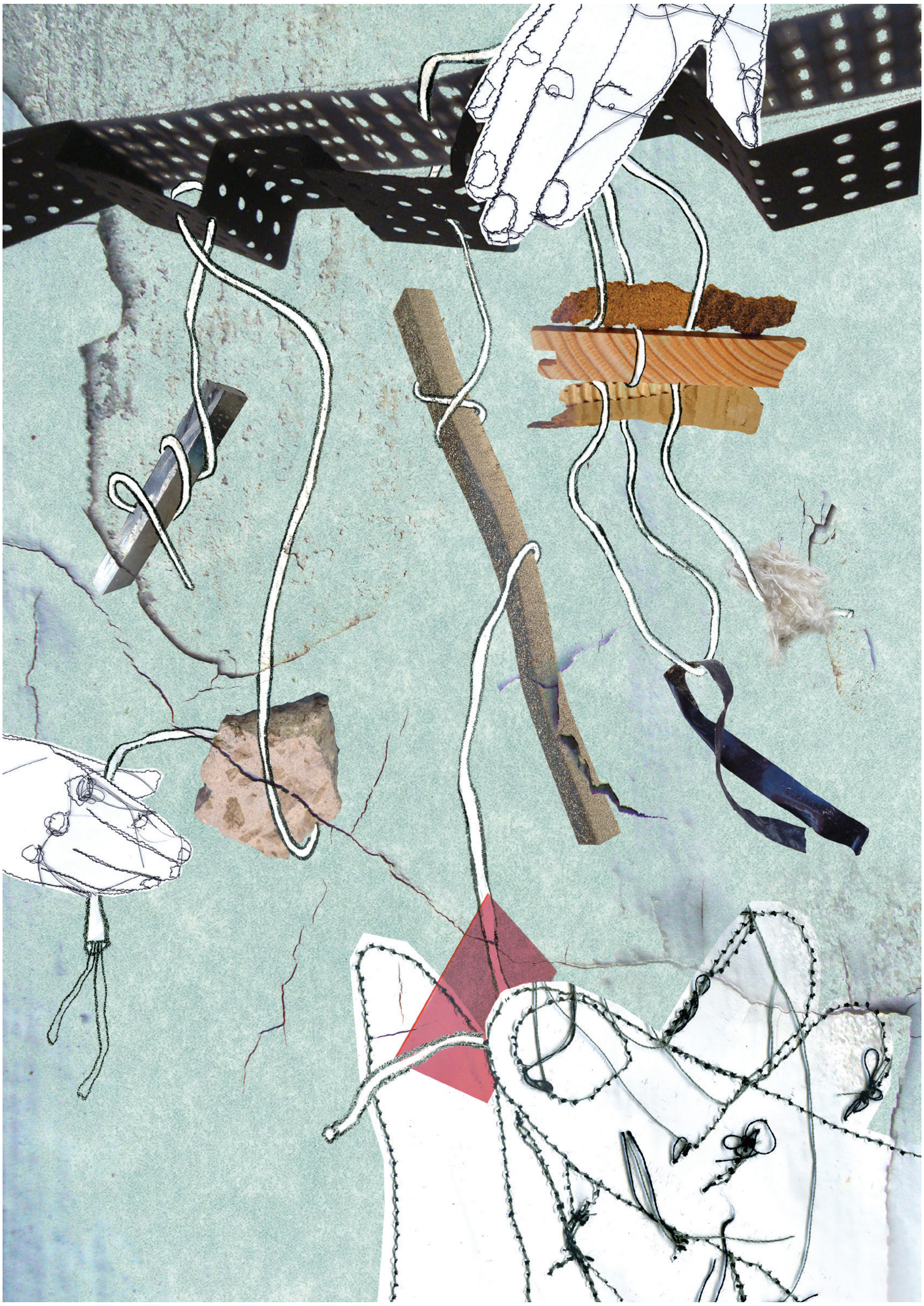

Tangible Means

EXPERIENTIAL KNOWLEDGE THROUGH MATERIALS

EKSIG 2015 – KOLDING

International Conference 2015 of the Design Research Society Special Interest Group on Experiential Knowledge

Conference Proceedings
Full Papers

Design School Kolding
University of Southern Denmark
25-26 November 2015

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Welcome

ESKIG 2015 – Tangible Means

Welcome to EKSIG 2015: Tangible Means!

EKSIG2015: Tangible Means, International Conference 2015 of the DRS Special Interest Group on Experiential Knowledge (EKSIG) is hosted by Design School Kolding and the University of Southern Denmark.

EKSIG2015: Tangible Means – Experiential Knowledge Through Materials aims to provide a forum for debate about materials as a means for knowledge generation by professionals and academic researchers, exploring the role and relationship of generating and evaluating new and existing knowledge in the creative disciplines and beyond.

These proceedings contain the papers accepted through double blind review for the EKSIG2015: Tangible Means held on 25th and 26th November 2015 at Design School Kolding and University of Southern Denmark.

Conference theme

In recent years many creative disciplines have shifted focus from what is produced to why it is produced and how it is used. This includes a growing interest for combining craft traditions with design and other related issues such as sustainability.

As early as 1983 Schön defined designing "as a conversation with the materials of a situation" (Schön 1983: 78) and the designer as a maker of things even though it is acknowledged that the concept of design can be broader than 'making things'. Also in the 1980s Manzini (1989: 17) pointed out a need for further development of cognitive tools and cultural references in order to catch up with the technical and scientific development of materials. Recently Karana et al. (2014) have expressed a need to study not only the functional but also the experiential side of materials. Thus, material knowledge is not only about 'scientific' facts such as functional and technical properties. It also encompasses personal, experiential, cultural, emotional, environmental and social aspects. In many disciplines, materials pervade all parts of practice, from the processes to the creation of artefacts and/or other kinds of physical manifestations and the interpretation through other professionals, such as curators, critics, historians etc.

With this conference, we wish to explore different ways in which experiential knowledge through materials can be given more appropriate consideration within the framework of research. This may include for example investigations into the nature, aims, validity, evaluation and/or necessity of different modes of communication and exchange.

References

- Karana, E., Pedgley, O., & Rognoli, V. (2014) (eds.). *Materials Experience: Fundamentals of Materials and Design.* Oxford: Butterworth-Heinemann.
- Manzini, E. (1989). *The Material of Invention: Material and Design.* Cambridge, MA: The MIT Press.
- Schön, D. (1983).*The Reflective Practitioner. How Professionals Think in Action.* London: Ashgate.

Questions of interest are for example:

- What do we mean when we say 'material knowledge'?
- What are the current understandings of material as a knowledge generator?
- Why might materials be important for any research conduct?
- How can materials be utilised within the framework of research?
- How can we articulate material knowledge, which might be tacit and embodied within the process of research?
- What frameworks are there to guide the communication of material knowledge?
- What differences are there between the pure sensing of materials and sensing of materials in a context?
- What means and methods can be utilised to transfer and replicate material knowledge?
- How can knowledge about materials be integrated and used within the framework of research?
- How can we articulate and/or communicate material knowledge within the process of research?
- What contribution can the use of creative practices make to the understanding and communication of material knowledge in research?
- What means and methods do we have to transfer and iterate material knowledge?
- What and how can we know from materials through research regarding the aspects of personal, experiential, cultural, emotional environmental and social issues?

Responses

As in previous years, the conference call received a great international response with submissions from 20 countries including Australia, Belgium, Brazil, China, Denmark, Finland, Greece, Indonesia, The Republic of Korea, Italy, The Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, UK and USA.

Submissions were interdisciplinary and stem from a variety of disciplines and discipline areas including design, fine art, applied art/craft, architecture, design engineering, museology, film making, knowledge management, education, philosophy and social sciences.

For the conference, contributions were selected in a one-stage process, comprising full paper selection, through a double blind review process by the conference's international review panel of 52 reviewers. From the contributions, the following eight sessions emerged: Means, Touch, Elements, Hands-on, Materials, Building, Patina and Oxymorons. Each session deals with one aspect of material knowledge and in total the sessions cover the widest possible understanding of experiential knowledge through materials.

EKSIG

EKSIG is part of a program of Special Interest Groups set up by the Design Research Society (DRS) to facilitate international exchange and advance in relevant areas of design. EKSIG is concerned with the understanding and management of knowledge in research and professional practice in design and design related disciplines in order to clarify fundamental principles and practices of using practice within research, both with regard to research regulations and requirements, and research methodology. The EKSIG conferences are part of a regular programme of the EKSIG group. They serve to bring together researchers and practitioners from different disciplines and to promote understanding and best practice concerning the integration of different forms of knowledge within design research and practice.

The EKSIG conferences are part of a regular programme of the EKSIG group. They serve to bring together researchers and practitioners from different disciplines and to promote understanding and best practice concerning the integration of different forms of knowledge within design research and practice. EKSIG promotes a multidisciplinary approach to engender multi-vocal debates and cross-fertilisation between the creative disciplines and other practice-led disciplines, including contributions from the design disciplines (design, engineering, craft, media etc.), philosophy, education, health and knowledge management that are concerned with methods and methodology in research and in creative and professional practice; with the nature, role, and management of knowledge within research; and with the role and use of creative practice (both as process and outcome) as a means by which to develop and manage experiential/tacit knowledge within research.

For EKSIG 2015 grateful thanks are expressed to: Design School Kolding and University of Southern Denmark for supporting the conference, the keynote speakers, the 52 members of the Review Team who facilitated the rigorous paper review process and finally the delegates who made the event possible.

Kolding, November 2015

Anne Louise Bang, Jacob Buur, Irene Alma Lønne & Nithikul Nimkulrat

Organisation

Organisers and review team

Conference Organisation

EKSIG 2015 is organised by members of the DRS Special Interest Group on Experiential Knowledge, and supported by the Design Research Society. The conference is hosted by Design School Kolding and University of Southern Denmark. Estonian Academy of Arts and University of Wolverhampton co-organised the conference. The conference is further supported by the Cumulus Association.

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KEYNOTE SPEAKERS

The Socio-materiality of Creativity

Prof Lene Tanggaard
University of Aalborg, Denmark

Biography

Lene Tanggaard is Professor of Psychology in the Department of Communication and Psychology at the University of Aalborg, Denmark, where she serves as co-director of The International Centre for the Cultural Psychology of Creativity (ICCPC), and co-director of the Center for Qualitative Studies. She has published several books and papers in the field of creativity and learning. Recent publications include Tanggaard, L. & Stadil, C. (2014). Showering with Picasso – how to spark your creativity and imagination. London: LIU Publishing and Tanggaard, L. (2014). Fooling around: Creative learning pathways. Charlotte: Information Age Publishers.

Abstract

This keynote takes its point of departure in an investigation of the potentials of looking at creativity from a socio-material analytical point of view. A socio-material perspective underlines that creativity is much more social and everyday like than has hitherto been acknowledged; materiality and arte-facts are to be seen as substantial components of creativity in itself (Tanggaard, 2013). In relation to current research on creativity within psychology and beyond, this is a rare point. It is still very common to state that "creativity is assumed to be present within every individual, although geniuses are rare" (Zeng, Proctor & Salvendy, 2011, p. 25). The source of creativity is time and again seen as residing within individuals. Furthermore, the result of creativity is often celebrated as a more or less individual achievement and creativity is still closely aligned with the exceptional and the genius (McDermott, 2006). As recently stated by Moghaddam, much psychological science, and I would claim psychological research on creativity, suffers from the 'embryonic fallacy' meaning that the independent individual is seen as the source and center of psychological experience (Moghaddam, 2010). This presentation aims at developing the socio-material perspective in more detail, which requires that theoretical elaborations and empirical studies go hand in hand. Examples from a recent study of a designer's work will be presented as part of the keynote. —

BACK

Design for Material Experiences

Dr Elvin Karana
Delft University of Technology, The Netherlands

Biography

Elvin Karana is an Assistant Professor in the Faculty of Industrial Design Engineering (IDE) at Delft University of Technology (DUT), The Netherlands. She undertook her PhD research at DUT, where she developed a 'Meaning Driven Materials Selection Tool' to support designers in their materials selection activities. Since then, she has been leading a number of research projects focusing on design for material experiences. In her work, she proved the notion of 'materials experience' to be actionable in design thinking and applicable to both in design practice and design research. Elvin is the main editor of "Materials Experience: Fundamentals of Materials and Design" (2014, Elsevier).

Abstract

Materials research constantly evolves to offer novel, superior materials as 'better' alternatives to convention (e.g. bio-based plastics, piezoelectric textiles, temperature sensitive polymers, advanced ceramics). As a priority, the pursuit of 'better' in newly developed materials should make sense from the perspective of bringing a utilitarian and environmental advantage. Yet, when embodied in daily products, a new material also brings the possibility of new sensations, thoughts, feelings, and behaviors. In search of a proper application through such an understanding, designers may arrive at an embodiment that as far as possible not only meets the practical demands of the design but also offers intangible sparks (Karana, Pedgley, & Rognoli, 2015)* that captivate people's appreciation and affect the ultimate experience of a product in and beyond its utilitarian assessment. I propose that designing with emerging materials through the lens of 'materials experience' is a powerful strategy to introduce those materials to societies through applications that make sense and give sense, and hence possibly shorten the gestation time of a materials innovation. However, this is far from straightforward. The potential experiences of the unfamiliar, the unusual and the rare emerging materials are often challenging to envision and to design for. In my presentation, I will introduce a method we have recently developed to facilitate 'designing for material experiences' when a particular material is the point of departure in the design process. I will illustrate how the method is applied in practice through a number of material driven design cases conducted within our research group over the last couple of years. —

* Karana, E., Pedgley, O., & Rognoli, V. (2015). On materials experience. Design Issues, 31(3). 16-27.

Harvested and Grown: The Rise of a New Bio-materiality

Prof Carole Collet
Central Saint Martins, University of the Arts, UK

Biography

Carole Collet is Professor of Design for Sustainable Futures and Director of the Design & Living Systems Lab at Central saint Martins, University of the Arts, UK. She has dedicated her career to develop a new vision for design, and pioneered the discipline of Textile Futures at Central Saint Martins fifteen years ago. She is now a full time Professor and her current research work is focused on biodesign, biofacturing and high-tech sustainability. Collet operates within a long-term framework and her research targets the year 2050 and beyond. By anticipating on future key socio-economic factors and technological timelines, she aims at impacting today's design directions so as to enable a more resilient and sustainable future. Her design vision fosters an integration of the design process in scientific arenas so as to develop meaningful sustainable future products and services. Collet's ambition is to elevate the status of design to become a powerful tool that contributes to developing innovative paths to achieve the 'one planet lifestyle'. Her recent curation of 'Alive, New Design Frontiers' (www.thisisalive.com) questions the emerging role of the designer when working with living materials and technologies such as synthetic biology and clearly establishes a new original framework for designing with the living. It is in this key area that her contribution to new knowledge is recognized at international level. One of Collet's characteristics is that she straddles different research roles, from designer, to curator and educator. This enables her to develop an informed critique of both the design outputs and the design contexts, from making knowledge to framing knowledge. Her work has been featured in international exhibitions and she regularly contributes to conferences on the subject of textile futures, biodesign, biomimicry, synthetic biology, future manufacturing, sustainable design and climate change. Collet is a prolific design researcher and works at local, national and international levels.

Abstract

We are in the midst of a transition from the industrial revolution to a biological revolution and this will have a great impact on what and how we design in the future. Not only we can acknowledge the advantage of biological systems in terms of zero waste, minimum use of energy and materials, but with synthetic biology, we can now 'biofabricate' like Nature does. Leather grown in a lab, yeast reprogrammed to produce silk, bacteria that grow a shoe, are but a few examples of current biotechnological breakthroughs. This keynote will map out the current landscape of biodesign and examine the rise of this new bio-materiality and its implication on design research. From botanical experiments to synthetic biology propositions, this paper will present a series of design case studies that question the notion of 'knowledge making' in the context of working with living systems. What becomes of the design process when working with living materials? If we can turn a yeast into a living factory, what language will designers need to learn? Could the intersection of design and biology lead to novel sustainable fabrication processes? What are the ethical implications of biofabrication? —

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PLENARY SESSION – OXYMORONS

Crafting Material Innovation

Danielle Wilde, University of Southern Denmark, Kolding, Denmark.

Jenny Underwood, RMIT University, Melbourne, Australia

Rebecca Pohlner, RMIT University, Melbourne, Australia

Abstract

When designing material interactions using digital and other technologies, ideation and development timelines can go out of sync. In this paper we discuss how a crafts-driven approach to wearable technologies can sensitise researchers to novel ways of moving forward when faced with such a challenge. We identify '*no-tech'* prototyping as a powerful paradigm for ideating wearable technologies when the technologies are not yet specified or available; and we describe four craft-based conceptual lenses – an *approach, expression, dialogue* and *language* – that support the development of no-tech prototypes at a range of resolutions.

The Poetic Kinaesthetic Interface project (PKI) serves as our case for study. PKI aims to support material innovation in the context of wearable technologies for enhanced embodied interactions. At a crucial point in an early phase of PKI we were stopped short by a delay in data delivery. Faced with an impasse, we turned to our crafts to find a way forward. The craft-based lenses and no-tech prototypes that resulted enabled us to undertake investigative, participatory experiments with a broad public and continue to move forward with the research.

To support our discussion, we unpack the notions of *no-tech prototyping* and *advanced material interactions*; we describe the PKI Phase I prototypes and discuss the value of working at different resolutions of conceptual and material finish. We then lay out our four lenses and reflect on how each of these lenses enable us to remain in a state of unknowing and continue to not only craft our way through our impasse, but deepen our embodied inquiry into the development of experientially rich material interactions.

The resulting *extended, reflective, embodied, craft-based* approach to material innovation is supporting greater public engagement with our core research concerns, as well as an expanded vision of how to effectively work towards material innovation. This research contributes to exploratory material-based and craft-informed interaction design and wearable technologies development. It also contributes to research into how to upstream public engagement with emerging science and technology, though this is not the focus of this article. The purpose of this paper is to use the case of PKI to reflect on how our approach may be fed forward, to be of use for others grappling with the challenges of multifaceted research into emerging materials and practices.

Keywords

craft; material interactions; advanced materials; embodied interaction; prototyping

Designing material interactions requires a multifaceted understanding of numerous elements. Methods and approaches are still emerging, but reflective design and craft-based knowledge are recognised to be of value (Wiberg et al. 2013), and a methodology for materiality drawing on a range of approaches has been described (Wiberg 2014). The research we discuss here expands on this work to include *no-tech* prototypes: developed using a self-reflexive, craft-based process, and deployed as probes in *Research Lab in the*

Wild cultural interventions (Wilde, Underwood and Pohlner, 2014). These probes assist people outside of the research process to engage with emerging research in a number of ways that we find useful. They enable participants to imagine future technologies and uses, informed, yet unconstrained by current knowledge. They afford discussion of difficult to articulate, often partially formed concepts. They support reflection around ethical, social, cultural, political and personal implications of what life would be like if yet-to-be-imagined technologies were real and readily available. The method also enables researchers to remain in a fruitful state of unknowing for as long as possible; to bridge scientific innovation with public concerns and desires; and arrive at unexpected outcomes. In this paper we describe the development of these methods in the context of the Poetic Kinaesthetic Interface project (PKI) (Wilde, Underwood and Pohlner, 2014).

Crafting *no-tech prototypes* to support *advanced material interactions*

While most people understand that everyday clothing, and basic craft materials often constitute complex technologies, in common parlance technology is typically understood to mean digital and advanced mechanical technologies, or recent scientific innovations. For the purpose of discussion, we will refer to these as 'contemporary technologies'. In our research the term '*no-tech'* refers to prototypes that are made without using such 'contemporary technologies' until we get to a point in our process that their use is so logical as to be unavoidable. The purpose of doing so is to avoid constraining our investigation to particular limits of use until the value of doing so has been determined. This approach allows us to explore applications of advanced materials such as intelligent polymers and nano materials (eg. Wallace et al., 2008; Rasmussen et al., 2012; Minuto and Nijholt, 2013), whose specific behaviours may not yet have been made concrete. It allows us to design *advanced material interactions* – interactions supported by embedding advanced or smart materials in soft, manipulable artefacts – to support, and even shape emerging innovation. Smart materials offer the potential for highly innovative human interactive systems to emerge. Yet they also challenge us to expand our approaches to how we design interaction (Vallgårda and Redström, 2007; Ishii et al., 2012; Rasmussen, et al., 2012; Minuto and Nijholt, 2013). This understanding is part of what drives our research.

The role of the prototype

Prototypes and prototyping are useful tools in opening up the potential for developing ideas (Sanders and Stappers, 2014). The prototype is 'as much a medium of interpersonal interaction as a tool for discovery, insight and test' (Schrage, 2013). As prototyping evolves, particularly in the field of interaction design, there is a move towards prototypes being deployed much earlier and in very rough forms (Sanders 2013). This approach enables a type of 'learning through making' (as in Andersen and Wilde, 2012) inviting a wide range of participants into the early stage of the design process. 'Prototypes have great utility in discursive and research-intensive contexts', serving as 'a great way to start a conversation' (Adamson 2013). They can form an integral element in an iterative loop of making, telling and enacting (Sanders 2013).

