online communities working together to improve, reiterate, redesign or simply alter existing resources by trading ideas and skills with the joint aim of gaining knowledge, much like the craft guilds of old.

Craft is a social activity, shaped by communal resources and motivations. The collective approach of craft

communities – or guilds – is characterized by the master-apprentice model, where practitioners devote significant time passing on their skills to the next generation. The open source software movement embodies the communal and highly skilled practices of craft guilds, but without the traditional economic function of those organizations. [3, p. 180] Participants engage in a type of 'technological craftsmanship' where the quality of the work can be its own reward [3, p. 180].

Not only does this talk of new methods of learning but also a change in attitude towards digital making, not simply using the technology as a tool to simplify or speed up an existing process but a change in the reasoning behind digital creation. To encourage this type of thinking in yet another project, Ross Stevens put the following proposition to the students:

As 3D printing technology continues to become cheaper and thus more accessible to the general public the opportunity for products to be made@home emerges. To maximize the ecological and economic potential of this it needs to be complimented with a de-making process allowing recycled@home [9].

The vehicle for this investigation was a $750 kitset printer from Makerbot which the students were expected to assemble and if necessary, to modify it themselves. The Glomus group is a good example of the type of response.

They envisioned the Makerbot as a creator of prostheses for broken objects in a scenario where broken, abandoned, unused or unloved artefacts would not only be repaired but also enhanced with a printed prosthesis. Their manifesto is compelling – their proposition is that the act of making increases the intimacy and sense of ownership between the user and the product and thereby enhances its perceived value and extends its lifespan. In other words you have invested in the product, and you have invested something more valuable than money – you have invested time, thought and care.

They capture this philosophy in a lifestyle scenario where, for instance; cutlery bought second-hand is personalized and becomes your own with newly enhanced handles, sunglasses found discarded on the street are taken home and given a new lease on life

**Fig. 27, 28, 29. Glomus Group (2010), Glomus, © Lulin Ding.**

and the eternal problem of the wineglass with a broken stem is solved by revitalising it with a replacement. Interestingly, this project moved beyond the brief of recycling products and created a process of re-making which allowed objects to be re-paired@home.
It is a scenario that uses new technologies to reassert emotional bonds between people and products. Ironically, it is the new technology that connects us to what we used to do – repair, rejuvenate, reuse and recycle – and the group has achieved it with a visual integrity and empathy for the obviously low resolution capabilities of the Makerbot.
They foresee a future where domestic 3D printers would be widely used and available in every household. An accumulative online database of default digitally modelled prosthetics could be produced for people to access in order to mend their broken items; similar to modern online databases like the Wikipedia community, where all parties will benefit through information sharing [10].

Essentially, this would break down existing manufacturing processes and mean that production takes on some of those guild-like qualities and becomes more akin to the creating and fixing practices of a bygone era such as darning socks and mending furniture, but though digital means. It also highlights the translation between both physical and digital as a means to inform and deepen our understanding of design.
These same issues are discussed by Richard Nelipovich, whose thesis looked at the use of digital manufacture in the creation of silverware.
Certainly there is value to pure formal and visual exploration in the virtual environment, but that exploration can only be taken to a level of synaesthetic haptic inter-action with a physical material object. There is a wealth of experience in the moment a spoonful of honey touches the tongue that just cannot be conveyed on a screen [6].

Another project that evolved from the brief was known as the Recyclebot. While the Makerbot 3D printer has created the potential for digital craft to be made@home

and the Glomus project has extended this to include found objects that are re-paired@home, the Recyclebot project goes one step further, offering recycled@home. In this scenario domestic plastic (bottles, toys) are harvested and transformed from specific and redundant objects into generic plastic filament that can feed through the Makerbot to produced completely new objects. This offers the potential for a closed material loop within the home where plastic is constantly transformed depending on needs, desires and whims of a new generation of digitally empowered craftspeople. They are no longer at the mercy of a far off designer's taste but are now part of the design process, becoming creators in their own right.

## 3  Digital Space and Collaborative Creation

Klaus Krippendorff, Professor for Cybernetics, Language and Culture at Pennsylvania University, who like David Pye before him, also questions the social cost of mass production; but in this case the disenfranchising or disconnecting people from designing and making as a fundamental human activity.