In PKI we expand this notion of early stage prototyping through using a craft-based approach, and no-tech prototypes at different resolutions to develop ideas, and also probe participants from outside the design process. This craft approach has become a critical means for engaging the broader public in an embodied conversation about, with and through our emerging research. In particular to support ideating wearable technologies when materials, technologies and or context are not yet known or imagined. In the next section we discuss the contextual development of PKI.

PKI – Background

The aim of the PKI project is to give participants the feeling of being in someone else's body, using physically engaging, wearable artefacts that incorporate advanced electro-active, and other shape change polymers. The aim of the research is to understand, on the one hand: if supporting people to move outside of their familiar movement patterns might shift their thinking, expand their understanding of what movement patterns might be of value, and reflect upon, perhaps even expand their notion of body typical. On the other hand, it is to advance understanding of different approaches to integrating electro-active, and other shape change polymers into soft, responsive wearable artefacts. A detailed discussion of the motivations and methods supporting PKI is provided at: (Wilde, Underwood and Pohlner 2014) with an overview at (PKI, 2014). In this paper we provide details only where they support our discussion of crafting material innovation. In particular, we focus on the role of craft in the development of three series of *no-tech* prototypes, which we use to probe participants, and the development of our craft-based lenses.

With PKI our original intention had been to design advanced material interactions using data from motion capture sessions undertaken with professional performers who have varying physical abilities: hypermobility, muscular saccades, muscular and skeletal deformations, and altered abilities due to age. We were to incorporate intelligent polymers in physically engaging worn structures (wearables) informed by the data, and test them on a broad public in the context of a major exhibition at a national gallery (LeAmon, 2013-14). Using research through design, our process was to be emergent. We did not decide in advance which polymers we would use, rather we intended to work from the body, with the aim of understanding characteristics and behaviours of interest, before deciding on which technologies might serve the project best.

We worked in one of the most advanced motion capture facilities in the southern hemisphere[1]. Nonetheless, the motion capture software was unable to map our participants' bodies to a standard skeleton, and the range and style of motion our participants were capable of proved highly challenging for elements of the system to 'understand' and interpret. This led to delays in data delivery and put our ideation and development timelines out of sync. Our public testing event was imminent, but we had no usable data to work from. In lieu, we had observations from the motion capture sessions, our own bodies, and some basic textile materials. Faced with these circumstances, we moved from the idea of *the body* to *our bodies* as tools in the process, and from data to ephemeral observations of motion. We then looked to our crafts to consider how to "knit" an emergent path through our impasse, and develop enriching interactions with the public. This process was not only emergent it was extremely experimental. Crucially, shifting our focus from technologies to our craft practices enabled us to engage with the potential of craft-based knowledge as a way to scaffold our emergent research. It supported us to think more imaginatively and ambitiously about the research potential in longer-term.

Craft-based approach to wearables development

There is strong precedence for craft as a tool for thinking and shaping material and other participatory interactions. Rosner et al. (2010), have investigated how the inherent creative process of crafting affords novel ideation, applications, and adoption of new technologies. They have found that craft can serve as "a resource for understanding the ways materials, techniques and relationships are continually re-bound in a digital age"; that the act of making can enrich collaborative processes (Rosner and Taylor 2011); and can be invaluable to an exploration of materiality (Rosner et al. 2010). Vaughan has used embroidery to explore the lived relationship between artefact, user and the experience of design (Vaughan, 2006). Fernaeus has used the textile craft of patchworking as a structural metaphor to assist

[1] Deakin Motion Lab: http://motionlab.deakin.edu.au/

children to code, and the model of the jacquard loom to identify patterns in the history of HCI (Fernaeus 2007 and 2012). Baggermann et al. have explored the social value of craftsmanship in service design (2013), and Kuusk, Koorishnia and Mikkonen (2015) demonstrate the value, and raise some of the challenges, of working at the intersection of craft and smart materials. Each of these examples demonstrates the importance of craft as "the condition in which the inherent qualities and economies of the media are encouraged to shape both process and products" (McCullough, 1996). Our work builds upon and extends these different ways of thinking about the convergence of crafting, design, material and participatory interactions, by focusing on wearable technologies, embodied interaction and ideation (Wilde, 2012 & 2015).

As Adamson (2013) contends, craft is not oppositional to technological advances. Rather they should be seen as sitting alongside one another. Crafting our no-tech prototypes is providing a way for us to engage in cultural, material and technological potentials. Rather than being constrained by technical know-how, our focus embraces the yet-to-be-imagined (Wilde, Andersen, 2009).

No-tech

The prototype series discussed here are all decidedly low tech, considering we intended to work with intelligent polymers (leaving aside, for the sake of argument, the technical sophistication of textiles and garment engineering processes). Using readily available digital technologies for our prototypes would have risked constraining our imagining to *the digital possible.* Our challenge was how to prototype so that the breadth of experiences advanced materials afford might be understood and mindfully leveraged, in prototypes that afford physical as well as conceptual interaction. In response to this challenge, we articulated an iterative framework for the inclusion of technologies into prototypes: *no*-tech (as defined above), *known*-tech (known and easily accessible technologies) and *emerging*- or *advanced*-tech. This framework enabled us to conceptualise the value of reducing technological experiments to those that are culturally assimilated into our understanding of crafts. The resulting notion of *no*-tech became a powerful framework for moving forward. Opening, rather than closing down our potential to imagine.

Crafting wearable and body-able probes

Once we were thinking through our crafts, we worked with our hands and let the materials guide the direction of ideas and inform our thinking. Our crafts thus enabled us to literally 'stitch', 'knit' and 'weave' our ideas together. As authors, this was our first collaborative project. Our expertise encompasses embodied interaction, live performance, wearable technologies, advanced material integration, garment engineering, textile crafts, sculpture and myotherapy. We used textile crafts – our common thread – to work through our impasse and provide a point of entry to critical thinking, leaning on the familiarity and social adhesiveness that crafts provide (Adamson, 2007). This social dimension was valuable as a means of learning to work with each other as well as for opening up the research to inform how we would navigate participant engagement. Craft thus became a device to draw each other in without knowing exactly where we were headed: when the characteristics of our materials were not yet concrete, and the context was not yet settled.

Working with familiar, embodied and material processes rather than with less familiar, advanced technologies, allowed us to express ideas quickly and not get caught up in technical or vocabulary issues. This approach allowed for openness, and work at a range of resolutions. We thus used our bodies and our experiences of other, varied *bodies* and ways of moving, as loci in an emergent process that intertwined these

Fig 1. (l-r) (a) Green knits; (b-c) Blue Cushions: Scapulo Humoral Rhythm (b) and Varus (Trendelenberg) (c); (d-e) Sleeves: Red and Black Sleeve (d) and Yellow Sleeve (e).

bodies and ideas with materials and behaviours. Doing so enabled us to develop novel intermediary outcomes that we used to probe the public.

Our approach takes its origin in a conflation of Cultural Probes (Gaver, Dunne and Pacenti,1999), Placebos (Dunne and Raby, 2003) and Participatory Innovation (Buur and Matthews, 2008). Our probes are finely crafted prototypes that have been designed to be worn on the body, or engaged with in such a way that they challenge the wearer and might provoke or support an emotional reaction. We expose and evaluate these probes through a flexibly responsive participatory process that has been designed to encourage and record elements of lateral thinking and subconscious associations (building on Wilde & Andersen, 2009). Our aim is not simply to collect inspirational data, but rather in keeping with the methodologically subversive nature of the original probes (Boehner et al., 2007), to allow that data to guide the project as it moves forward. We pay very careful attention to the process itself as we attempt the move across methodologies from probe to placebo, from embodied experience to imagining material potential, leveraging understandings from Participatory Innovation to help us to guide this process in a responsive manner. In Participatory Innovation new interactions between people from disciplines that usually do not meet are seen to enable new understandings to emerge (Larsen and Have, 2012). The practice focuses on what can be learned from the qualities of ‘conversations’ that take place in interactions that are paradoxically enabling and constraining at the same time (Buur and Larsen, 2010). We apply this thinking as we probe the public using our finely crafted no-tech prototypes of emerging material innovations, to understand the emergent unfolding from this entanglement. We then apply what we have learnt to our emerging research.

We next describe three different sets of probes that represent three broad design enquiries into the key question of PKI: *How can we give people the experience of being in someone else’s body, with different abilities and constraints?* Green Knits (Fig.1(a)), Blue Cushions (Fig.1(b-c)) and Sleeves (Fig.1(d-e)) each guide, constrain and/or (re)frame movement to enable the wearers or users to ‘feel’ and reconsider how they perceive particular movements, by prompting them to make those movements. Our discussion focuses on the impetus for the development of each probe series, and the process of crafting that supported their emergence.

Green Knits

The Green Knits (Fig.1(a)) were designed to prompt people to follow a particular movement pathway. Their development was informed technically by an exploration of potential modular means of integrating polymers into a knitted structure; inspired by anatomical notions around biotensegrity (Schleip et al., 2012). The aim was also to design an intriguing interaction – not too straight-forward or simple to “solve” – that might render the desired movement awkward and challenging in a similar way that some of the movements made by our disabled, hypermobile and mature-aged motion capture collaborators may be perceived. A knitted tensegrity structure that supported a simple spiral movement of a person's hands coming together and apart resulted.

Emergent development process

We began by experimenting with origami paper folding, to explore shapes that would afford folding and unfolding, wrapping and unwrapping. Prototypes that seemed successful were then converted to knit, using the Brother (model KH860) low tech hand-operated flat knitting machine. The first knitted probes seemed simple, highly unresolved: developed in wool, they combined different stitch architectures to create a nature fold. The materials and techniques in combination seemed to construct an inherent memory, which was embodied in the form, naturally guiding the user to fold the probe in on itself. As we experimented, each prototype in the knit series informed the next. The aim was to make them easy to use, but not too easy; in a form that lends itself to folding and unfolding and guides participants through a particular movement pathway. At one point we constructed a longer green knit probe. It was considerably harder to handle, and was not so obvious to refold. The effects of gravity were more pronounced, frustrating and interfering with the form's tendency to almost refold itself. We inserted magnets to help guide the user, nonetheless, the longer knit remained surprisingly challenging, and this changed how people engaged with it. More structural struts and magnets were added in key positions to assist people to engage with it. This outcome contributed to our ongoing discussions about the characteristics and potential of future materials.

The Green Knits demonstrate how iterative crafting is helping us to understand how we might think in more complex ways about more advanced materials. Not only are we making our ideas more tangible by crafting them into being, we are problem solving and asking questions of where the research might lead, unconstrained by a prior choice of material technology. Rather than working to constrained characteristics and potential behaviours, we can openly consider what material qualities we might desire. If shape memory yarns are added, for example, where and how would this material be best optimised? In many regards, the Green Knits represents the start of a more creative approach to 'future material' thinking. The benefit of future thinking through the presence of craft is an ongoing flexibility around material and technology choices. Craft was a meeting point for us, as researchers, to discuss and make ideas feel real and accessible. It enabled us to contribute equally, despite varied experiences and understandings of advanced materials. It also allowed for different contexts and personal meaning to be woven through our enquiry. Our prototypes become an invitation to innovate, allowing us freedom to go beyond known norms and values (Schrage, 2013). We hoped they might serve a similar purpose during our engagements with public participants.

The Green Knits are deceptively simple and drew people into the research. The different Knits seemed to elicit different cognitive behaviours: different ways of thinking, and of intertwining thinking and moving. This characteristic provides varied entry points, allowing for idiosyncratic ways of learning and engaging. We speculate that the Green Knits might be used as a tool for use in rehabilitation, not only to physically train the body but perhaps to stimulate more holistic body/mind integration. Crucially, the Knits have been kept very open as an idea, to allow us, as well as our participants to try, play and continually make suggestions about how they might evolve.

Blue Cushions

The Blue Cushions (Fig.1(b-c)) emerged from a conflation of insights gleaned during the motion capture sessions, the myotherapy expertise of the third author, and previous work by (Wilde & Andersen, 2009).

Emergent development process

Guided by the expertise of the third author, we began to consider how we might give people very different feelings as they make everyday gestures and movements – such as raising their arm, walking or sitting down – by applying soft pressures to nerve pathways and muscle groups using carefully positioned, custom made cushions. Opportunities to pressure different nerve and muscle groups to achieve various effects were identified. Wearable cushions were then created (see Wilde, Underwood and Pohlner, 2014 for details). The resulting accessories provide an unusual profile for the wearer, and from an observer's perspective the cushions seem to have little impact on movement. Yet the feeling of their effects experienced by wearers can be dramatic.

Sleeves

To further our investigation into providing people with unfamiliar (dis)abilities, we began experimenting with the notion of creating dynamically shifting wearable movement mazes. Two sleeves were created: one in which the maze is visible, but constantly shifting (Red and Black Sleeve (Fig.1(d)); and one in which the maze is stable, but hidden (Yellow Sleeve (Fig.1(e)).

Emergent development process

We began with a series of draping experiments, drawing on myotherapy, anatomy and garment engineering, while playing with the material characteristics of constructed textiles (felts), woven textiles and a range of elastics. Different physical structures were created by combining these textiles with the body: pinning and draping between body parts, experimenting with dynamically shifting poses and gestures. The end results were structures that the wearer could navigate in different ways by moving their arm.

The Sleeves help us better understand the kinds of experiences and feelings we might be able to prompt in wearers. Though as obstacles or impediments to a wearer's movement intentions, they have varying success. On the one hand, they seem to provoke strong reactions, but in their current form, the desire to engage is fleeting. Rather than being stimulating objects for regular wear, the sleeves serve better as objects for ephemeral experiences that afford deep reflection and discussion.

Four Lenses

Our craft-based knowledge, combined with our *no-tech* approach to prototyping provide us with four conceptual lenses that have proven invaluable:

1. An *approach* for working through the research ideas and engaging with the full potential of the intelligent materials and advanced technologies we intend to use.
2. An *expression* to materialise form and make tangible our research ideas for public testing, unconstrained by current technological capabilities.
3. A *dialog* with public participants enabled by the probes, and further augmented by responsive crafting of additions and modifications in situ.
4. A *language* to understand our emerging research structure and expand our vision for how it might evolve.

These lenses afford different ways of thinking about how to expand the research potential. They collectively enable us to remain in a state of unknowing, to draw participants into the process, and deepen our embodied inquiry into the development of material interactions.

Craft-based approach

Using our crafts as point of departure and guide opened up how our research could develop. It expanded the way we thought about exploring the potential of the materials we were working with, thus evolving our material consciousness (Adamson, 2007; Sennett, 2008). As noted by Sennett (2008), such an approach affords imaginative leaps and guides “towards what we sense is an unknown reality latent with possibility”.

This approach also seems to be supporting enriched participation. Compared to interim experiments in the lab, when our prototypes were presented in public participants entered the space highly curious and free of expectations, providing a ride variety of responses (Wild, Underwood & Pohlner, 2014). Many were drawn by the fact that we were crafting on site. As they interacted with the finished probes, we often responded by crafting modifications. The crafting on site created real time feedback loops between participants, our core research concerns and the probes.

Craft-based expression

Crafts' capacity to materialise form and spark curiosity (Sennett, 2008) helped make our research accessible to a diverse public. The emotional dimension of craft and crafting afforded extreme critical experimentation. Craft draws and connects people to memory and is deeply linked to traditions (Gordon, 2011). As such, crafts and craft-based artefacts are inherently accessible. Our crafts provided both a short term stopgap as well as a longer term vision for the project, allowing us to communicate ideas, explore material characteristics, and expand possibilities for engagement no matter how challenging the research ideas. Additionally, the ambiguous nature of the prototypes seemed to leave space for memory and emotion, as well as the potential for otherness (Gaver, 2003). The range of resolutions we worked with (different prototypes were more highly resolved in terms of their conceptual finish) provided space for varying levels of cognitive and physical engagement, reflection and play. The more open prototypes made space for participant interpretation, while the more resolved prototypes provided additional guidance, to better support critical engagement with our research ideas. Through direct engagement – trying things on and trying things out – understanding of the research concepts seemed to shift from abstract and intangible, to concrete understandings experienced directly by the body. This direct engagement afforded satisfaction to participants as they contributed their responses and thinking.

Craft-based dialogue

Our craft-based dialogues were fourfold: amongst ourselves, with our real and our imagined materials, and with participants. Through these dialogues we created a type of *craft circle*. As Ravetz (2013) states the social and performative nature of craft proves a rich site for inviting and opening up exchanges of ideas.

This process began with our prototyping in the lab, where the process of crafting dissolved our disciplinary boundaries. Coming from diverse backgrounds, with different skill sets and levels of experience with research, the action of crafting was essential to establish teamwork, collaboration and communication. It was a way to understand each other and exchange ideas quickly. Concepts would begin being formed by one of us and then move to someone else’s hands to be developed.

These dialogues also allowed us to develop future material thinking. As the green knits revealed, by working with our hands we were able to converse with potential future materials. *What do we need these materials to do? How might we work with them*?

Dialogues were further opened up with public presentation. By crafting on site, making responsive modifications and additions to our prototypes, we provided a recognisable space for storytelling and sharing (Gordon, 2011). Our actions kept the research ideas accessible, real and lively; allowing people to observe, linger, tell stories and ask questions: *My mother knitted, what's this about? Is this fashion...?* It was a highly social activity, a site for collaborative creativity and exchange.

Craft-based language

Moving forward, a metaphorical language based on the textile craft of weaving has emerged. This language is assisting us to deal with unknowns. We use it to scaffold an open, responsive research structure centred around public engagement. For example, we posited our participatory exhibit as a *loom*. Our *warp* was the dynamic constellation of our evolving probes, and our *weft* was the public's engagement and responses to these probes. Over the course of the exhibit we dynamically repositioned our *warp* elements within our *loom* to allow the *weft* to pass through in different formations and form an array of patterns. With this language, we are not only looking for a novel and accessible way to think about how to support engagement. We are using weaving to help us to weave metaphorical research cloths that may later be draped, folded or laid out in ways that privilege different perspectives, so that they might inform our thinking as the research moves forward.

Our weaving metaphor was not communicated to the public; rather it stayed in the background guiding our emergent decision-making, enriching our thinking and our engagements with the public. We see our metaphorical language of weaving as a type of *expressive instruction* (Sennett, 2008) that could be of use for others grappling with the challenges of multifaceted research into emerging materials and practices. An extended discussion of our metaphorical language is in development.

Discussion

Our embodied engagement with crafts is enabling us to prototype probes within an extremely fecund process, designed specifically to develop novel advanced material innovations. In line with Crotty (1998), the craft-based phenomenological perspective is enabling us to 'break with inherited understandings' and 'awaken fresh experience of the phenomena we [are] dealing with': varied ways of moving outside of a relatively constrained norm. Experience itself becomes our point of departure (Alvesson and Sköldberg, 2009: 76)

By crafting no-tech prototypes of varying resolutions, we have been able to create a space that is open enough for interpretation and increased interaction from a wide range of participants. Our research is as much a physical act, as it is social and discursive. It calls on phenomenological perspectives, as discussed in (Gallagher and Zahavi, 2008; Wilde, 2012), and foregrounds the valence of a critical research question when crafting critical design (Wilde, Underwood and Pohlner, 2014). But it is not only tightly articulated critical questions that elicit focused engagement from participants. The ability for participants to find themselves in research, to identify social and cultural relevance can be pivotal to engagement. For this, context is key.

In our process, the context is provided by the act of crafting. We leverage the richly varied characteristics of craft and crafting to shape the design of aesthetically and technically sophisticated, embodied, and advanced material interactions. Our different craft techniques and approaches are used to develop emergent prototypes, at varying stages of resolution, without the use of advanced technologies. The intention remains to be open to possibilities, rather than to tie down outcomes early in the research process – to bypass the adjacent digital possible, and leave space for meaning-making. This approach is enabling us to not only design advanced material interactions, but to design speculative interactions using yet-to-be-imagined materials and technologies for as-yet-unknown applications, and to probe the public as to what kinds of material innovations our prototypes might lead them to imagine.

Conclusion

The extended, reflective, embodied, craft-based approach to material innovation articulated here is expanding our research potential. The craft-based conceptual lenses – the *approach, expression, dialogue* and *language* – are supporting the development of novel *no*-tech prototypes at a range of resolutions. When used as probes, these prototypes are affording rich investigative, participatory experiments with a broad public. The process enabled us to craft a way through a challenging impasse that arose when our development resources went out of sync.

The case of PKI provides pertinent examples of how these perspectives play out in the field and why they might be useful for others. We hope the details we have provided serve to inform and inspire other researchers to experiment with similar approaches. As this process has provided us with an enriched understanding to better position us as we move forward.

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Temporal patterns – new forms of material thinking in Textile Design

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Abstract

This paper discusses a group of experiments *named rhythm exercise*. It is a series of experiments which is based within the field of Smart Textiles, especially in the area of light emitting textiles. *Rhythm exercise* is one series of experiments out of a larger body of work (Jansen, 2015a), exploring the visual effects of movement using light as a continuous time-based medium in the field of textile design. Thereby investigates to expand an understanding about time and light as new forms of design materials in the particular context area.

The experiments present new forms of instruments, textile instruments, interfaces which allow displaying light compositions inside diverse textile surfaces. The textiles are based on braided structures integrating PMMA optical fibres which are activated by light-emitting diodes (LEDs) and use a digital interface to realize light-emitting textile expression. They explore in different ways the light emitting material, thereby not only creating new forms of physical objects, furthermore introducing tangible (physical) as well as intangible (non-physical) aspects of design expression – forms of material expressions, the light emitting fibres and the light as such, and its preceding design processes. Thereby the tangible and intangible forms of material expressions are fused into indivisible matter performing unique forms of expressions.

Keywords

time; light; movement; PMMA optical fibres; textiles

Rhythm exercise is a series of experiments out of a larger body of work, which extensively explores to expand an understanding about time and light as new forms of design materials, in order to allow designers to compose time-based patterns when designing light integrated into textile structures. The experiments are routed in the question: What does it mean, if time and change – constant movement – become part of the textile design expression? Thereby, the textile design pattern reveals its composition, not in one moment of time any more, but in fact over time. This practice based research work aims to create time-based textiles with an emphasis on developing aesthetics of movement – or to establish movement as an aesthetic moment in textile design.

Thereby *rhythm exercise* is specifically looking at the creation of rhythmic light sequences, whereas the design aim is to examine different ways of dividing time to facilitate the creation of different rhythms, speeds, dynamics and tensions in the composition of movement, using monochrome white light. The paper is based on extracts of the PhD thesis *Composing over time, temporal patterns – in Textile Design* (Jansen, 2015a).

Prelude

Textiles - Smart Textiles

With the beginning of the era of Smart Textiles, the textile designer is challenged with a range of materials which are characterized by their ability to change expressional and functional properties. These materials respond to environmental stimuli, user interaction and pre-programmed parameters and visualize their responses to the viewer. They open up opportunities to explore new material behaviours and designing with novel and complex aesthetics (Berzina, 2011; Krogh, N.D.; Layne, N.D.; Taylor, 2010; Wingfield, N.D.; Worbin, 2010) The availability of these new materials changes the conditions of conventional textile design; a textile pattern expression is no longer static, it once had one face, one gestalt or expression, whereas now it can show different expressions, a definite or indefinite number of times.

Up until recently the physical dimension of a textile piece, together with a specific design brief for expression and functional needs, set the parameters that frame the design work. The created textile expressions and functions are supposed to be static, stay the same, over the lifespan of the created textile object.

Introducing a new generation of materials, raises the challenge to design several different expressions that appear one after the other over time. Even though early experiments have described the individual static expressions which appear at different moments in time, for example by the use of thermochromic colour change dye systems (Cf. Worbin, 2006, 2010), however those are rather looked at as frozen moments in time instead in the context of a fluid time progression. Although were has been created a big range of projects where time as a design element has been started to be explored in practice, it has not always been pointed out as such (Berzina, 2011; Gullickson, 2012; Hauan Johnsen, 2008, 2012; Hietanen, N.D.; Iversen, N.D.; Krogh, N.D.; Layne, N.D.; Ligorano, 2010; Taylor, 2010; Wingfield, N.D.; Worbin, 2010). There still exists a gap of documentation which formulates different ways of how to design over time with these new forms of materials in the context of textile design. And actually placing the temporal aspects of design at the centre and beginning of the design process.

Therefore the work presented in this paper places time and the temporal frame, within which changes will occur at the starting point of the design. Furthermore the research work presented aims to expand and document an understanding about time as a design material, in order to allow designers to compose time-based patterns when designing light integrated into textile structures.

Light -Textiles - Expressions

Integration of light into textile surfaces opens up new possibilities in lighting design, as textile surfaces are flexible as media and materials. In recent years, a range of light-emitting materials have been investigated in textile applications by artists, designers, researchers and companies. The integration of LEDs, electroluminescent wires, fluorescent and phosphorescent materials, as well as optical fibres have been tested and first prototypes, art pieces, site-specific installations and products have reached different audiences and the market, both craft and industrially produced (Glofab, N.D.; Gullickson, 2012; Hauan Johnsen, 2008, 2012; Iversen, N.D.; Krogh, N.D.; Layne, N.D.; LBM, N.D.; Ligorano, 2010; Lumalive, 2004-2008; Luminex, N.D.; Wingfield, N.D.; Worbin, 2010).

Each of the light-emitting materials supports different forms of light expressions. Three main forms of expressions can be observed and created inside textile structures: dotted, pixel like (created via LEDs), linear (created via electroluminescent wire or optical fibres), and even light surface (created via electroluminescent film or optical fibres). For example the work of Barbara Layne (Layne, N.D.) features messages emitted via LEDs embedded in woven structures, *Spår* (Traces) by Anna Persson and Linda Worbin (Worbin, 2010) incorporates electroluminescent wire inside woven carpet, as well as *Moonlighter* by Delia Dumitrescu (Dumitrescu, 2013) inside a knitted structure. *Dimma* (Foggy) by Persson and Worbin

(Worbin, 2010) involves electroluminescent film under a tufted structure and *Inner Light* by Sarah Taylor (Taylor, 2010), *Ikat I-III* by Astrid Krogh (Krogh, N.D.) and works by Barbara Jansen (Jansen, 2007, 2008b, 2009, 2015a) involves integration of optical fibres inside woven structures.

Lighting Material

The light-emitting material used in *rhythm exercise* is PMMA (PolyMethylMeta-Acrylate) optical fibres. They have been integrated into hand braided structures, and emit light through the use of white LEDs which are controlled by microcontroller digital interface.

Lighting System

There is currently no standard LED system on the market that is able to connect to textile applications (incorporating optical fibres). The present work uses a special customized LED lighting device system, which has been developed in collaboration with UK based electronic specialists, Circatron Ltd. It is a further developed version of the lighting device system used by Sarah Taylor for *Inner Light* (Taylor, 2010). The system allows coupling of the optical fibre ends to the LEDs and a digital Mix (DMX) replay system controls the lighting sequence via various programming processes, facilitating the research work presented in this paper.

Textile Lighting Quality

PMMA optical fibres are from a design perspective interesting to use as a light-emitting material in a textile context, as they are in their appearance quite close to a transparent thread. Using a “light thread” offers an opportunity to make light become a textile piece in itself. In this way light and textile structure melt into each other and become indivisible.

As the fibres are nothing more than light-transmitting media they may be connected to a range of different light sources. The light-emitting textile surfaces could be connected directly to daylight for example through the Parans Solar System (Jansen, 2008a, p. 8, 14, 42; Parans, N.D.) or to diverse artificial light sources. Allowing to generate a vaiety of light qualities (warm to cold white light, coloured light, etc.), besides that to create varaiations of light quality in one surface area, as well as over time.

Rhythm Exercise

Introduction

Rhythm exercise looks into different ways of dividing time to facilitate the creation of different rhythms, speeds, dynamics and tensions in the composition of moving white light. Play and pause, i.e. activity in the form of movement and silence in the form of the absence of movement, and how these two states interrelate create the foundation for a specific feeling of rhythm, speed, dynamics, etc.

In the following, descriptions of the experiments, the metaphor of *instrument* and *composition* will be used. Each textile structure (in this case braided structures) is understood as an *instrument* on which various *compositions*, i.e. light sequences, can be played. A *composition* can consist of one or several voices, one or several sections activated independently in the textile structure. Thus, each voice can play its own melody or play in unison with other voices.

Experimental Set-up:

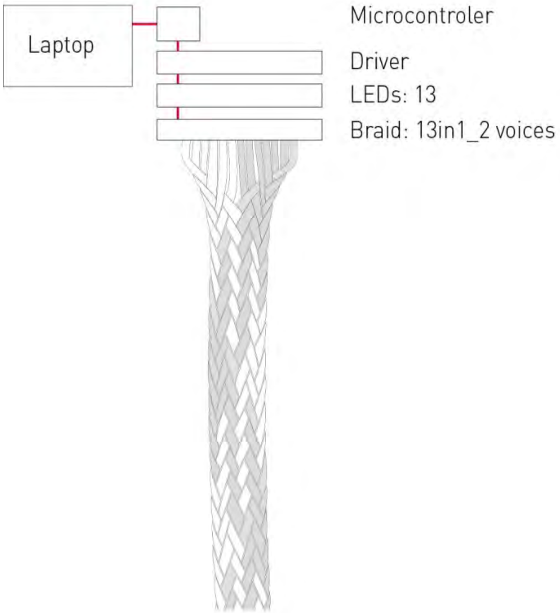

Fig 1. Rhythm exercise_part 1

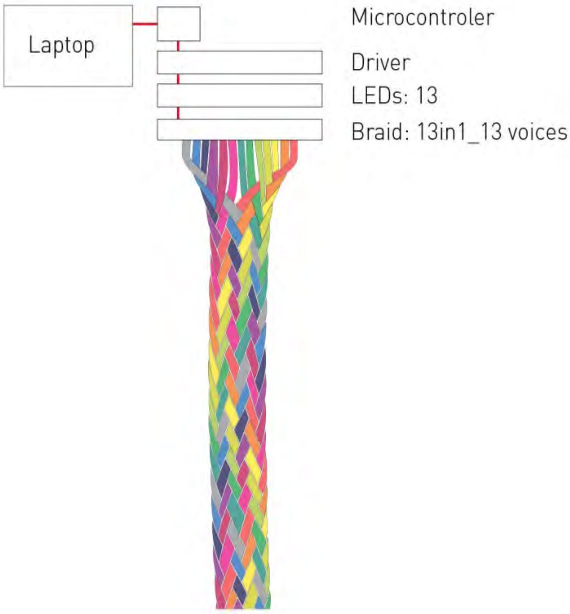

Fig 2. Rhythm exercise_part 3

Instrument = tangible means of design expression

Hand braided structures: each braid is based on thirteen strings of PMMA optical fibres, the individually strings are connected to white LEDs and individually programmable to create moving patterns of white light using a microcontroller and a digital interface. Meaning this instrument consists of thirteen voices. They can be either played in unison, activated at the same time; one monochrome lighting surface appears or play their own melody creating moving patterns of white light inside the surface structure.

In the case of *rhythm exercise* the Arduino programming has been used. The developed code facilitates individual control of thirteen LEDs [thirteen DMX channels]. Thus, each LED/voice can be activated independently and given its very own rhythm. When the light sequence of one LED has been run once, it automatically enters into an endless series of repetitions with an identical modus.

Function of LED

Generally spoken there are two ways in which a LED can be switched on or off: via *holding time*, the change of light intensity occurs in distinct steps and via *fading time*, the change of light intensity occurs through a dimming/fading process within a scale range, or a combination between *holding* and *fading* time appears, see figures 3-5.

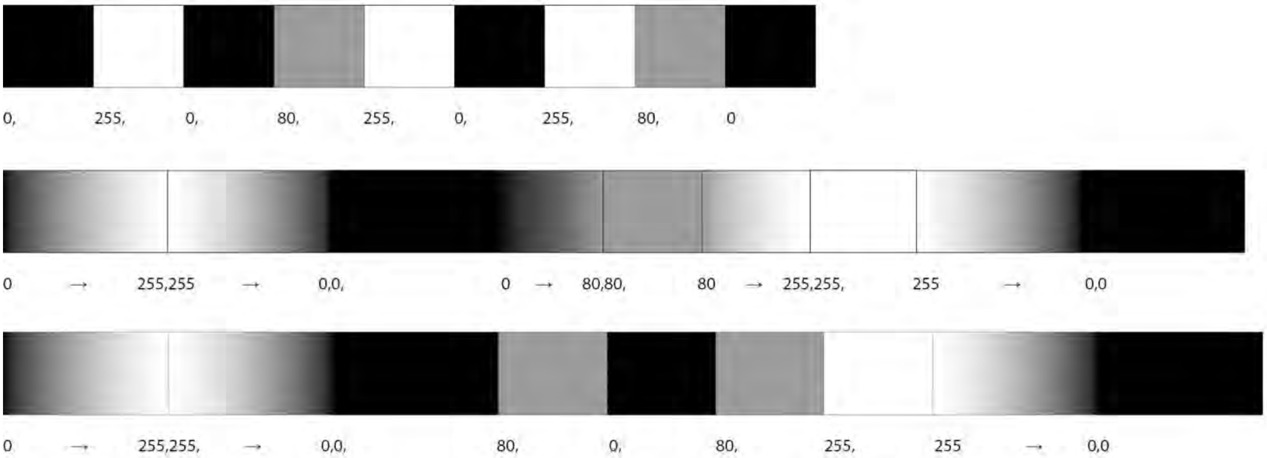

Fig 3-5. Light being switched on and off: via holding time; fading time; holding + fading time

Notation system - a way of designing

The following signs have been used as a basic notation system to allow thinking and developing time-based rhythmic structures. The height of a horizontal line represents the level of intensity of the light (pitch height in musical notation) and its length represents the time duration of the light at the indicated intensity. The diagonal lines represent fading between different light intensity levels. The height at the beginning and end of the diagonal line define light intensity and the horizontal length time duration (see example figure 6). The vertical lines at the beginning and end of a sequence mark the beginning and end of each sequence or phrase. One or several voices inside one composition are connected via the vertical line at the beginning of the composition. The two dots indicate a repetition of the previous phrase, the two dots and the infinity symbol on top of the vertical lines an endless identical repetition of the preceding phrase.

Fig 6. Example of notation of two voices playing parallel

Composition = intangible means of design expressions

In six series of experiments the creation of moving white light patterns has been explored. In the following *rhythm exercise_part 1* and *_part 3* will be shortly introduced. *Rhythm exercise_part 1* as an opening exploring short movement patterns/phrases and *rhythm exercise_part 3* is an elaboration on building more complex moving light composition based on several successive parts.

In *rhythm exercise_part 1*, the initial group of experiments the thirteen strings of the braided structure were divided in two groups and treated as two voices. Either the full braid is lit on or off or the right or left half of the structure is lit on or off, exploring a basic combination of *holding* and *fading times*.

The nine individual rhythms of *rhythm exercise_part 1* are based on a ground beat of one second. All rhythms are based on two voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms, see figures 7-9 (Cf. Jansen, 2015a, page 85ff and Appendix 2: Poster 2).

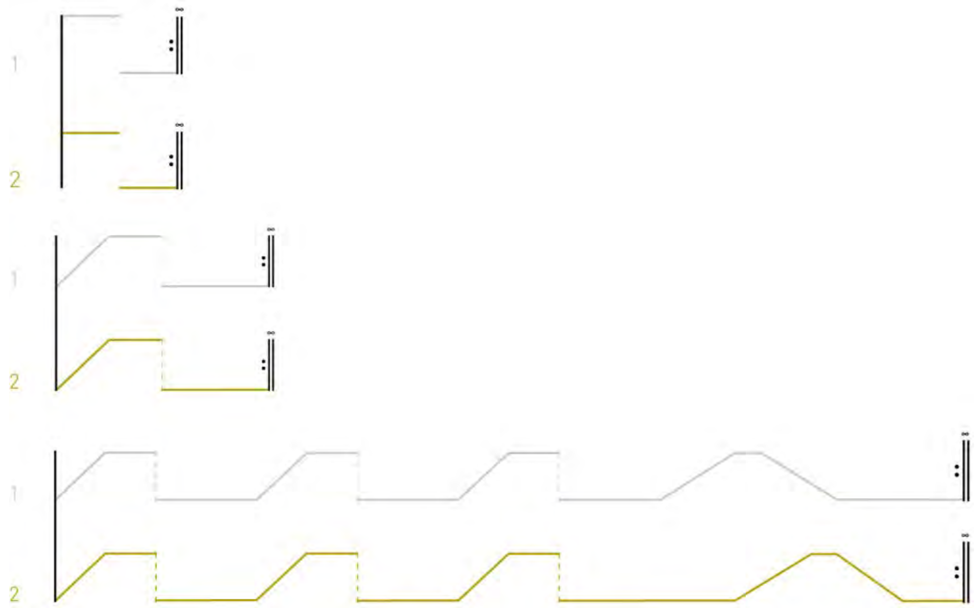

Fig 7-9. Rhythm exercise_part 1_1; rhythm exercise_part 1_6; rhythm exercise_part 1_9: each notation shows two voices parallel

In *rhythm exercise_part 3* all thirteen strings/voices of the structure are activated and treated as individual voices, an elaboration on building a more complex composition based on three parts. Part one is a long progression phase of twelve mini phrases played behind each other, thereby the ground beat of 500 milliseconds is the continuous metrum, displaying an increasing scale from “step by step → wavelike” expression. *Phrase 1*: every LED turns on and off, “step by step”-like, in a blinking manner. Thereby the time duration of the LED being on is 500 milliseconds. *Phrase 2:* every LED is turned on, “step by step”-like, holds for 500 milliseconds, and then fades out over a period of 500 milliseconds*. Phrase 3*: every LED is turned on by fading in over 500 milliseconds, holding 500 milliseconds, and fading out over a period 5000 milliseconds. *Phrase 4 – 12:* the time periods for fading in, holding, and fading out are extended for each phrase by 500 milliseconds until they all reach 2000 milliseconds (see figure 10).

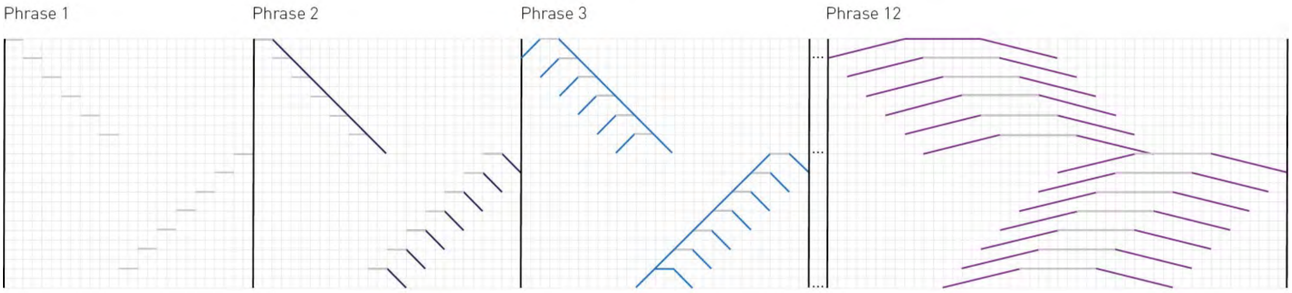

Fig 10. *Rhythm exercise_part 3:* part one: thirteen voices parallel

Part two plays with variation of part one *“step by step → wavelike”,* thereby the 12 mini phrases are each divided in two parts (LEDs/voices 1-6 + 7-12) and counter posed to each other in order. The following order is performed: *Phrase 1/LEDs 1-6* + *Phrase 12/LEDs 7-12, Phrase 2/LEDs 1-6* + *Phrase 11/LEDs 7-12, Phrase 3/LEDs 1-6* + *Phrase 10/LEDs 7-12, Phrase 4/LEDs 1-6* + *Phrase 9/LEDs 7-12, Phrase 5/LEDs 1-6* + *Phrase 8/LEDs 7-12, Phrase 6/LEDs 1-6* + *Phrase 7/LEDs 7-1* (see figure 11).

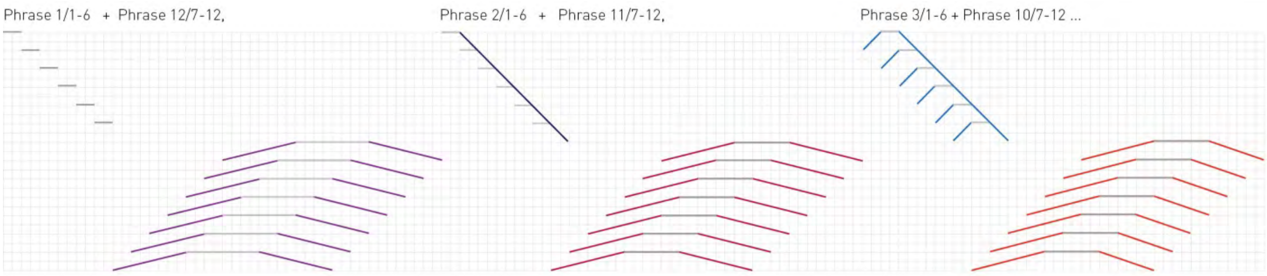

Fig 11. *Rhythm exercise_part 3:* part two: thirteen voices parallel

Part three: “*mistaken*”: is a further variation of the composition from “*step by step → wavelike*”. In the initial coding of the composition “*step by step → wavelike*” major mistakes were made. For example, two voices became “independent” and played a cross-rhythm to the other voices. Moreover, one of them created a time-overlap, meaning that voice twelve is still playing *part three* when all other voices go back to play *parts one* and *two* again. Hence, from here onwards will appear an endless number of variations of the original phrase. (Cf. Jansen, 2015a, Appendix 2: Poster 3, video of *rhythm exercise_part 3* in Jansen 2015b, page 112.)