Before the industrial era, there were millions of craftsmen, artists, poets, and thinkers who invented new techno-logies, created new visions, and experimented with new practices of living. The industrial era eradicated most of this creative activity by enforcing the distinction between creative designers and uncreative consumers who had to be told how to live and what to do in the service of mass production.

The idea of THE user is a fiction conveniently maintained by designers who believe in their superiority over those for whom their design is intended. These terrible conceptions have lost their force. Increasingly, ordinary people demand making their own choices and designing their own environment with what they find. I am suggesting that designing is fundamental to being human and contemporary society increasingly realizes the fact that making things is fun and the opportunity

Fig. 30. Recyclebot group (2010), Recyclebot, © Paul Hillier. Fig. 31, 32. Recyclebot group (2010), Recyclebot, © Jason Mackie.

to play with possibilities, and to invent rules rather than follow those imposed by others, enables people to realize themselves [2, pp. 14-15].

In his paper Krippendorff suggests a number of solutions to this observation – one being the concept of "Cooperative design" as a new paradigm or approach to design where, as he puts it, stakeholders are involved in the process of design. This is based on the idea of co-design and indeed, the Glomus proposition of making as a form of social networking where default designs would be made available through a Wikipedia type online community starts to address at least some of the issues Krippendorff is referring to.

We can begin to see here a potential for the digital and the physical to mutate and become embedded in our lives through such machines as the 3D prototyper.

Even if they are mechanical machines, their purpose is to connect. They form a rhizome with the world – a symbiosis, a symphony. Moreover, the nature of this connectivity is dynamic. It is based on free flows and nomadic intensities [1, p. 10].

This brings a new dimension, not only to the social context of making, but also to the process of manufacture and distribution. Along with the ability to create from home, we are seeing the beginnings of localised manufacture, the process by which products are dreamt up in any corner of the globe then, via the internet, sent to the digital manufacturer closest to the products' final destination, and turned into real material. With these changes in making and producing through the use of digital technologies, the use of materials, production times and even the simple lack of tooling cost become hugely significant to the field of industrial design. "Freedom is fostered when the means of communication technologies are dispersed, decentralized, and easily available" [11, p. 5].

It is an interesting proposition – making as a form of social practice, recapturing in virtual space our older

practices of sociable creation – transforming production from the anonymous activity it has become, to a more personal and communal activity through digital guilds. It also raises questions about the future role of designers in society and the Glomus and Recyclebot groups are not the only ones asking these questions. With the expanding presence of online communities, the role of the designer is becoming an increasingly prevalent question. As at-home production technology becomes more readily available, what then constitutes a designer, maker or user and where are the lines to be drawn, if at all?

the most significant boundary not only being crossed but being dismantled is the boundary between professional and amateur, or more pertinently, between 'designer' and 'user'. Recent design methodology has stressed the importance of taking a user-centered approach, but has not envisioned a position where designer and user are essentially one and the same. This change in perspective has the potential to trans-form design education, design practice and the consumption of design [12, p. 137].

Across the globe, there is a bourgeoning guild of online digital fabricators and makers. Here in Wellington we have one of the first companies to tap into the digital making revolution: Ponoko. Started in 2007 and now with over 5,500 users, they are an online platform from which anyone around the world can upload, buy, sell or create products.

This is somewhat akin to a specialised commercial Fablab, or Fabrication Laboratory. An idea created at MIT and now with labs from Kenya to Afghanistan, Iceland to India and across much of the states and Europe, Fablabs are small-scale workshops that use digital technologies to create personalised fabrication. What is clear in both these examples is that the user and 'designer' are both involved in the creation process, at times even as the same person, a potential answer to Krippendorff's idea of 'Cooperative Design'.

However, if you talk to any of the pioneers of online design and making like Ponoko, Shapeways in Holland, Materialise in Belgium or Fluid Form in Austria (which, curiously, was co-founded by a New Zealander) they will all tell you that the real challenge is to actually facilitate the creative act of designing. What is second nature to us as designers is in reality a complex process and constitutes a serious inhibiting factor for anyone, particularly the uninitiated, wanting to engage with online design and making at a satisfying and sophisticated level.