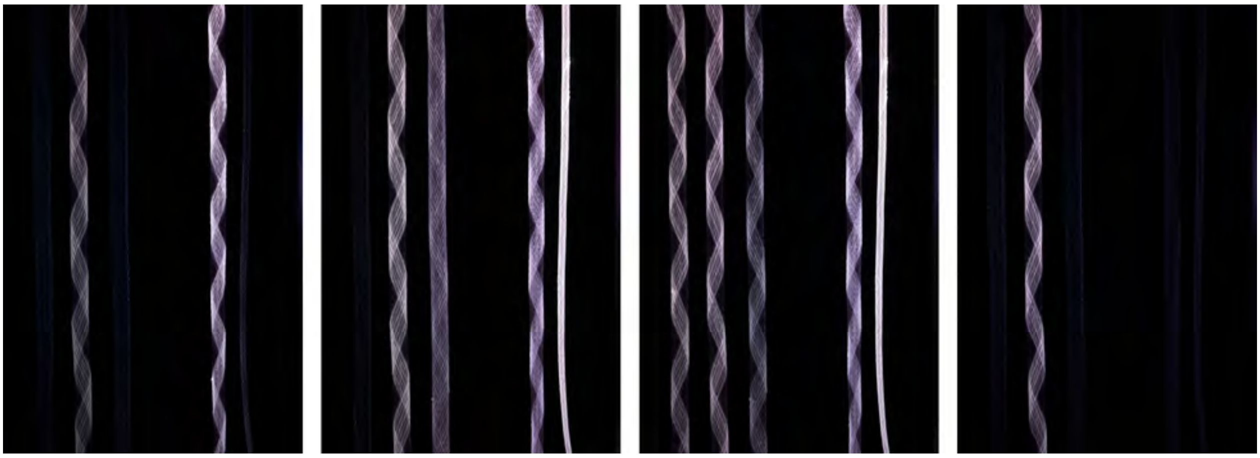

Fig 12. Four stills of five braids playing a composition based on r*hythm exercise_part 1:* each braid plays with two voices

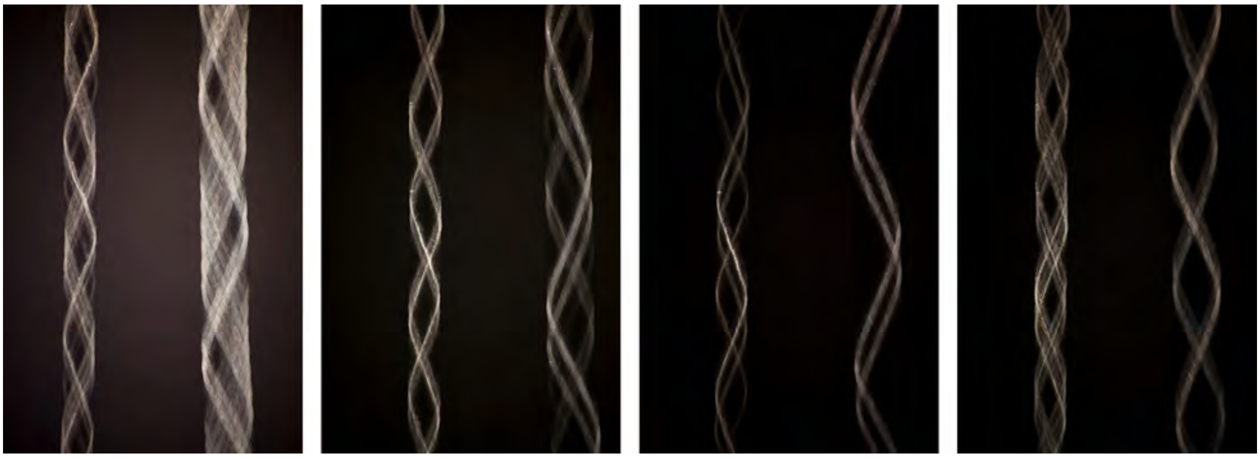

Fig 13. Four stills of two braids playing a composition based on a further development of *rhythm exercise_part 3:* each braid plays with thirteen voices

Discussion

Composition – Pattern

Traditionally a textile design expression is built up through the composition of colour, form (2D and 3D), structure, touch/haptic and materiality. Usually a visual/pattern composition, inside or on top of the textile structure (created by weaving, knitting, printing, etc.) is built up through:

Pattern elements: single forms and lines: circle, square, triangle, ...

Pattern units: several pattern elements defining a group, or a group of pattern elements

Pattern composition: one form, or one pattern unit, or several pattern units create the overall pattern

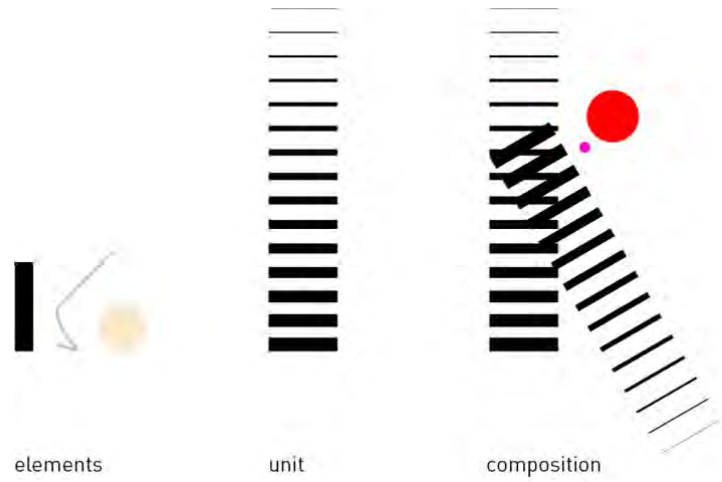

Fig 14. Pattern elements for traditional forms of textile design

The way in which one or more pattern elements are arranged, positioned and repeated creates a “direction” in the pattern as well as an overall aesthetic/expression, an overall composition of the pattern. However, what happens if time and changing forms of expression are introduced into the textile design expression, e.g. in the form of constant change and moving artificial light?

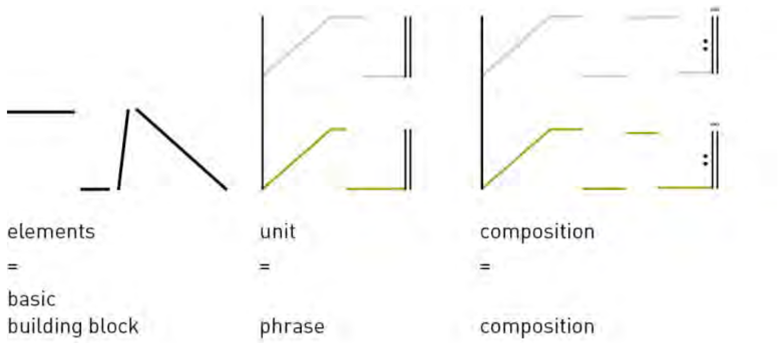

Fig 15. Pattern elements for time-based forms of textile design

The most elementary part, element or building block used to create a time-based pattern using light is switching the light on or off. There are only two forms of expressions the light can take on: switched on via *holding* or *fading time* or switched off via *holding* or *fading time*. A pattern unit, a phrase is created through an episode of either *holding* or *fading times*, or a combination of these. Already with these basic elements, a rhythmic structure of time and movement in the structure (using a minimum of two voices) can be created. One building block or one or several phrases create the overall composition. Thereby, the overall composition is formed by a series of unique or repeated phrases.

Composing – Notions

In order to be able to describe these new time-based expressions and to compose over time, new *notions* (definitions) and *design variables*, i.e. elements to design with, have been defined in the context of time-based textiles.

Intangible Variables:
(non-physical variables)

Light	needed	Tempo	create
Darkness	in order	Rhythm	overall
Light intensity	to create	Time	composition/
Colour		Movement	expression
Duration			

Notions:

+

Tangible Variables:
(physical variables)

textile structure

[colour,	
form,	traditional
structure (weaving or braiding),	Design Variables
touch/haptic,	
materiality]	

Fig 16. Variables and Notions

Instrument - Composition

During the research process, it became very clear that the time-based composition is not alone in defining the final expression. The textile structure displaying or playing the time-based composition is equally important: both of them equal influence the movement expression. Now, one could say that the textile design/composition is based on two main elements: the *instrument* and the *composition*. Each specific instrument has its possibilities and limitations, wherewith it sets the frame for the temporal compositions. It defines the amount of possible voices inside one instrument, as well as the form the light is shaped to inside the structure, i.e. the instrument.

For example: a braided structure which is based on thirteen strings has its maximum capacity to play with thirteen voices. Thereby a smaller amount of voices is possible, in case several voices are connected to one light source. The individual voices are shaped in wave-like lines throughout the whole length of the structure. The voices can be played in chronological or non-chronological order, this and the shape of the voice creates a specific movement form and character.

Only when a specific *composition* is played on a particular *instrument* a certain expression is created. Several expressions can be created through/on one instrument when different compositions are played on it. A specific shaped instrument lays the foundation for the intangible matter, non-physical material to act, to move, to express itself, the light.'

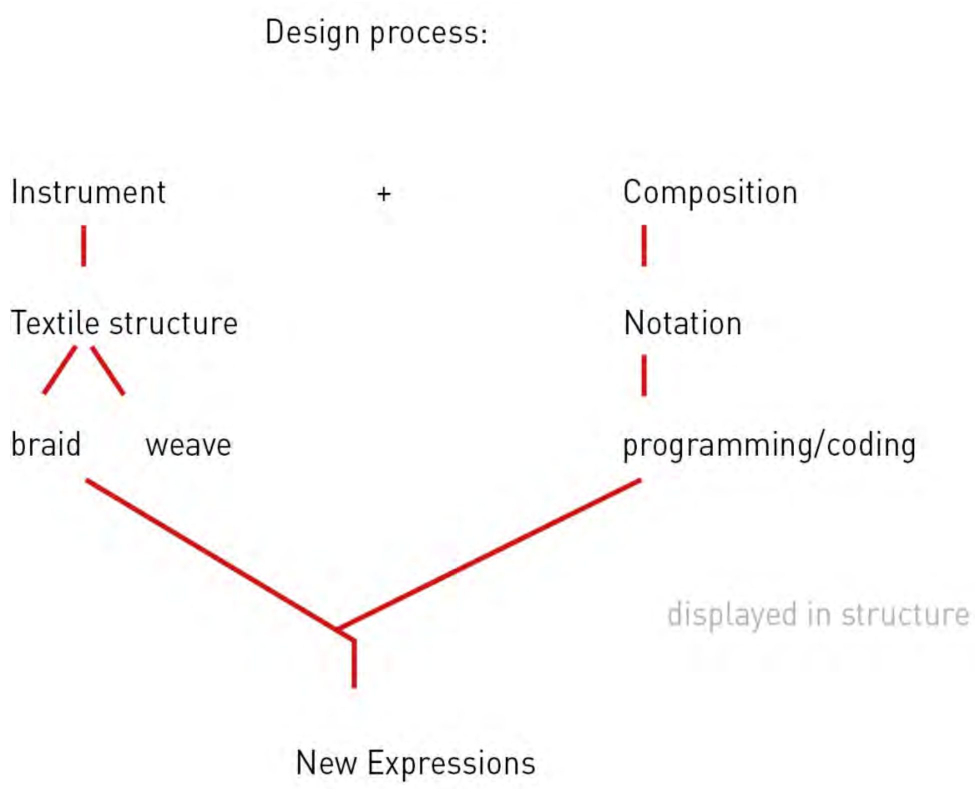

Fig 17. Instrument – Composition

Coda

Concluding the research work conducted has resulted in a series of objects that display a range of time-based light patterns/compositions inside textile structures, thereby, demonstrating a variety of new expressional possibilities in the field of textile light design.

The experiments propose new ways of thinking whilst designing with changeable material expressions. Light and Time, both used as tangible and intangible forms of material (optical fibres/LEDs and light, programmed time duration and changing form of expression over time) create instruments (textile structure) and compositions (lighting sequences), fused into indivisible matter performing unique forms of expressions.

Coming back to my initial research question: What does it mean, if time and change – constant movement – becomes part of the textile design expression? Through the design processes a first platform and understanding about time as a design material has been developed, which allows composing time-based patterns in light design. New design variables (light, darkness, light intensity, light colour and duration), notions (tempo, rhythm, time and movement) and tools (notations, programming, etc.) have been defined and established.

The use of new design variables (light, darkness, light intensity, light colour, and duration) immediately requires new ways of working and, therewith, opens up towards new ways of design thinking whilst working with temporal forms of design and composition, especially by the use of light emitting materials and light sources. The most important tool to the creation of complex rhythmic light patterns in monochrome lighting from the design point of view was hand written notations done in order to pre-vision time-events, i.e. movements of light inside textile structures. Whereas programming (via Arduino coding) became the most important tool for technical realisation into physical matter. Furthermore, the use of new design variables lead to new forms of expressions that add new expressional qualities to the textile designer's palette, like tempo, rhythm, time and movement.

The new expressions will hopefully lead to discussions on and envisioning of future textiles. Through my research work I wish to "expand notions of what it means to read a piece of work" (Koskinen, 2008, p.19 (31)). Exposing new textile expressions to an audience and in public spaces provides opportunities to open up an general preconception of what a textile is supposed to be, to show, to express, etc., therefore expands *notions of what it means to read a piece of textile work*. Throughout the entire PhD such platforms have been approached. Art, design practice and research create new human experiences. The displayed objects perform new expressions and therefore create new experiences, new insights, understandings and knowledge about the world of textiles. Adding the time perspective of the work makes it necessary for the viewer to expose himself or herself to the work for a certain period of time.

It remains a challenge to communicate the full scope of achievement in the frame of disseminating a written form of documentation, as both the created expressions, as well the process of making reach beyond linguistic matter. Even though the paper and especially the thesis it is based on, is accompanied richly with in-depth graphic material and video. (Jansen, 2015a, Jansen, 2015b) New forms of tangible and intangible materials and expressions call for new forms of communications. It remains my hope that we continue striving for them into the future. Might our next dialogue be accompanied by tangible and intangible means in order for you to actually really understand what I am talking about.

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Figures

Figure 1-11: by Author.

Figure 12-13: photgrapher Henrik Bengtsson

Barbara Jansen

Barbara Jansen is a textile designer whose design research aims to explore the interaction between textiles, light, movement and time. Jansen has recently graduated with a PhD in Textile Design from the Swedish School of Textiles, University of Borås/Sweden. Furthermore she has a MA in Textile Design from The Swedish School of Textiles, University of Borås/Sweden and a Diploma in Textile and Surface Design from the School of Art and Design Berlin Weißensee/ Germany. In addition, she spent one year studying the fine arts under Prof. Apolonija Šušteršič at the Royal Institute of Art in Stockholm/Sweden and has been a guest researcher at the School of Textile and Design, Heriot-Watt University/UK, the College of Arts and Humanities, University of Brighton/UK and the Architectural Lighting Lab at the Royal Danish Academy of Fine Arts, School of Architecture/Denmark. Her early steps into the world of textiles have been as a travelling apprentice at different textile craft ateliers in Germany and Switzerland.

RE: VIEWING fashion: A digital materiality of the moving image

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Abstract

The paper addresses the development of a digital-visual methodology to examine the sensuous and embodied dimension of fashion. The paper discusses the conception and use of designed garments called DRESS⁺. Body-garment interactions are the central focus of this research, conceived as participatory activities generating a range of physical movements including behaviour, gestures and utterances for visual and thematic enquiry. This approach is presented in relation to *Design Probes* and emergent new media forms notably *Fashion film.*

The paper considers two video case studies. The paper utilizes a phenomenological orientation and research from the field of Body Studies, specifically the notion of *Affect*. The studies seek to bring the materiality of the garment into view. Materiality is considered not in isolation, but in its reciprocity with the human body. In this regard, materiality is conceived in terms of the responsiveness of the human body and the potential for research participants to embody garments.

I outline the research design, including discussion of the design instruments as well as a discussion of their methodological rationale. The video studies are undertaken as a visual enquiry into the interaction between designed fashion garments and human beings. I discuss these in terms of the way in which they visualize the materiality of the fashion garment in relation to micro-corporeal movement. The studies provide an alternative to conventional representational treatments of the body in fashion; particularly the way bodies and garments are shown in lived-body time. They run counter to the dominant representations of fashionable bodies as symbolic, immaterial and a-temporal. I conclude the paper with discussion on the significance of the bodies depicted in the visual studies. The studies critically respond to the way in which habitual and embodied aspects of dress practices are largely absent in the field of fashion studies. I argue in the context of the research that participants orient themselves *meaningfully* and *corporeally* to find a kind of situated equilibrium with the garment and I conclude by arguing moving imagery conceived in a digital-visual context has potential to transcend immaterial bodies-as-images by revealing the embodied, sensuous and materially inflected dimension to being dressed. This has implications for the development of innovative research within the field of fashion.

Key words

Fashion; body; materiality; design probes; visual methodology; fashion film; affect

Introduction

This paper presents research addressing sensuous and embodied aspects of fashion and dress. This study presented relates to a broader research enquiry into potential role of fashion film in communicating the materially inflected dimension of being dressed in garments. In this paper, I argue digital technologies in the context of experimental fashion practice have the potential to reconfigure understandings of the body by bringing into view aspects of the interaction between garments and bodies that under normal viewing conditions are imperceptible. In doing so I seek to highlight the materiality of the fashion garment as a catalyst for human movement and meaning. While in the context of fashion, new media products such as for internet 'Fashion Film' have enabled new possibilities for viewing fashion, to date they have been deployed in largely conventional affirmation of the body as immaterial image, sign or symbol at the expense of the embodied and material dimension of fashion.

Background

Contemporary fashion is a heterogeneous affair, yet over the last decade digital technologies have brought about shifts in the way fashion is produced, represented and experienced. Fashion film popularised by online portal *SHOWStudio* is now an ubiquitous element within the fashion landscape. Its development has mirrored the expansion of the internet and digital media technologies.

The fashion film has recently been the subject of critical attention (Khan, 2012, 2013; Uhlihrova, 2013) as has fashion's relationship to digital culture (Rocamora, 2014; Shinkle, 2013). These texts locate fashion film in relation to cultural and technological predecessors; cinema and fashion photography. They also seek to place fashion film within a paradigm typified by increased interactivity and participation.

Khan's *Cutting the Fashion Body: Why the Fashion Image Is No Longer Still* (2012) places fashion films within a digital context, arguing they offer novel experiences of fashion, time and imagery. Drawing upon Showstudio's 'The Fashioned Body', she Khan argues the relationship between movement and stillness typified in representations of the body in fashion film reflect "a permanent presence" (Manovich, 2001) thus creating new modes of fashion spectatorship and temporality.

The body in fashion film remains the central motif. Khan (2012) argues the body moves from the photographic to the digital moving image it undergoes a transformation from the iconic to the symbolic. She suggests this has implications for fashion's relationship with time and spectatorship, yet the body remains in the realm of the imaginary or immaterial. In this sense it could be argued that fashion film tends to affirm rather than challenge conceptions of bodies as they undergo transformation from carnate bodies into symbols.

Nascent within new media forms lies potential for expression of the tactile and affective. Uhilorova (2013) points to an affective spectatorship with reference to film theory and Deleuze's notion of movement-images. Fashion on screen possesses the potential not only to be poetic and impressionistic but also to "touch" the viewer via tactile and emotional affects. Yet fashion's current visual practices and attachment to conceptions of bodies as images and symbols preserve an incorporeal stance.

Alternatively Fashion Film as an emergent new media fashion not only enables new ways of viewing and consuming fashion but also novel ways to create, conceive and conceptualise the fashionable body. The ability of digital media technology to capture, re-view, re-frame and manipulate the moving image enables an extended examination of the interaction between bodies and garments. On is then able to recalibrate how we understand bodies through digital media's capacity to identify, emphasize and amplify particular aspects of body-dress interaction that would otherwise go unnoticed.

Dress$^{+:}$ Fashion Design Probes

The project utilises Fashion probes called DRESS^{+}. These are a range of garments that contain beads in pockets and pouches within the garment design. They are provided to participants to wear over a short period. These *Fashion Probes* generate and enable the capture of data that can subsequently be examined for research purposes. Participants take part in an initial 'try-on' session documented using digital video. The approach draws upon precedents in Sensory Ethnography (Pink, 2009) and Design Research practice via the use of Design Probes (A. Dunne & Raby, 2001)

Design Probes emerged in relation to a 'Critical Turn' in Design in the mid 1990s[1]. Critical Design explicitly questioned the underlying assumptions of design practice and industry, in relation to the development of electronic products (A. Dunne & Raby, 2001). This focus has since expanded to encompass a range of disciplines, concerns and practitioners embracing the participatory, critical and speculative . Di Salvo identifies the underlying motivation as "making visible and known the complex situations of contemporary society, so that people might take action on those situations" (2009, p. 49).

Design Probes were originated by Gaver, Dunne & Pascenti (1999) and utilised ambiguity to elicit responses from participants that might inspire design. They reconceptualise the designed object and provoke oblique and idiosyncratic perspectives within participatory research contexts. Rather than fulfill functional purposes Design Probes engage participants in activities that produce data for qualitative interpretation. Responses are returned for interpretation and to catalyse new perspectives on an issue. In this sense "inspirational data" is desired rather than an "objective" perspective (Gaver et al., 1999, p. 25). Following this intent Dress+ are designed to be open and ambiguous, to provoke a range of interpretive responses consisting of bodily movements and talk.

While Design probes have been mobilized broadly within the HCI community and into wearable forms (Wilde & Andersen, 2009) they are less prevalent in the Fashion Research which arguably has been slower to address the embodied and sensory aspects of dress (Candy, 2005) or develop research programs addressing contexts of use or participatory methods (Von Busch, 2007).

DRESS+ elicit behaviour, gestures, movements and utterances that can be documented, reflected upon and examined. DRESS + brings into consideration the way in which wearing fashion is a material practice with a sensory dimension. The sensory and embodied emphasis of sensory ethnography seeks to bring into view often aspects of sensory experience often marginalised a by the focus on speaking subjects (Pink, 2009).

This capacity to generate phenomena can be understood in relation to design probe's capacity to bring into view, or for consideration, perspectives we would not normally be aware of. Michael characterises this approach as an "ethos" of creating artefacts that produce unlikely or 'unexpected relationalities that "de-sign" or "ambiguate" the conventional significations of the object (2012, p. 178) . That is, design probes challenge conventionally understood meanings of objects, and the relationships in which they are held. DRESS [+] problematize conventional understandings of the fashion garment as image-objects, that is designed thing primarily for visual consumption.

Dress+ : A phenomenological rationale

Participants in the study include five women and one male. They are drawn from networks across cultural, arts and university sectors. Each participant exhibits a sense of personal style, appears sensitive to fashion and engages in practices of self-styling. The participants are invited to try on and wear one of the garments from the DRESS + range and to take the garment away, then wear them two to three times over a fortnight period. The initial try-on session is documented using digital video, while the participants take part in a post-wear video interview on the completion of the wearing period. An edited video package of the try-on session is also produced and presented to participants at the post-wear interview session.

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1 The critical turn was heralded by the publication of Anthony Dunne's *Hertzian tales: electronic products, aesthetic experience and critical design* (1990).

DRESS+ items are designed to interact with the somatic and experiential rhythms of embodied life. The approach is informed by Leder's account of embodiment which provides insightful perspectives on the way the human body is experienced as a dynamic interplay of absence and presence (1990). For much of the time, the human body withdraws from explicit awareness, while we become acutely aware of our bodies in moments of fatigue, illness, injury, sexual expression and learning.

DRESS^{+} is designed to elicit a form of somatic reflection. Somatic reflection is defined as the first-person or felt dimension of embodied experience, from a phenomenological perspective. This can transpire on a conscious or non-conscious level. Sensations associated with body-garment interaction can lead to conscious reflection on bodily experience.

Alternatively, the video case studies capture the non-conscious dimension to reflection, which is reflected in the bodily movements, actions and gestures that take place outside conscious thematic awareness. There movements are the kind of embodied responsiveness and adjustment people makes in response to novel context/situation they are in. In this sense the 'try-on' sessions produce bodily responses, although these may not necessarily be conscious or intentional. These are movements that in conventional situations would not necessarily be noticed. For example people undertake a broad range of actions in an absent minded or non-conscious way. In post-wear interview when participants are shown a video of the initial try on session, they are often unable to reflect on the significance on their own movements, thus tending to confirm the non-conscious dimension to much body and garment interaction. In addition the try-on sessions are conducted with no mirrors being made available to the participants, thus denying the potential for them to observe how they look.

Somatic interpretation

While each of the garments operate at a conventional level of fashion meaning, as forms of apparel with all the customary significations of aesthetics and functionality in place, the integration of the beads problematizes this reading of the fashion garment. The beads are located on the back of the dress and top, in a small pouch or in overly deep pockets within a pleated skirt. The objective of the beads is to produce an anomaly within the conventional experience of wearing. This generates a requirement that participants interpret the garment, as they must put on, wear, and come to terms with the garment and its anomalous aspect. The video studies that are the subject of this paper feature participants wearing DRESS + for the first time. A range of movements can be characterised as a process of incorporating the dress into their embodied habits and attitudes.

Interpretation, as conceived here, draws on the phenomenological perspective that interpretation need not be exclusively a cognitive or mental activity but operates as a pre-reflective, non-thematic modality of coping in our everyday activities (H. Dreyfus, 1991, p. 3) In this sense all practical activity can be understood as intelligent and is underpinned by the embodied interpretive effort that is at once bodily and non-conscious. This intelligence underpins all human skilful action. Philosopher Merleau-Ponty argued human movement is primarily meaningful, accounting for it in terms of a human's *motor intentionality* (1962, p. 158). This intentionality renders the material impedimenta human beings come into contact with, meaningful and significant in terms of bodily capacity and skills. Human movement is underpinned by the body's pursuit of certain implicit objectives through material engagements that comprise human life, ranging from ordinary and commonplace activities of eating, reading, or talking to highly complex technical or artistic feats.

Within human existence Merleau-Ponty identified a propensity to find an optimum position within our perceptual and practical activities. He argued human beings do not encounter the world as some kind frictionless environment; rather novelty, resistance and human learning characterize the environment. Merleau-Ponty characterized two features to account for the success of embodied life, *maximal grip and the intentional arc* (1962, p. 157). He describes the maxminal grip in terms of the way in which we our interact with our environments, always being solicited into a kind of contingent and dynamic optimum:

I adjust my body, for example by turning my head and moving my eyes, squinting or cupping a hand around my ear, leaning forward, standing up, reaching, trying all the while to achieve a 'best grip' (*meilleure prise*) (1962, p. 309).

The quest for maximal grip orients us to the acquisition of particular skills, capacities and dispositions over time. The notion of an intentional arc captures the idea that all past experience is projected back into the world (H. Dreyfus, 2002). The intentional arc gives coherence to what presents itself to human beings – we encounter things on the basis of our prior experience of them, and through the skills and capacities we have acquired in engaging with them. The intentional arc structures the way in which the world appears for each of us. It provides us the capacity to make sense of and to respond to things appropriately. Merleau-Ponty describes this capacity as "that concrete liberty which comprises the general power of putting oneself into a situation" (1962, p. 156).

Thus for Merleau-Ponty the vast range of human movement is intelligent, and is meaningful against the background of past experience, the current situation and human endeavour or projection. Human beings' responses to situations is the visible referent to our embodied movements and interactions with objects, environments and others. Movements in the context of this research become 'embodied' material for visual analysis and interpretation.

Body- image, Affect and reconfiguring the visual

Affect has received critical attention across the humanities and social sciences over the last decade. The concept builds on philosophical precursors Spinoza, Deleuze and Bergson, paying attention to body, sensation, movement and felt experience. Affect according to Massumi renders the body dynamic, with the capacity to "affect and be affected" defined by *relations* of movement and rest (2002, p. 15). The idea of affect has informed lines of inquiry for visual practices such as media, film and communication studies, visual art, performance and architecture. For fashion Affect, is significant, not withstanding its potential for re-conceptualizing the body in general, but to consider the effects of an emergent digital paradigm that enable a re-thinking of the body and materiality in fashion.

Featherstone (2010) characterizes Affect in relation to Body-Image, a key notion for fashion. Fashion images have served a significant role as *the* discursive-object of study over recent decades. Similarly images have played a significant role in the development of a global fashion system (Shinkle, 2008). Featherstone characterizes body image as a bodily-self-identity, which forms a mental construct of how others see you. The concept is operational in psychology and Consumer studies where it is argued beauty ideologies are propagated by advertising and fashion's drive to motivate consumption. Underlying this is static-body imagery formed by fashion photography.

Drawing on Massumi's notion of Affect (2002) he cites alternate perceptual modalities associated with movement, intensities and sensation that operate beyond static, narcissistic identification with static-body-image. Featherstone argues, the notion of Affect, realizes a "body-without-an-image" and enables a thinking of bodies in terms of intensities and movements.

The affects of bodies can be felt trans-subjectively yet operates at the level of the imperceptible. The notion of screen presence or charisma is offered as one example to account for these trans-subjectively felt affects that are not perceived or observable in a 'look' but altogether 'felt' (Featherstone, 2010, p. 195). Moving imagery in contrast to still imagery reflects a body time, that has the potential to affect ineffable intensities and exceeds the of photographic representation.

Featherstone argues moving image technologies, such as cinema, television and digital video in contrast to photography work in a “body-time” or a ‘movement-image paradigm’, thus realizing a “body-in-process”, “which can convey and receive a range of affective responses, intensities which are difficult to decipher and articulate in language – especially in the duration of lived body time” (2010, p. 199).

Within a digital paradigm, typified by the capacity to capture and manipulate video documentation, moving images can work in a register that exceeds the operation of still imagery. Digital video can thus enable the visualisation of a range of bodily behaviours, actions and gestures that within conventional viewing conditions are imperceptible.

A materiality of digital bodies

Digital video possesses the capacity to capture, re-view, re-frame, freeze-frame and manipulate the moving-body-image. Through these digital functions, one is able to recalibrate how we understand bodies by the capacity to identify, emphasize and amplify particular aspects. Through an iterative approach to the visual material, I developed an approach to interpret and analyze the video documentation. The objective is to examine and identify aspects of human –garment interaction not normally the subject of consideration in fashion. These are the micro-corporeal movements that underlie human-garment engagement.

The primary focus of the videos was to visualise the materiality of the garments as a locus of human movement. A range of different frames and perspectives are examined (see Figure 1). The studies are organised on a case study basis, with each participant’s interaction providing the focus for that particular case. Movements and gestures are examined as attributable to a collection of material impedimenta, with a specific focus on the garments.

Figure 1. Soma Poiesis. Video still Compilation. Author. Courtesy: Author

The video case studies consisted of an examination of the interactions undertaken by participants when they tried on the DRESS + items for the first time. Through visual study particular movements and gestures are identified and highlighted through specific framing and repetition. The framing reproduces and amplifies imperceptible movements that are the product or result of human-garment interaction. In contrast to the vast majority of fashion imagery, the objective is to create moving-image-bodies in a lived-body time. This approach is critically positioned in relation the disembodied symbolism of the fashionable body as represented in much contemporary fashion film that functions outside of time (Khan, 2012).

Figure 2. Becoming Dress (2015). Video still. Image courtesy of the Author

Becoming-dress (2015) shows a series of micro-corporeal adjustments produced in the encounter between body and garment. The video shows particular actions shown in isolation, enhanced by repetition. Firstly action is undertaken by the hands working upon the garment. These actions are repeated, each repetition subtly transitioning to the next in a movement-flow. Hands and fingers show remarkable dexterity to collect and distribute fabric around the body, particularly the waist. In this sense, the participant appears to *feel* her way into the garment. This initial instrumental and directed handwork is then replaced by a more reflexive and sensing body-work in the later scene where palms of the hands, press and smooth the body with a focus on the hips. The video study shows a process of body-dress synthesis, or in other words, the participant *Becoming-dress.*

Double loop (2015) the shows the *e*xpressive, gestural and inter-corporeal. This video focuses on a series of self-referential movements. The gestures are made in relation to participants' verbalised reflections on her dress tastes and dispositions. As a part of the try-on session, the participants comment on the garments as they wear them. This discussion takes the form of responses to the garment itself, in terms of fit, or style as well as reflections on personal dress tastes and dispositions. The embodied gestures shown in the video accompanied these verbal responses to the garment. In an expressive mode, the participant utilises her body and the garment in a self-referential manner.

This video shows an unchanging frame establishing a social space of exchange and affect. It depicts a social environment rather than the flat tableau typical of much fashion film and photographic representation. This reveals social dynamics and processes in a lived body-time noted by the entrance of the participants either side of the frame. They are in dialogue, although audio is removed, and like the absence of faces in both videos, intensify through their removal the micro-corporeal and the gestural. The participant performs a series of looping movements with her hands and arms. These are expressive and communicative gestures meant to illustrate aspects of a body-dress synthesis.

Figure 3. Double loop (2015). Author. Video still. Image courtesy of the Author

Discussion

As outlined above*,* the vast range of human movement is intelligent, and is meaningful against the background of past experience, the current situation and future projections. Human beings in their embodied responsiveness to the world are solicited to find an optimum path. Their movements are the visible referent to this encounter with the material world, self and others. Merleau-Ponty argues that to understand this process as one of learning or "habit", requires us to alter our notion of the body, so our body becomes the "mediator of a world"(1962, p. 167).

Using this as a framework the visual-digital documentation showing the movements and interactions between body and dress become 'embodied' material for visual analysis and interpretation.

Taken together the videos show the way participants encounter and begin to interpret the experience of dress, as a dimension of lived experience. A part of this encounter shows a body, within a social milieu, coming to terms with a new garment, such that this foreign object must be appropriated into embodied habits and attitudes. As Merleau-Ponty writes "habit expresses our power of dilating our being-in-the-world, or changing our existence by appropriating fresh instruments" (1962, p. 169). In each of the videos this manifests in different ways. The participant's responsiveness in *Becoming-dress* is marked by auto-manipulation, that is, a kind of *grasping* which can be interpreted as the embodied response to a new garment. This self-touching can be understood as the body's projection to establish a new equilibrium between self and the world.

The responsiveness of the participant in *Double Loop* reflects a projection towards social equilibrium. That is a desire to communicate particular aspects of her embodied existence to others, in this case the researcher. Her appropriation of the garment is undertaken by its deployment as a referential instrument. Her movements revolve around particular bodily locations (waist and hips) while at the same time, they refer to her dress dispositions, that is the ways in which she is disposed towards dressing, in terms of her personal tastes and predilections. In some regards the appropriation of this garment, is achieved almost immediately, where, on the first occasion of it being worn, it becomes effortlessly deployed as an expressive medium.

This process of appropriation for both participants can be understood as interpretive, if we take the intelligent movements that achieve it to be intrinsic to its realization. The video studies show the affects upon the body, of the garment conceived as a kind of impedimenta, that is, a material thing that must be dealt with in some way, as things we must come to know and to learn about, *to embody*. In short, things we need to appropriate and in doing so incorporate within our habits.

The body is central to this process of appropriation. The video studies show the way in which designed things, in this case fashion garments, through their materiality, and the way they enclose the body form a specific mode of address to the body in its tactile, proprioceptive and kinesthetic possibilities. That is, the wearer's capacity to encounter the garments in their phenomenological materiality and their self awareness through tactile perception on the skin, and sense of the garments in space, and how their sense of movement is experienced whilst wearing the garments.

As Merleau-Ponty highlighted human beings experience the world, not in term of geometrical space, or a spatiality of position but a "spatiality of situation" (Merleau-Ponty, 1962, p. 115).The garments and the broader research design of these activities serve to prioritize these embodying aspects of dress and seeks to illuminate garments and at the same time how their wearers become embodied through them.

Thus video studies bring explicitly into view the situated, embodied and materially inflected aspects of the dress experience. This perspective is absent within discourse on fashion and dress. Gill argues the material and mundane is largely absent in account of fashion. She writes,

In dress studies, although there may be an increasing awareness of the public spectacles of fashion that disseminate through the culturescape, variations on the theme of the body (images and forms), situating bodies historically and ideologically, there is little explicit analysis of dress as mundane and habitual practice which shapes the daily appearance and experiences of being a clothed body ' (Gill, 2002).

While the literature in Fashion Studies accounts for the social forces producing these dress-bodies, the digitization and manipulation of their living trace (as visual data) shows these concrete processes in play. In this sense, what can be viewed is the embodied responses made in the context of fashion' s disciplining dimension whereby dress codes, beauty and aesthetic regimes delimit a range of possibilities. For example the participants hands busy themselves, smoothing, arranging and manipulating the fabric to achieve a *meilleure prise* upon the garment and as corollary the world.

Fashion has historically been mediated by the printed image. This in turn has prioritized the body as symbol or image, rather than in its lived–material forms. This research seeks to develop critical and practical resources to account for the garment in its lived materiality. As dePerthuis notes the representational practices typical of fashion transform living bodies into immaterial signs and symbols dissolving all that is natural "into the artifice of fashion", thus the very materiality of the garment and its affects are erased (2005, p. 410). This research seeks to provide an antidote to these current and historical practices through the development of new practices and conceptions of fashionable representation as well as inventive approaches to fashion research that result in a re-embodiment of fashion.

Conclusion

The objective of the research addressed in this paper is to establish a research method and accompanying methodological rationale whereby the embodying aspects of fashion can be brought to a kind of presence for visual and thematic enquiry. I have outlined some background context to fashion's representational practices, which tends to result in the disembodiment of the fashionable body. I have also provided a phenomenological framework to account for the responsiveness of the body in relation to its encounter with the fashion garment. In an emergent context signaled by an interest in moving fashion imagery, as well as the availability new theoretical and research instruments in the form of 'design probes' and digital visual technologies I have demonstrated the potential to view the fashionable body in a different way. This in turn brings into view the materiality of fashion garments in a way that demonstrates the *affectivity* of the fashion garment – that is what they do, rather than what they look like.

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Todd Robinson

Todd Robinson has a background as a fashion designer and artist. His practice traverses fashion design, sculpture and installation. His work seeks to cultivate and provoke consideration of the embodied dimension of everyday experience and often takes the form of novel strategies that draw attention to bodily or felt-experience. He is a lecturer in Fashion & Textiles and a PhD researcher at the University of Technology, Sydney, Australia. His PhD research explores the embodied dimension of fashion.

Why making matters – an exploration of neurobiological perspectives on woodcarving.

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Abstract

In this paper I begin unpacking the woodcarver's experiences of working in green wood from a neurobiological perspective. The woodcarver's experiences are often characterized as having an intense internal focus and an urge to overcome resistance. Previous research has discussed this overcoming of resistance as a preconscious and a conscious negotiation between maker and material. Recent research on neurobiology has increased our knowledge on the basic nervous system in humans. The aim of this paper is to try to bring together current neurobiological descriptions of the basis of what the wood carver do and experience. It is asserted that neurobiological knowledge on the woodcarver's experience may open up a new and complimentary understanding of why or even if making matters. It is one in a series of three papers contributing towards developing a research-based hypothesis for a future possible interdisciplinary study.

In the main body of the text, I describe the neurons and neural circuits needed for moving and sensing. I also describe the cerebellum where data driven coordination of muscles takes place. Throughout the text, I discuss and relate these descriptions to the wood carver's experience.

The paper ends with drawing up three tentative ideas for further exploration: 1) The overflow of information in cerebellum and the experience of intensity; 2) The function of cerebellum as generator of deliberate actions without the conscious self necessarily being aware and the pre-conscious element in the negotiation; and 3) the importance of the neural circuit between sensory input and muscle output at the cost of neural circuits between the cerebral cortex monitoring and self-reflection and the maker's experience as being close to the material.

Keywords

Woodcarving; experience; neurobiology; moving and sensing; cerebellum

Carvers working in green wood often describe the making process in similar ways. Such descriptions are found in a wide range of sources from blogs like Woodspirit (Dahl & Dahl, 2015), online groups like ("Spoon Carving, Green Woodworking and Sloyd - Facebook Group," 2015) and theoretical studies and research approaches, like Ingold (2013), Crawford (2009) and Fredriksen (2013). Video-narratives of such experiences are found in a variety of sources like Osbourne's TedX-presentation of the project where she gives people an opportunity to use a day to make a wooden spoon: "it's allowed us to kind of tap in to a place deep within and connect with being ok with imperfections. And to really truly be celebrating and be enjoying living in the moment[sic!]."(Osborne, 2014).

Figure 1. Carving bowl made from green birch, cut down with axe in a mountain forest and carried down strapped to backpack after spending the December night in a gamme (outdoor shelter).

In an early study, conducted as a part of a master degree in art education, I studied my own wood carving experience (Figure 1), and described a similar experience of intense internal focus and immense joy, linked to an urge to overcome resistance:

Slowly warmth spreads from within my body – hands soar, clutching the iron as shapes evolve. I fight the wood in the first phases: The gouge is pressed down and wriggled forward resulting in notches left to be smoothed by a knife. This part of the work feels like an exhausting negotiation between two wills. The wood and I have to compromise. I introduce my original idea about figure and shape like a persuasion with gouge and club.

Reluctantly the wood give in with chips falling off in their own tempo and their own direction. Before my eyes shapes are erased and arise from shivering growth rings under the gouge's strive. Hard labor and physical strength wriggles the idea into shape.

The wood needs a long period of intense persuasion to accept my ideas, but when the shapes are found at last, the knife follows the directions of the fibers. When they meet, the fibers and the knife, they unite like rivers connect, meet gliding down through shallow valleys (M. Gulliksen, 1997, 2001).

In that early study, I described and interpreted the experience as negotiations between 'the maker' understood as a unity [mind+body] (Bresler, 2004) and 'the material' understood as a unity [form+matter] (M. Gulliksen, 1997, p. 41). I sought to describe this negotiation and how the maker's initially vague intentions and projections of intended results of the process is met and re-shaped by the material's physical and abstract properties. Both parties were ascribed some sort of agency, however the initiator and leader in the process, was the human agent. This meeting between maker and material entailed an overcoming of resistance on three levels: the physical level, the aesthetical-idea level and the cognitive level (M. Gulliksen, 1997, 2000, 2001). I used perception phenomenology based in Merleau-Ponty as a theoretical foundation for the discussion (Merleau-Ponty, 1962). On this basis, I discussed this negotiation as both a preconscious and a conscious experience of the maker. The relationship between the two types of experiences (conscious and preconscious) were central in explaining the content and the meaning of the embodied making.