This leads us back to the concern of digital craft. We are now only at the start of the digital era in making and there is much still to be learnt, understood and imagined. This is part of an ongoing dialogue but by challenging students to push the boundaries of our existing understanding of the digital, we are already seeing the ability to create crafted products through the dialogue of digital to physical and back again.

## 4 Conclusion

The interplay between the value of digital craft and the potentials of digital space is currently a focus of much discussion. The processes, materiality and outcomes of our comprehensive practice-led experimentation reveal and vividly illustrate the vast, nearly infinite, possibilities within the digital and stand to highlight the current shifting paradigms in the design world. As the digital proliferates and our physical world reels with the impact, how do we, as designers and design educators take the seeds of these changes and grow them into a new world of design, where digital and physical are the mutual founders in our new lands of creation?

Where the sea meets the land, life has blossomed into a myriad of unique forms in the turbulence of water, sand, and wind. At another seashore between the land of atoms and the sea of bits, we are now facing the challenge of reconciling our dual citizenships in the physical and digital worlds. Our visual and auditory sense organs are steeped in the sea of digital information, but our bodies remain imprisoned in the physical world [13, p. 1].

A part of what can be learnt from the projects mentioned is that a possible way forward is to cease to view the digital world as a linear progression from digital input to physical outcome. There is a need to view these processes instead as a constant feedback loop to allow for richer, more contextualised and more intriguing design. To move beyond the old models of 'file to factory' [14] and begin to use the potential of evolving design through both the digital and the physical so that each is the better for it.

'File to Factory' protocols have indeed pushed ahead our vision as designers with regards to efficient CAD/CAM/CAE processes and yet the other way around, 'factory to file', has never been considered. In other words, machine execution should not merely be regarded simply as a service tool for materializing design but rather an opportunity to inform the design process as one which integrates machine-logic across all scales of production [14, p. 2].

As digital technologies continue to proliferate, it is easy to be swept away by their potential, and it is, indeed, incredibly important to embrace and examine the world of the digital. But, by moving fluidly between the digital and the physical realms, we have the opportunity to gain powerful insights into the possibilities of both. The challenge now will be to not only understand the landscape 'growing' from new expressions of the material qualities we value within the traditions of craft, but to also understand that the design innovation potential of digital fabrication technologies is but one small part of a larger network of design thinking, which is ultimately changing notions of what design is and what designs will mean in our imminent future.

It is certainly a design challenge and a paradigm shift that we are already witnessing in industrial design, manufacturing and mass production and it is yet to be seen how the notion of made@home will challenge the power of made in China mass manufacture. It may well not be a question of one or the other, simply a matter of how they co-exist. But as, Jamer Hunt hypothesised in his Manifesto for a Postindustrial Design, the seeds of change "are implanting themselves in the cracks of the industrial foundation. And with that, new species of products will soon emerge." [15, p. 122].

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*Craft without Hands*
BDes Honours Thesis. Supervisor: Professor Simon Fraser. Student: Daniel Emery.

*Nexus Group*
Course Coordinator: Senior Lecturer Ross Stevens. Students: Gina Rawlings (Group Leader), Sean Antrobus, Lisa Howell, James Mayne, Ulrich Meyer, Mark Owbridge, Andrew Porter, Mauricio Vera, Jasun Woods.

*Mig-me Group*
Course Coordinator: Senior Lecturer Ross Stevens. Alex Keegan (Group Leader), Jonas Claudy, Solomon Fry, Fraser Hadley, Kane Lochhead, Henry Reed, Palarat Ronokait, Karna Sigurðardóttir, Jay Wang.

*Glomus Group*
Course Coordinator: Senior Lecturer Ross Stevens. Gina van Berlo, Christoph Brautzsch, Anindita Candrika, Justin Davies, Lulin Ding, Luisa Fonseca, Tenzin Heatherbell, Cody Law, Stewart Mcgregor, Daniel Starkey.

*Recyclebot Group*
Course Coordinator: Senior Lecturer Ross Stevens. Daniel Collinson, Amelia Diggle, Jenny Drinkard, Avid Kadam, Ben Kitchen, Jason Mackie, Lou Mutsaers-Hoyte, Jono Watkins, Luke De Villiers.

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