The last decades we have seen a surge of neurobiological research, also on creative practices, some of them presenting descriptions of the practices that are very much in tow with the phenomenological descriptions from last century. Especially studies conducted by researchers from the practice fields and the science fields together have made headway into our understanding of the biological basis for designers or artists experiences (Goguen & Myin, 2000; Seitamaa-Hakkarainen, Huotilainen, Mäkelä, Groth, & Hakkarainen, 2014; Varela, Vermersch, & Depraz, 2003; Zaidel, 2005).

This new line of research makes it possible to revisit my prior study to begin describing the wood carving experience in a neurobiological perspective. I propose that such an exploration could advance the discussion beyond the previous distinction conscious vs. preconscious, and contribute to further explaining the relationship between the maker and the material in the making situation. Based in our knowledge of neurobiology it is, in my opinion, likely that there could be a neurobiological basis for the distinct experiences described by makers.

I assert that it could be possible to use this knowledge to get a better understanding of why woodcarving, for so many, is intensely experienced and vividly remembered. Could neurobiology give us an explanation of why making matters? In this paper presented to researchers within the fields of making and scholars in experiential knowledge at the Eksig-conference, I attempt to explore these questions.

This paper targets green woodcarving in particular, to retain a clear scope of the discussion. However, it is to be assumed that the experience of making in other materials have similarities to carving in wood. However, woodcarving is a rare activity in the 21st century. Studies indicate that, in Norway, carving, along with the aesthetical subjects in general, are regarded as pleasant but not very important subjects in schools (Bamford, 2006). Few persons today carve in their everyday life, and introducing sharp tools in the education of children is by some regarded as dangerous and something to be avoided. Therefore, if we believe that experiencing carving is important, we need to generate more evidence for it, and make this evidence possible to communicate to outsiders in order to argue for why we after all should include these making activities in our lives. Also, as researchers on experiential knowledge, we might even need to be open for the idea that we may be wrong: that some of the previous studies might have been overly optimistic misconstrued to support prior beliefs and expectations. Revisiting previous studies with a new theoretical and methodological framework is therefore both a useful and a necessary strategy to develop our knowledge on why or even if making matters.

Limitations

The paper is not a conclusive discussion of the topic. I am a wood carver and a craft teacher and researcher, working in the field of culture education (Figure 2). Currently I hold a position of professor in culture education, culture production and aesthetical practice. This presents me with an opportunity to combine my own research and teaching phd-students from various fields of material practice. I have followed the developments in research on neurobiology from the outside in some twenty years, and only the last ten years read more extensively on the subject in addition to participating in seminars and taking courses, like the course "The neurobiology of everyday life" at University of Chicago, led by professor Peggy Mason(Mason, 2015). There is an obvious danger in discussing neurobiology without a full scholarly knowledge of the field. Many articles points towards non-scientists making too strong claims on too weak understanding of the concept. For example does Goswami at the Centre of Neuroscience in Education address this problem (2006) as did the participants at the symposium "Minds on minds" at Western, Ontario (*Minds on Minds - Education-Neuroscience Symposium*, 2014). The warning is about neuroscience content or terms being used "purely to put a new, modern gloss on some very old ideas from 1970s psychology. This is not to say that it is necessarily bad advice. But these are old ideas, given a slick re-packaging and being sold as brand new."(Wall, 2014). My aim in this paper is therefore not to conclude or speculate, but to try to bring together current neurobiological descriptions of what the wood carver do and experience in a coherent way, as a basis for further exploration of the theme together with specialists in neurobiology and neuroscience. In the research group I lead at my university, Embodied Making and Learning (M. S. Gulliksen, 2015b), we have recently developed an international consortium of research groups where neuroscientists also are included. In the future, we will begin exploring this topic together.

Figure 2: Carving bowl in aspen wood, on medieval marked, Norway 2012

Neurobiology, neurons, the nervous systems and its functions

Neurons are a type of cells responsible for registering, translating and transmitting information in the body. Neurobiology is a term used to refer to the study of the basic nervous system in all animals, herein humans (Mason, 2011; Purves et al., 2012).

Neurons are organized in two main systems: the central nervous system (CNS) which is the forebrain, brain stem and spinal cord, and the peripheral nervous system (PNS) which is all the other neurons sending or receiving information to and from the CNS (Mason, 2011, p. 4). The nervous system has four basic functions: Voluntary movement (everything we do), perception (everything we consciously appreciate), homeostasis (the continuous process of keeping our body balanced and alive) and abstract functions (everything we think, feel, learn – what makes us a human being) (Mason, 2015).

Neurons register information from the outside world by a process called transduction: Through a range of different means, a part of the neuron, called dendrites, are stimulated by signals from the outside world (light waves, sound waves, mechanical pressure on our bodies etc). The neuron, at rest, has what is referred to as a resting membrane potential: that there is a stable difference of electrical voltage between the outside and inside of the cell. The stimulus of a cell will result in a change of the electrical voltage in the cell, a release of an action potential. This elevated electrical voltage will form a rhythm and an intensity which together function as a signal that moves through the neuron towards the cell body, soma, where it gets processed and sent further down the neuron's axon. At the axon terminals, the action potential release neurotransmitters which set of a chemical message which transmits the signal to other neurons (in a synapse) or innervate another type of cell like muscle cells etc (Mason, 2011, p. 55). The signals can be affirmative, negative, fast and slow. These electrical signals is the ways in which we can breathe, see, move, and think, everything we are as living bodies.

More synapses between neurons, and even new neurons, can be made if much information travels a particular path. If less signals travels, the path can wither and even disappear. This plasticity, called neuroplasticity or activity-dependent plasticity (Purves et al., 2012), can be measured by different means like the increase of blood flow to a certain area. Every brain is slightly different from another, and our experiences are important for how it develops. There are two main types of neuroplasticity: experience expectant plasticity and experience dependent plasticity (Twardosz, 2012, p. 100). A famous example of this, is a study of taxi drivers in London, which had an increased number of synapses in an area of the forebrain related to spatial organization (Maguire et al., 2000). Likewise, did Elbert et al. show differences in the cortex devoted to right and left hand of musicians playing stringed instruments where the two hands perform quite different tasks (Elbert, Pantev, Wienbruch, Rockstrosh, & Taub, 1995). A probable consequence of such a plasticity could be that the brain of the experienced wood carver thus could be expected to be especially trimmed to process just the type of signals needed in his or her carving. For the sake of this paper, one of many relevant questions to ask would therefore be as to where such possible changes could occur, as the cause of which processes and what it could entail for the carver's experience.

For the wood carver, like every other animal with a brain, many types and circuits of signal are active at the same time, as an integrated whole. This is why experts in the field emphasizes: "assignment of a function or functions to certain neurons or brain regions should not be viewed as a precise description of nervous system operation, but as a current best guess and as a teaching device" (Mason, 2011, p. 22). Nevertheless, in order to approach it, the discussion needs to proceed one part at the time to be manageable. Carving wood is a manual practice; therefore, the neurons and neural circuits needed for moving and sensing would probably be of particular interest. I will therefore in this paper focus on the neurons that transmit sensory input to and in the CNS, and those who transmit motor output to the PNS.

Some of the information is autonomous, meaning that we do not have any conscious control over it, some of it could be consciously recognized but is usually done automatic and without thinking, while other information is voluntary, deliberate and sometimes also conscious. For a signal to be recognized by us or being processed by us, as for example the sensation of green wood under our fingertips, it must travel all the way from our fingertips in the outer regions of the PNS and into the cerebral cortex, a part of the forebrain and the CNS, visually recognized as grey matter. On its way there, the signal moves through a series of loops and multiple circuits of synapses and could end many places at once.

Sensory input and motor output of the wood carver

The wood carver needs both sensory input and voluntary motor control in order to experience her carving or to carve. Neurobiologists explains that various receptive sensory cells (hearing, seeing, tasting, light touch, hard touch, pain, kinesthetic body position receptors) in the body register information from the outside of our body. This they call sensation. The wood carver senses all her surroundings, all in a relative scale dependent on how much stimuli there is. Receptors in the carver's hand will for example send information of friction, vibrations, hair movements, temperature, and oxygen levels in muscles, as well as the state and position of muscles, limbs and joints. The carver will perceive or consciously appreciate this as meaningful information on the wood: shape and surface or if it is still green, and information on the state of the hand: pain, tired muscles, injury (blisters or cuts).

However, the carver only perceives a very small part of the many sensations. Her conscious self will not register the low oxygen levels in the tired muscles, but she will begin feeling the resulting fatigue and her unconscious self will engage in measures to raise the oxygen levels. In the carving quote above, the focus was on the shape of the object and how it was changed by moving the gauge. The perception focused on the tactile sensory input on the wood's shape, not on the visual input. The visual input was still there, but the tactile sensations was more important for the experience right then.

The carver's tactile sensory input from the arms comes into the spinal cord in the cervical region near the top. At the same time sensory input from the trunk and legs to the thoracic and lumbar regions of the spinal cord, informs the carver where she is in relation to the work bench and the room. The sensory input from the peripheral nervous system (PNS) changes side when entering the spinal cord and synapses to other neurons in an area of the CNS called the thalamus. Thalamus translates the signal to a rhythm the cortex can understand and transmit it further into a part of the cortex called the primary somato-sensory cortex. Thalamus could also "pump up the volume" by firing a batch of action potential upon receipt of an action potential to increase attention to a particular stimulus feature if necessary (Mason, 2011, p. 278). This explains why some information suddenly captures our attention, for example when a cut flows "just right" down the shape of the wood, and it informs the carver where the shape is right and the work is finished.

When recognizing that more cuts are needed, the carver decides where and how to cut. Motor output to the arms and hands travels from the CNS, comes out through the same region of the spinal cord as sensory input from these limbs: the cervical area. Instructions to the legs are sent to make sure that the cut has enough strength behind it, and the muscles controlling the gaze is also central for the wood worker when steering the gauge and knife. This actions engage a large part of the brain, for example areas called the primary motor cortex (an area of the cortex in the frontal lobe of the brain controlling arms/legs movement etc), the pons (controlling horizontal gaze) and midbrain (controlling vertical gaze). The motor output comes, like the sensory input, in the form of an electrical signal, an action potential. The action potential travels through a very long axon of a motoneuron that begins in the primary motor cortex in the frontal lobe and travels all the way down into the spinal cord. It changes side at the point where the medulla meets the spinal cord, and synapses in the spinal cord with a motoneuron that innervates a muscle and makes it move. We have over a million fibers in the cortico-spinal tract, which enables us to do the very fine movements necessary to hold a gauge and carve detailed patterns in wood.

One interesting part by this detailed and complex process is that neither the sensory input nor the decision to make a movement needs to be consciously controlled all the time. Despite being too complex a movement to be a reflex (like the knee-jerk reflex), it happens semiautomatically the same way we walk with a particular gait (Mason, 2011, p. 509). A reason for that is what can be referred to as "patterned activation and relaxation of specific muscles […] in the absence of peripheral feedback or supraspinal input"(Mason, 2011, p. 511). In short this is called the central pattern generator (CPG). The notion behind the CPG is that single circuits of neurons interlinking can generate multiple movements without our conscious choice of action. The CPG is located in the brainstem and cerebellum. There is however much neurobiologists does not know of how this CPG actually works on a cellular level in humans. Experiments are done in vertebras and other species, but such experiments are not done on humans. The understanding CPG therefore remains as a conceptual framework (Mason, 2011, p. 511). However, there is more knowledge of one very central part of this system of semiautomatical motor control and decision-making, the cerebellum.

The role of the cerebellum when carving wood

Cerebellum is a part of the brain stem, and as such, a part of the CNS. It is wrinkled and lies in the back end of the brain, underneath the large gray forebrain (Figure 3).

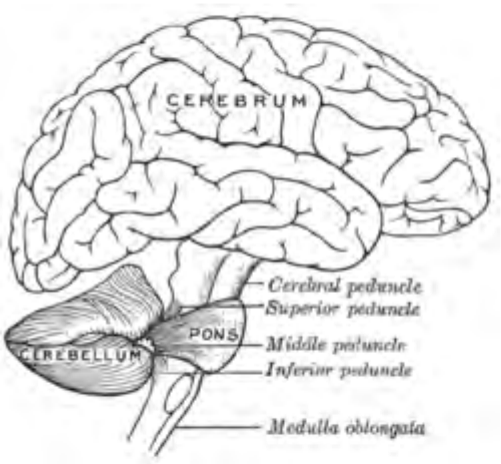

Figure 3. Cerebellum. Image source: http://en.wikipedia.org/wiki/Cerebellum

Even though all perception and abstract functions are controlled by the forebrain, cerebellum is utmost central in motor learning (both long term and short term) and motor execution/coordination. The cerebellum is the site where data driven coordination of muscles takes place. It is always sensing and interpreting sensory input to make sure that our movements are smooth.

The cerebellar topography consists of middle part called vermis which controls core body movement: standing, walking, talking. Next to vermis is the paravermis that controls arm and leg movement. For the wood worker the paravermis is particularly important, as it is a necessary part for reaching out, grasping, making small finger movements etc. In the outer region of the cerebellum is the lateral lobes. Researchers discuss if the function of the lateral lobes influences the ability to learn new motor movements. For the wood carver the lateral lobes of the cerebellum could be important when learning a new technique, or even getting familiar with the particularities of a new type of wood.

Cerebellum is constantly repeating and confirming, re-learning and providing different output when necessary. The cerebellum is also flexible, making it easy to adapt to new, short term changes, as if you need to carve with a band aid on your thumb for some days. The way the cerebellum can do this, and also the reason for its importance to the wood carver, is that it receives much information in neurological information language, electricity or action potential. It receives much more information than what it sends out, in a ratio of 40:1 (Mason, 2015). The ratio is explained by several sources sending information to the cerebellum at the same time: The motor cortex sends copy of what it intends to do to cerebellum (afference), the muscle sends copy of what message it receives to cerebellum (afference), and muscles and joints sends information of what they have done (sensory reafference).

The cerebellum monitors if all input match. If it does not match, it varies the output i.e. which type and strength of signals to send out (efference) to which muscles in the body. A mismatch of signals also triggers cerebellar learning. This, neurobiologists call associated learning and movement might change slightly. When carving green wood, there is much repetitive movements, at the same time as each cut is slightly different from the other (new angle, harder wood, a slip of the knife etc). When learning to carve, the carver constantly repeat motor movement, and when it is learned, she will remember it even if she does not practice it for a while.

The cerebellum, as a part of the brain stem, does this all by itself without the conscious control of the forebrain. Much of what is going on in our voluntary muscle movements is thus working automatically, as patterns. This is why the cerebellums function also is referred to as a part of the Central Pattern Generator.

Three tentative ideas on possible consequences of the neurobiological basis for 'why making matters'


Figure 4 and 5: "Bowl and lid". Teak and flake metal. Ca 30 x 8 x 6 cm. Given to previous mother-in-law. Never seen again.

In the previously mentioned early study of the experience of carving wood, I described the process as an intense experience and a preconscious and conscious negotiation between maker and material (M. Gulliksen, 1997, 2001; Merleau-Ponty, 1962). Studying the function of the cerebellum, have given us many possible angles to look for a neurobiological basis for the described negotiation with the wood and the intense experience of the carver. Of these possible angles, I will mention three tentative ideas that this angle has brought up, and which may have potential interests in a possible future exploration:

Firstly, our nervous systems senses a wide range of information about what is going on in the world and what we intend to do. This communication between muscle output and sensory input travels through our nervous system, and every small detail is constantly monitored by the cerebellum. The sheer overflow of information going in and out in a ratio 40:1, could possibly be related to the reported experience of intensity in the woodcarving process. If it is, and if so – how, is a question that could be explored further.

Secondly, as the neurobiological knowledge of the cerebellum tells us, only some of the information processed in this 40:1 ratio is perceived. It is not needed for us to be aware of something, to react on it. The cerebellum monitors this information and helps us making deliberate actions without our conscious self necessarily being aware. Our carving wood can in this context be explained as the cerebellar controlled and monitored action led by general guidelines originating in intentions and thoughts in the forebrain, sent and filtered by the cerebellum. This description bears similarities to what I in the previous study drew on Merleau-Ponty's phenomenology to refer to as pre-conscious, and could therefore be a tentative idea to explore further.

Thirdly, the wood carver's experience were described as a negotiation, or overcoming of resistance, between the maker and the material. A possible basis for this could be deduced based on knowledge on which neurons are "in the loop" or included in the active or functional circuits in the CPG. When carving wood the functional circuits of active neurons were dominated by the circuit between sensory input from the material and muscle output, guided by general guidelines of idea about the wanted shape as well as what the material could offer of possible forms. The aware, or conscious, self could be somewhat distant in these circuits: monitoring not necessarily guiding. This could perhaps be one possible basis for the maker's experience of being tightly interwoven with the material, as the reflective and self-questioning awareness that provides possibilities to distance oneself from the situation, is less included in the loop. A possible future study could therefore tentatively explore this idea.

An obvious problem with such deductions as these three above, are that they in this initial state only are tentative ideas, and as such they could be only "new modern gloss on some very old ideas"(Wall, 2014). A rigorous study is needed for us to know if such deductions are relevant or not. Such a study has several methodological challenges, given the complex nature of it (Mason, 2011, pp. 22-23).These methodological issues must be addressed before a study can be conducted, and by addressing them. However, addressing them will in itself open up a line of knowledge based arguments that could be used as an entering point into new targeted studies. For example all three indicates that it could be relevant to look for possible neuroplasticity related changes in the cerebellum in carvers vs. non carvers.

Another problem with this paper, is its narrow focus on just some part of the interwoven nervous system. For example have I not addressed the basal ganglia and their functions in choosing which action to take, and many other more or less probable influential systems and neurons active in the wood carver's experience.

I will end this paper with another sample of my own writing of the wood carver's experience. It describes a particular situation relatively common for carvers. Based in this paper's presentation of some of the neurobiological basis of the wood carver's experience, the example possibly can describe a situation where the cerebellum suddenly receives a massive dissonance in afference, efference and re-efference, or between intended motor action and received sensory input. The CPG pattern is disrupted and conscious control of muscles is suddenly needed, ending the repetitive intense negotiation between sensory input and motor output, by the acute experience on becoming aware:

As the tools perform the tasks they were constructed for, they gradually grow into extensions of my body. The gauge is hot from the work it does, and my hand is a willing participant. Through the shaft I feel whether the edge glides with or against the fibers, whether it is sooth or rough wood. I hear the sound of cuts gradually getting deeper, while the other hand is resting underneath the bowl, telling how thick the walls are and where to remove wood to make them even. The tool has become part of an extended arm that performs my will before I am even able to formulate my ideas.

Not until my concentration breaks I realize that the gauge is not my arm. Now, all of a sudden, the gauge slipped, and uncontrollably flies directly into my thumb. I let out a small scream. Why did I scream? Not from pain that's for sure: cuts from sharp tools rarely hurt much. Neither because the flooding blood frightened me; I have cut myself more times than I care to remember. No the reason why I screamed was because I was so surprised that the gouge was a sharp tool actually able to hurt. In the process of working, the gouge had been materializing the edge of my will. It was a part of me and represented my own opportunities to shape the wood.

The moment the gouge turns against me and cuts my finger, the situation represents an immediate contrast to the way I just worked. Now when I look back on it, I can still picture my left hand running over the wood, holding it, searching it, looking for yet undiscovered shapes, while *the right hand was just a vague shadow behind the edge of the gauge. The prompt disruption makes me remember it like if it was happening right now. The cut is there like a glass-wall through which I can peek into my own subconsciously conscious work. If I had stopped working any other way; to take a break or to change tools I would not have been able to remember it this way because my concentration would have been focused elsewhere (Gulliksen, 1997: 67).*

As the examples show, woodcarving is a complex activity, engaging many more areas of the nervous system than those discussed here. In another paper, presented at the LearnXdesign conference in Chicago, June 2015, I presented a related paper where I explored a related area of the wood carver's experience: the neurobiological basis of the memory of it, in particular the role of the hippocampus in storing and re-collecting semantic declarative memories (M. S. Gulliksen, 2015a). In a third paper I, together with colleagues from educational research and neuroscience, will attempt to discuss how recent studies on learning induced autonomy of the sensory motor system (Basset, Yang, Wymbs, & Grafton, 2015) could expand our knowledge of the wood carver's experience further. This series of papers will form the basis for a future research based hypothesis for a rigorous study by an interdisciplinary group of researchers.

Even a small and limited discussion as in this current paper, could in my opinion be useful for makers and researchers studying experiential knowledge. Scholars in the field of making have traditionally seldom been exposed to knowledge from the fields of neuroscience, and if we are, it tend to include overarching or general descriptions, not in smaller neurobiological details. Knowing about the cerebellum's role in datadriven coordination of muscles, its role in motor learning, the sheer mass of input vs. output it relays and how small part of all of this execution finds way to our consciousness, informs our understanding of experiential knowledge and provide new approaches to target the study of the experience of making.

I therefore propose that making experiences should continue to be studied through a variety of methods from the descriptive or phenomenological perspectives to neurobiological or other neuroscience perspectives in order to further explore the experience of intensity, joy and urge of overcoming resistance reported by wood carvers. The three tentative ideas described in this papers could possibly be a way into this theme, and I would like to discuss possible practical and academic implications that may emerge from studying these ideas with the audience at the EkSIG-conference.

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Materials in footwear:
an empirical study of hands-on textile approaches to sandal design

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Abstract

Commercial sandals are often designed in a 2D format and materials are generally applied during design development rather than the earlier stages of the process. In contrast, hands-on woven textile design is often carried out through making and interaction with materials. This paper presents the findings of an action research case study that investigated the use of 'hands-on' woven textile approaches to sandal design at different stages of the design process. The role that hands-on interaction with materials plays at each stage is analysed to assess areas of potential for its integration. The case study presented in this paper focuses on an aspect of wider research that investigates the potential for innovation through hands-on interaction with materials in the sandal design process.

The research questions for the study are: is there potential for the in-depth knowledge of materials and construction gained through a hands-on approach to be applied in the sandal design process; where and how does it have the potential to be integrated; how does the use of hands-on interaction with materials compare with more conventional approaches at different stages of the design process?

The case study was undertaken in the form of a sandal design project that incorporated the use of hands-on woven textile approaches. The designs produced were informed by knowledge generated through hands-on weaving techniques. The discussion of the empirical research refers to a literature review that was conducted alongside this case study. The findings indicate that there is potential for a hands-on woven textile approach to sandal design and it may be integrated at all stages of the design process. Key challenges were noted in relation to issues of time and cost efficiency in comparison to using conventional footwear design approaches alone. Benefits in terms of opportunity for innovation, generation of in-depth knowledge and immediacy, along with control in decision-making are discussed. Hybrid approaches are also identified as being suitable for bringing together outcomes that consist of a number of different formats.

Keywords

woven textiles; footwear; hands-on design; practice-based research; material interaction

Woven textile design processes often rely on making as a method of generating and realising design ideas whereas footwear design more commonly relies on the use of 2D approaches such as drawing (using CAD or by hand). Through hands-on interaction with materials, intimate and experiential knowledge is gained of the materials and construction (Philpott, 2012, p. 69; Sennett, 2009, p. 160). This paper reports on an action research case study that investigates the use of hands-on woven textile approaches to sandal design. The case study forms part of wider research into the potential for hands-on woven textile approaches to facilitate innovation. An overview of the wider research context is presented in Figure 1 and includes data collection through additional case studies and interviews with designers. The case study presented in this paper consists of a design project that uses hands-on interaction with materials as a method of design and development. The potential for the integration of woven textile processes with sandal design is discussed and comparisons between design approaches are drawn. Categorised according to whether they are 2D, 3D, digital, non-digital or hybrid, the roles these methods of design played are presented. The findings are relevant to the design and craft industries and academia through contribution to knowledge of design approaches and the role of making and interaction with materials in design.

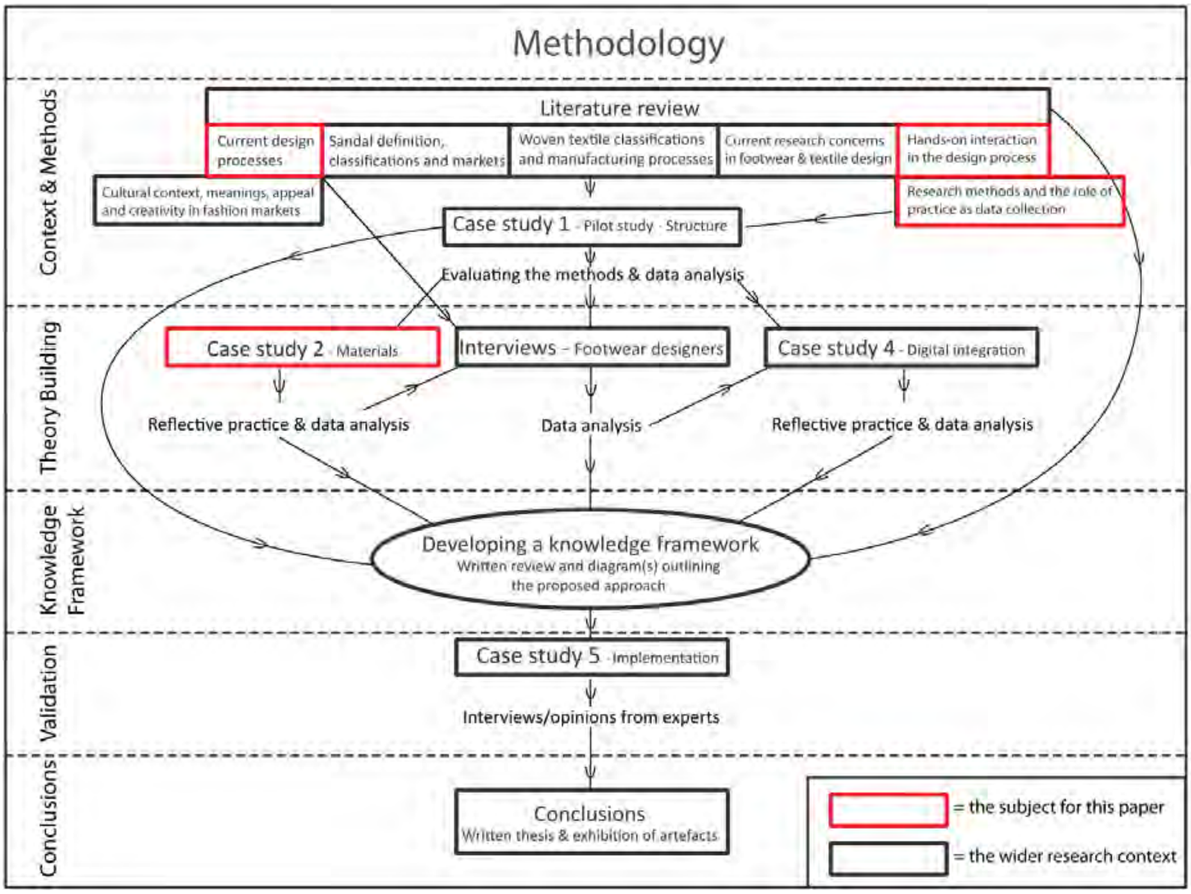


Figure 1. A diagram showing the practice-based case study within the wider research context

The roles of differing approaches are investigated at different stages of the design process. These stages have been defined by the data and a model of the general design process as presented by Wilson (2011, p.58). They consist of concept development; initial research; in-depth research; idea generation; design development and presentation. The literature review focuses on two of these stages, ‘idea generation’ and ‘design development’ allowing for the comparison of the use of different approaches in explorative (idea generation) and practical (design development) stages.

Approaches to design: Idea generation

This section discusses three contrasting approaches to the design process at the ‘idea generation’ stage. This is the point when design ideas are conceived. The stage is creative and holistic and occurs before an idea is developed and made to work in a practical sense (Tovey, 1997, p.10).

Sketching and drawing

Drawing by hand is a common method used in footwear and other disciplines in order to generate ideas. It has been noted as crucial to the creative process (Law- son & Loke, 1997, p. 172) and Purcell and Gero (1998, p. 392) describe how drawing can develop the form of a physical object. They describe how information is drawn from the long-term memory during this process along with bringing attention to alternative aspects of a design, leading to novel interpretations. This idea was previously introduced by Schön (1992, p.5) who describes the design approach as "seeing-drawing-seeing" and states that this process aids the generation and evolution of design ideas. A detailed and ingrained knowledge of a design can be gained through the drawing and re-drawing of a form by hand.

Computer based methods

The use of digital design methods can yield a number of benefits, such as the ability to speed up the design process (Cross, 2001, p. 46; Sennett, 2009, p. 39; Sweet, 2013, p. 31; Tovey, 1997, p. 18) and create variations on a design with ease (Zaman, Özkar & Çagdas, 2011, p.225; Zequn & Rui, 2010, p.223). It also allows designers to generate complex forms and visuals that would not be possible otherwise (Lawson, 2002, p. 327; Philpott, 2012, p. 56; Sweet, 2013, p. 31) and it is this potential for new opportunities rather than the imitation of existing ones that is seen as important in order for CAD to aid creativity (Lawson, 2002, p.327). It has been found in a number of studies that the use of CAD/CAM in the early stages of the design process can restrict creativity and spontaneity (Evans et al., 2000, p. 189; Lawson & Loke, 1997, p. 174; Treadaway, 2007, p.46) and only when software can be used instinctively can it provide advantages in creative innovation (Lawson, 2002, p.327). The sole use of CAD/CAM in the design process removes materiality and also the ability to gain embodied knowledge through touch (Philpott, 2012, p.60) that can build in-depth knowledge of processes and materials. Hands-on computing solutions are being developed with the aim of providing a suitable method that suffices both creative and practical needs (Evans, Wallace, Cheshire & Sener, 2005, p.489). However, it appears that, at present, technology has not been developed to a stage where it can successfully replicate real interaction with materials as an instinctive process (Evans, Cheshire & Dean, 2000, p. 193; Philpott, 2012, p. 60).

Material interaction

In hands-on woven textile design, the early stage of idea generation usually consists of sampling on a loom, during which the designer will experiment with different colours, structures, and yarns (Wilson, 2001, p.14-15). Touch is particularly important in textiles (Philpott, 2012, p.54); making and interaction with actual materials can contribute to the development of form (Leader, 2010, p. 413; Philpott, 2012, p. 54) along with informing creative thought (Treadaway, 2007, p.35). In some situations, hands-on making can also contribute to the development of novel materials (Yair & Schwarz, 2011, p. 312) meaning that it is a viable approach to innovation within the discipline.

Flaws in materials can be identified by developing and experiencing them first-hand in the early stages of a design project (Sennett, 2009, p.159), allowing adjustments to be made. It is possible for CAD systems to store and use information of material properties in order to undergo testing in a digital format. Such software is being developed within the performance textile industry (Adanur & Vakalapudi, 2013, p.716) to address the need for designs to be tested at an early stage in order to speed up the design process. This example is from a function-led industry, however, in creative design, products also evolve through a number of subjective alterations (Wallace & Press, 2004, p. 42).

Although there is the potential for significant advantages in the use of making as a tool for idea generation, it may not always be possible to work in this way due to practical constraints. Within the context of using a woven textile approach to sandal design, one problem could lie in the availability of weaving equipment which is generally bulky and noisy. Time and cost are the main challenges, with hands-on making often being a slow and expensive process (Philpott, 2012, p.61). This must be compensated for elsewhere in the design and development cycle or have significant benefits in the final outcome.

Approaches to design: Design development

Design development is the point at which the design ideas are developed and refined and so has a more functional/practical objective than the idea generation stage. This section discusses the role different outputs of the design process have to play at this stage.

Two-dimensional representations

Drawing by hand or with CAD software can be used to create 2D technical working drawings of a design. These are common within footwear design and specification sheets are generally used to communicate design ideas to the sample room for prototypes to be constructed (Schaffer & Saunders, 2012, p.156). However, there are limitations for a two-dimensional approach to communicating details of three- dimensional products (Tovey, 1997, p.26). For example, when refining a design on paper or on screen, it is possible that the scale and proportions may look correct but that they may not translate into three-dimensions (Glanville, Worswick & Golding, 1934, p.103; Sennett, 2009, p.41). This means that there is potential for misinterpretation and 2D representations may lead to issues in understanding. However, the time efficiencies of this method are much greater than that of three-dimensional ones (Tovey, 1997, p.11).

CAD drawings can easily depict a number of variations of a design (Philpott, 2012, p.60) and central databases can organise design work and supporting information (Tovey, 1997, p.18). The use of two-dimensional representations is common in the communication of designs within the footwear industry (Schaffer & Saunders, 2012, p.156-157). Therefore, this must be considered for the successful integration of novel approaches, which could support current methods rather than fully replace them.

Three-dimensional representations

Three-dimensional representations can be created using CAD software to generate digital models or through the use of modeling materials which are different to the actual material and construction to be used. The ability to see an object in 3D can allow for the form to be refined, providing a “higher degree of realism” (Jimeno-Morenilla, Sánchez-Romero & Salas-Pérez, 2013, p.1371) in comparison to 2D representations.

Digital 3D models can speed up design and development (Cross, 2001, p. 46; Sennett, 2009, p. 39; Sweet, 2013, p. 31; Tovey, 1997, p. 18) and aid accuracy (Sennett, 2009, p. 81), reliability, in terms of memory (Lawson, 2002, p.328), and organisation (Tovey, 1997, p.18). The availability of rapid prototyping has meant that CAD/CAM methods are now much more accessible (Evans et al., 2000, p.188; Philpott, 2012, p.69) giving designers the ability to model designs physically. The disadvantage to using 3D CAD as opposed to physically modeling an object is that what is produced on screen is actually a 2D representation of the 3D model and manipulation of that model may lack control (Joneja & Kit, 2013, p.252). The majority of benefits of CAD/CAM systems appear to relate to efficiency, cost and other factors that do not contribute to creative thought processes. However, in footwear design digital 3D modeling can actually slow down the design process (Antemie, Harnagea & Popp, 2012, p.415) and hands-on/physical methods are generally used (Zequn & Rui, 2010, p.222). Improvements in efficiency could potentially apply to footwear design, if more appropriate software was developed (Antemie et al., 2012, p.415; Azariadis, 2013, p.321).

Physical artefacts/actual materials

A wealth of knowledge can be gained from objects (Cross, 1982, p.224) and designs can often be misinterpreted (Schön, 1992, p.5), however, it is conceivable that designs in the form of actual objects are less likely to be misunderstood as they may be reproduced almost directly. The process of creating a physical prototype of the end product can also extend the designer's knowledge of "materials, processes and technologies" (Lommerse, Eggleston & Brankovic, 2011, p.391) and in turn, there may be a greater chance of success in the outcome.

While there are limitations associated with communicating designs using representational media (Sweet, 2013, p.391; Tovey, 1997, p.26) success in its use can be aided by knowledge gained through prior design experiences (Cross, 2004, p.432). When using constructions, processes and materials which are widely known, the use of artefacts within the product development process may not return many, if any, advantages. Knowledge can be gained through both making by hand and other representational design activities (Schön, 1992, p.4). However, the way in which designs are presented and translated by product development teams and manufacturers is another consideration. Meaning that an expert designer may be able to use prior knowledge to generate ideas that will work in practice, however, if they are not conveyed effectively to the people constructing them, then time may be wasted through unsuccessful sampling. Transportation of physical samples presents issues regarding efficiency, however, the benefits could make the transportation worthwhile.

Methods

A practice-based case study was undertaken in the form of a sandal design project led by in-depth research of materials through weaving. The design process integrated hands-on woven textile approaches with conventional footwear design methods (see Figure 2 for examples).

Practitioner as researcher

The primary researcher's background and experience as a footwear and textile designer was pertinent to the decision of employing practice as a research method. Nimkulrat (2012, p.1) states that, "positioning craft practice in a research context can facilitate the reflection and articulation of knowledge generated from within the researcher-practitioners artistic experience, so that the knowledge becomes explicit as a written text or as a means of visual representation." Similarly, Evans (2010, p.8) presents the theory that practice and reflection can access knowledge that may not be derivable from other sources and this is the reason for its use. There are difficulties associated with the communication of tacit knowledge and the ability of an expert to make design decisions/judgments based on their experience is not a straightforward subject for data collection. Niedderer and Townsend (2010, p.8) identified that tacit knowledge can be recorded, in part, by documentation through both written and visual media. In this case study the outputs of practice along with written and visual documentation are all considered forms of data.

Action research and case studies

Case studies were identified as an appropriate research method due to the ability to collect data that is rich in detail and empirically relevant/valid (Eisenhardt, 2002, p.29). The case study was undertaken using action research which is described by Birley and Moreland (1998, p.34) as “research conducted by a professional into their own activity with a view to bringing about an improvement in their practice.” The professional experience of the primary researcher means that this method is applicable and valuable in discovering and evolving processes through practice.

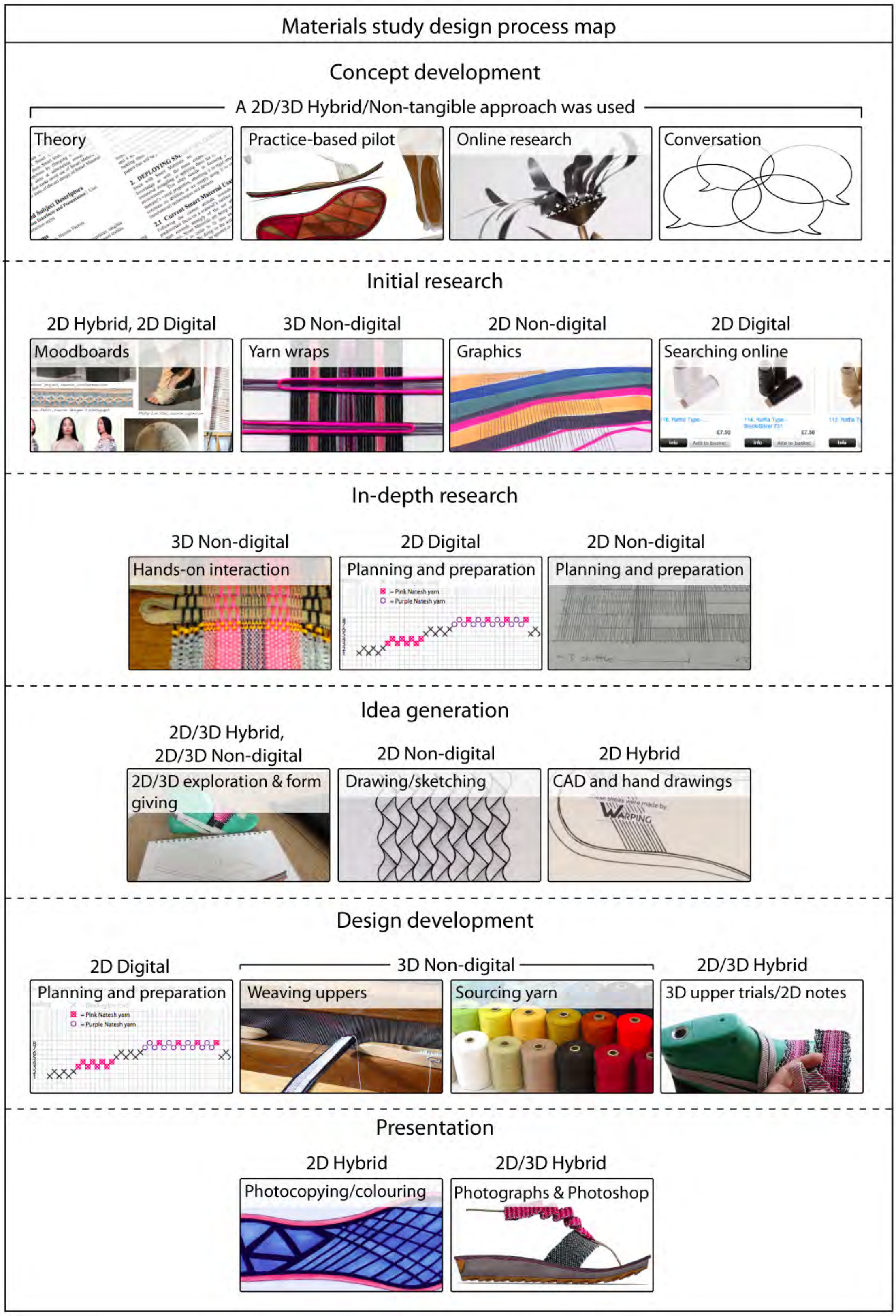


Figure 2. A diagram of the design process and methods used in the case study

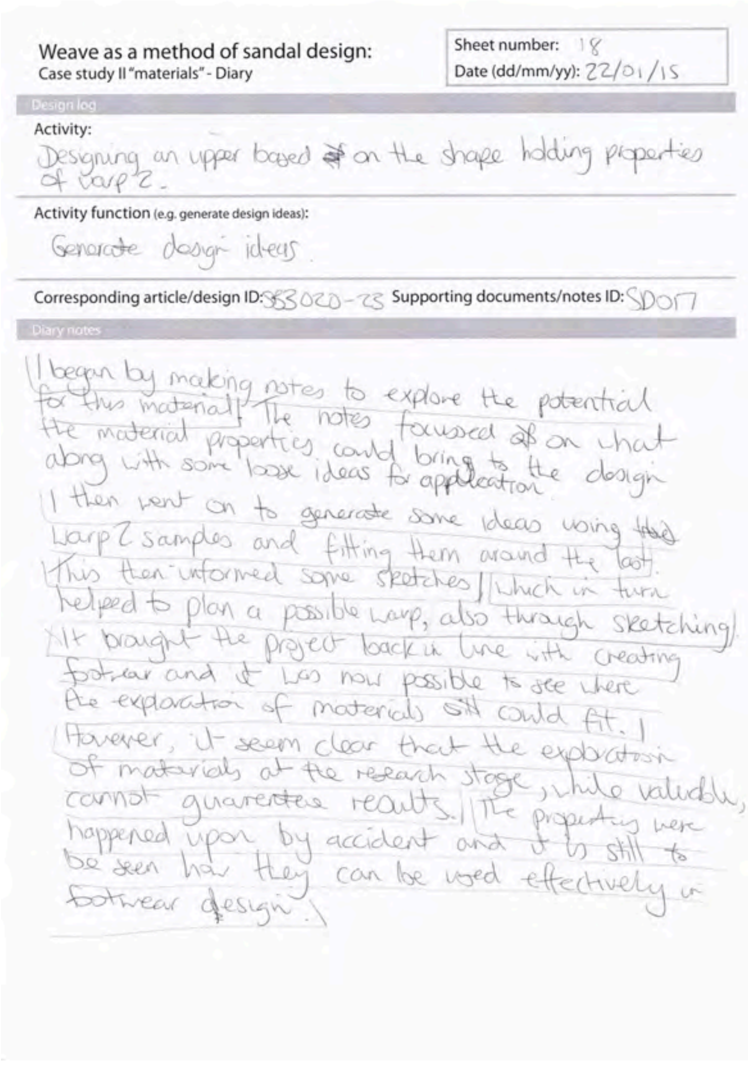
Data collection

Diaries, and more specifically “end-of-the day reporting” (Pedgley, 1997, p.220) were used as the main method of recording the design process. Pedgley (2007; 1997) identified them as striking a balance between accuracy of information and interference with the normal design process. This balance was important to the research and this, along with the ability to record and link a number of different data formats formed the reasoning for its use.

While diary entries were the main method of documentation, data collection was undertaken in a number of formats:

- Diary entries
- Diary log
- Supporting documents
- Sketchbook pages
- Physical artefacts
- Design sheets
- Digital files

The diary entries, diary log and supporting documents were used to keep track of all activities within the case study. Examples are shown in Figure 3 to 5. The additional data formats consisted of the outcomes of the design project; these aided the researcher in building a full picture of the design process for analysis.


Weave as a method of sandal design:
Case study II "materials" - Diary

Sheet number: 18
Date (dd/mm/yy): 22/01/15

Design log

Activity:
Designing an upper based on the shape holding properties of warp 2.

Activity function (e.g. generate design ideas):
Generate design ideas.

Corresponding article/design ID: S3020-23 Supporting documents/notes ID: SD017

Diary notes

I began by making notes to explore the potential for this material. The notes focussed on what the material properties could bring to the design along with some loose ideas for application. I then went on to generate some ideas using the warp 2 samples and fitting them around the last. This then informed some sketches. Which in turn helped to plan a possible warp, also through sketching. It brought the project back in line with creating footwear and it was now possible to see where the exploration of materials still could fit. However, it seem clear that the exploration of materials at the research stage, while valuable, cannot guarentee results. The properties were happened upon by accident and it is still to be seen how they can be used effectively in footwear design.

Figure 3. An example of a diary entry used to document the process

Date (dd/mm/yyyy)	Activity	Time (hrs)	Diary Sheet number	Article/design ID code	Supporting material ID code	Comments
02/02/15	Weaving upper designs and finishing them/putting them on the last	3	21	Warp 3	SD020	
04/02/15	Evaluating samples for uppers 1 and 3 and making changes/suggections, then weaving upper 1 with some changes made.	6	22	SB3026-27, Uppers 1 & 3, warp 3	NA	
05/02/15	Weaving variations on upper 1 based on the evaluation of the 1st sample	4	NA	Warp 3	NA	This was more of a practical task, I will evaluate the outcomes and make judgements on them off the loom
17/02/15	Designing an outsole and drafting warp 4	2	NA	DS029-30, DF023	NA	
18/02/15	Designing an outsole	4	23	DS031-33	NA	
19/02/15	Designing an outsole and logo	4	NA	DS033-34, SB3028, DF024	NA	
25/02/15	Colouring outsole designs	2	24	DS035-37	NA	
05/03/15	Altering weave draft and setting up the loom	5	25	Warp 4; DF023	NA	
06/03/15	Weaving an upper design relating to SB3026	4	26	Warp 4	SD021	
10/03/15	Finishing weaving and cutting off and finishing the upper relating to SB3026	2	NA	Warp 4	NA	
12/03/15	Weaving a second sample relating to SB3026	2.5	27	Warp 4	SD022	
13/03/15	Manipulating sample 1 from warp 4 in order to generate some additionaldesign ideas and weaving a sample based on sample 1	4	28	SB3029-31, Warp 4	SD023	
18/03/15	Started weaving a sample based on SB3029-30 and sourcing yarn	0.5	29	Warp 4	NA	
19/03/15	Weaving a sample based on SB3029-30	5	30	Warp 4	NA	
20/03/15	Weaving a sample based on SB3029-30	1.5	NA	Warp 4	NA	The sample was finished and the warp cut off the loom

Figure 4. An image of the diary log used to document the design process

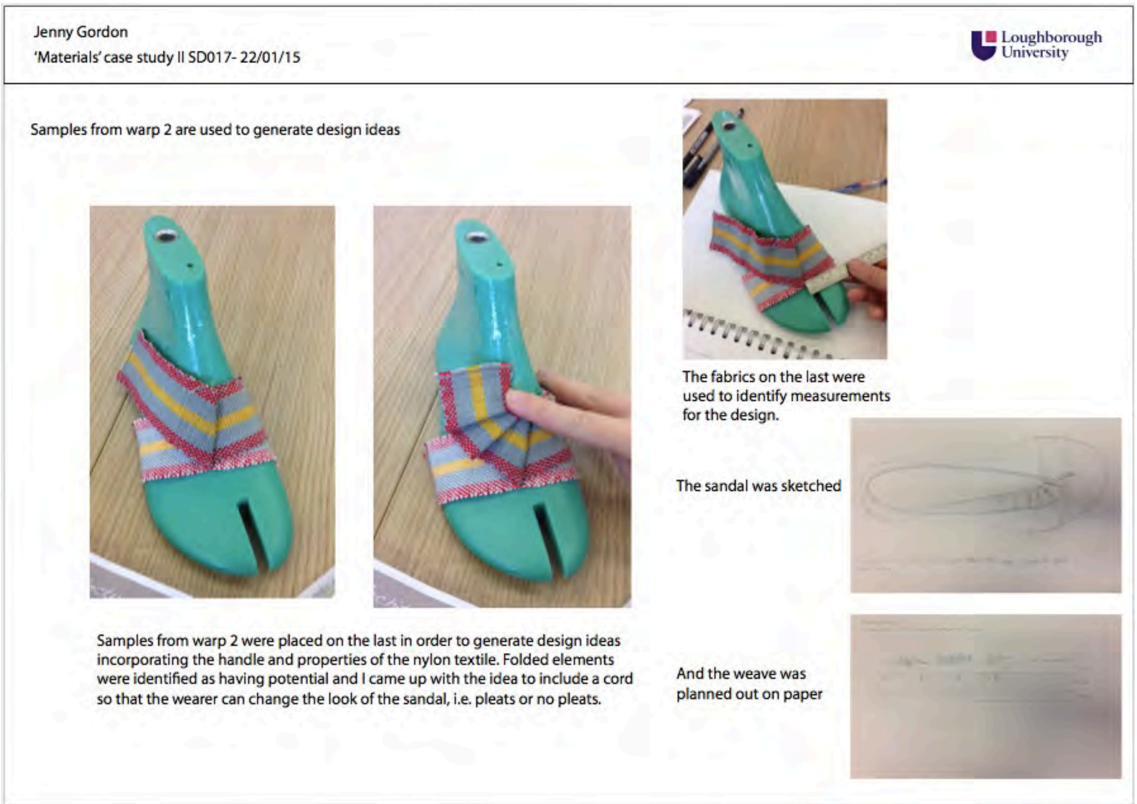


Figure 5. An example of a supporting document used to record the design process

The data was organised and analysed through qualitative data analysis methods, informed by Miles and Huberman (1994). Each form of data was systematically recorded, archived and assigned an identification code. This aided the relevant grouping of data during analysis, which was organised and reduced into activities. In order to achieve this some conditions were applied to what constituted as a single activity.

It was classed as a single activity if:

- It involved working towards the same outcome, for example the same sketchbook page or digital file.
- It involved the same process without any deviation and if it ran over numerous days then one working day had to lead seamlessly into another without another activity in between.

It was classed as a separate activity if the same process was used on a different day, was not working towards the same outcome and did not lead on seamlessly.

Whilst the activities from the diary log were being identified, they were also annotated and organised. Annotations provided the analyst's insights and because the data described activities carried out by the researcher/practitioner, it was possible to reflect on what the designer was thinking at the time. Perhaps providing an insight into the thought processes and tacit knowledge behind the actions. A map of the design process was created in order to organise the data into a logical format (see Figure 6). Each activity was assigned to a design stage relating to Figure 2, and was represented by a piece of data, which generally consisted of a sentence, or section of a sentence. Descriptive/insightful data was linked to the activities that they were associated with. Links were also made between activities, showing connections relating to what led to or informed another process, for example "Creating yarn wraps" led to/informed "drafting a warp". Colour coding was used within the map to represent whether the activities led to/informed the final designs, whether they did to a limited extent, or did not lead to/inform the final designs at all. Once this had been mapped out, it was possible to begin coding the activities based on what they involved. Some initial categories were identified from the research questions and literature review and they evolved through the coding process. The codes applied are shown in Figure 7 along with their definitions.

Figure 6. An image showing the organisation of data into a design process map

What the process involved - IN		
Efficiency	IN-EF	Where the process was time efficient/cost efficient/labour efficient
Inefficiency	IN-IE	Where the process was inefficient, for example labour intensive/took a long time/cost a lot of money
Exploration/Intuition	IN-EI	Where the process was significantly explorative, relying on tacit knowledge to make decisions
Systematic approaches	IN-SA	Where a systematic approach was utilised as opposed to or as well as making decisions using tacit knowledge, they were pre-planned or adhered to a system
Issues/problems (suitability)	IN-IPS	Where issues/problems of the suitability of the process were involved or highlighted. This includes issues of over complexity
Issues/problems (outcomesl)	IN-IPO	Where there were issues/propblems with the outcomes or their work in progress
Unexpected results	IN-UR	Where there were unexpected outcomes from the activity or where something was brought to light that hadn't been thought of
Material knowledge generation	IN-MK	Where new knowledge was generated regarding materials
Construction knowledge generation	IN-CK	Where new knowledge was generated regarding construction
Aided decisions	IN-AD	Where the process involved aiding decisions that were made in the design process
Led to a change in direction	IN-CD	Where the activity led to a significant change in direction or re-think
Successful problem solving	IN-SPS	Where the designer dealt with with problems/issues successfully
Unsuccessful problem solving	IN-UPS	Where the designer tried to deal with problems/issues unsuccessfully

Figure 7. Shows the categories that were identified and recorded, with codes and definitions

Findings and discussion

Once the data had been organised and categorised it was possible to search for patterns within it. This section discusses the findings at each stage of the design process.

Concept development

At the concept development stage there was one recorded activity, it was undertaken using a 2D/3D hybrid/non-tangible approach and informed the final designs. Due to the conceptual stage occurring before the project had begun, it was difficult to document it in detail. The activity incorporated theoretical research into hands-on interaction with materials, discussion with colleagues and the evaluation/analysis of a pilot study that was previously undertaken. Therefore demonstrating how a variety of approaches, including previous hands-on interaction with materials can inform design concepts.

Initial research

The most prominent approaches to make up the initial research stage of the design process consisted of 2D non-digital, 2D digital and 3D non-digital.

While 2D non-digital was prominent at this stage, the processes and outcomes did not contribute to the final designs. This points to a lack of suitability for a 2D non-digital approach at this stage. Mainly used to inspire or plan 3D non-digital tasks, when it came to carrying them out, intuition took over and the plan was not used.

2D digital approaches were more suitable, with two out of three activities leading on to inform the final designs. They were used to source materials, which gave the designer access to a wide range of products, however it did not provide a clear understanding of what the material is like. The designer noted, “I will need to wait and see the yarn before making a decision on whether to use it.” 2D digital and 2D hybrid approaches were also used to gather and consolidate inspiration in the form of a moodboard. As with sourcing materials, it provided an efficient approach with access to a wide range of information. Digital methods were used as part of the hybrid approach to consolidate information/inspiration from a variety of sources.

3D non-digital approaches also appear to be suitable, with two out of three activities informing the final designs, the other one led to the final deigns to a limited extent. The function of them varied from being a planning tool, to providing design inspiration and highlighting areas of concern. However, the knowledge of materials gained was relatively superficial. It became apparent at the in-depth research stage that some of the materials selected using this approach were not suitable.

In-depth research

The in-depth research stage consisted of three approaches, 3D non-digital, 2D digital and 2D non-digital. The majority of the in-depth research was conducted using 3D non-digital/hands-on methods. Forty percent of the 3D non-digital activities informed the final designs and an additional forty percent did to a limited extent. The approach was suitable at this stage but with elements of uncertainty.

Figure 8 shows the comparison between the coding of 3D non-digital approaches, grouping them by whether they informed the final designs, informed them to a limited extent, or did not inform them. The activities that informed the final designs appear to be more efficient and systematic and they aided decisions. In the activities that did not inform the final designs problem solving was unsuccessful and there was a higher degree of inefficiency. While systematic approaches appeared to inform the designs more than explorative/intuitive ones, the material knowledge generation that led to the final designs was gained through unexpected results. This points to the theory that in-depth research of materials has the potential to be valuable within the design process and can lead to innovation through unexpected results. However, there is no guarantee of useful results and experimentation can lead to dead ends.

The length and uncertainty of the in-depth research of materials in the design process means that it would be problematic to incorporate into a seasonal/commercial design process where designers are subject to time pressures. For this reason it may be that in-depth research of materials would be more suitable as an ongoing and separate activity to the creation of commercial/seasonal products. Additionally, in order for this to justify the time and financial investments necessary there would have to be sufficient potential for innovation.

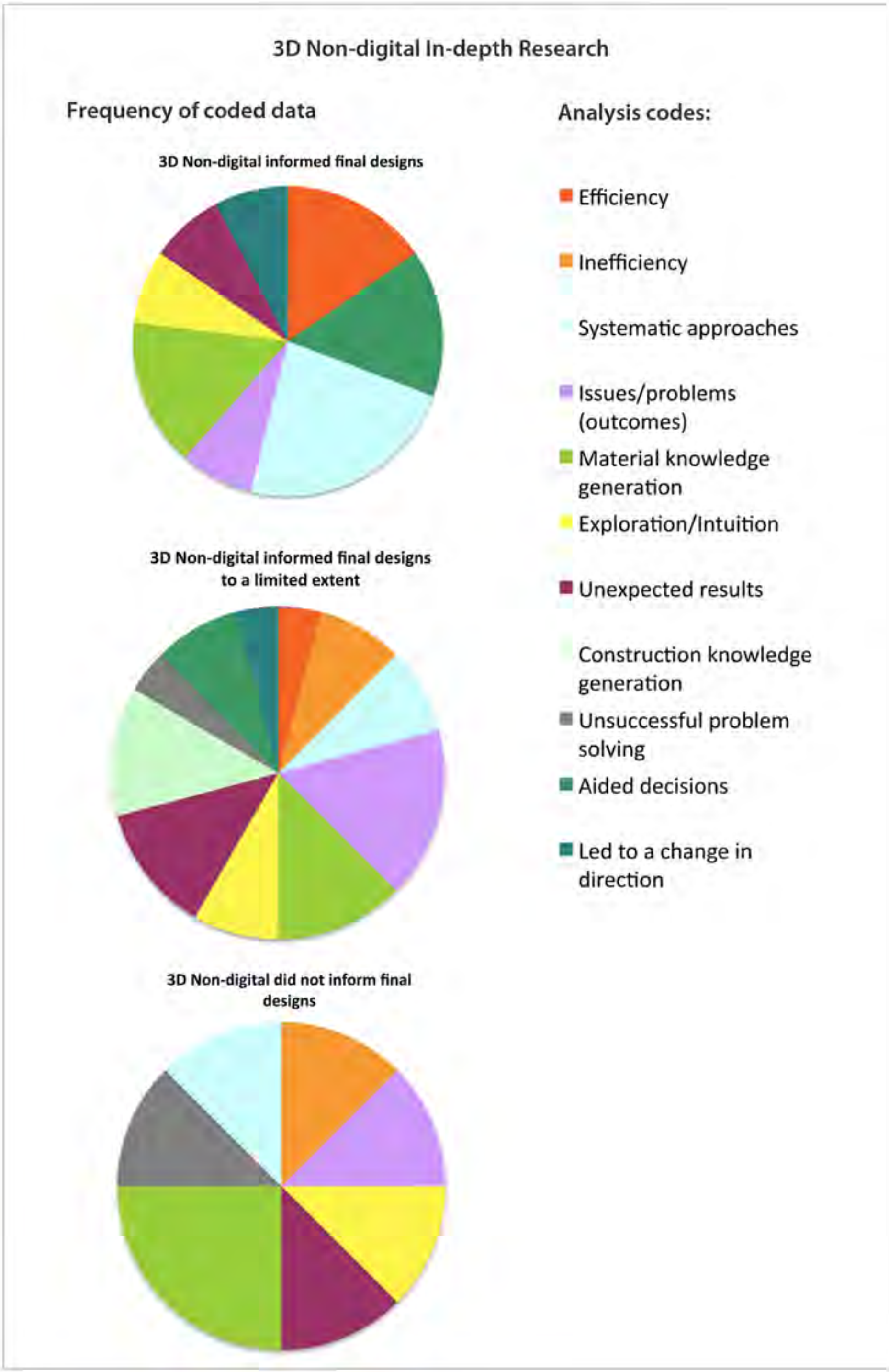


Figure 8. Three pie charts showing the distribution of analysis codes in the 3D non-digital processes used at the in-depth research stage

Idea generation

At the idea generation stage four approaches were used, 2D non-digital, 2D/3D hybrid, 2D/3D non-digital and 2D hybrid. The most prominent was 2D non-digital, which generally consisted of drawing by hand. This appears to reflect to the literature review that points to the suitability of drawing at this stage. It is notable however that the majority of 2D non-digital activities did not inform the final designs and all related to the design of the outsole. A few attempts were made at designing the outsole and it was interspersed between the other activities. The immediacy and efficiency of the approach allowed for this and also meant that a number of attempts could be undertaken. The other 2D method was a hybrid approach and again, this was used with regards to the outsole design. The 2D approaches were generally identified as being intuitive/explorative and involved some elements of efficiency.

2D/3D approaches (non-digital and hybrid) were used for the upper design. They consisted of forming samples around a sandal last in order to generate ideas. These were then developed and recorded in 2D through sketching (see Figure 9). The process used here was much faster than the weaving that was done at both the in-depth research and the design development stages. In each case of this approach being used, form was generated in 3D and then taken into a 2D format. This leads the researcher to question why this was done. It was not described as being purely for the purpose of recording the designs and they were developed on paper. It may be that visualising the design in different formats provided alternative views and aided the development of ideas, or perhaps it was habitual. Drawing can be used to develop the form of an object (Purcell & Gero, 1998, p.392) and it appears that this is how it was used here.

Figure 9. 2D/3D approaches to idea generation

Design development

At this stage 2D digital, 3D non-digital and 2D/3D hybrid approaches were used. The most prominent was 3D non-digital, with the majority of these activities leading to the final designs. The 2D digital approaches all refer to drafting a warp, which is a planning/preparation task, efficiency and systematic approaches were prominent here. This appears to reflect the theory presented in the literature review in which CAD lends itself to practical tasks, leading to benefits in efficiency. The activity itself did not evolve the designs, but allowed for that to happen once the loom was set up. The 2D/3D hybrid approach refers to the evaluation of samples through trying out uppers on the last, photographing them, and making notes/sketching to suggest changes. This is a very similar approach to the one used at the idea generation stage and allows the designer to visualise the design in 2D and 3D.

The 3D non-digital approach mainly consisted of weaving upper designs along with some preparatory tasks, for example yarn wraps and setting up the loom. The charts in Figure 10 illustrate the comparisons of coding distribution between 3D non-digital approaches that informed the final designs and those that did not. Exploration/intuition was quite prominent in the approach that informed the final designs and did not feature in those that did not. It is possible that this exploration and intuition made the design development successful. Alternatively, it may be that when a design was seen as successful, the designer felt that it was appropriate to evolve it. When an activity led to problems that did not seem solvable or worth solving they were quickly abandoned. For example, alternative structures and materials were tried and dismissed when they did not work as expected. Tacit knowledge was employed to decide if a problem was solvable or worth solving and if there was a need for further exploration. This leads the researcher to believe that the lack of exploration/intuition was a consequence of an unsuccessful design as opposed to a reason. Issues/problems were fairly prominent in both scenarios, however, problem solving only features in the activities that informed the final designs, again, indicating the lack of a perceived need to develop the ideas that in the end did not inform the final designs. Systematic approaches were prominent across both sets of data and so this points to a general systematic process being utilised at this stage.

Presentation

2D hybrid and 2D/3D hybrid approaches were involved at the presentation stage. There were only three activities here so it is difficult to identify patterns. However, it is notable that all of the approaches used are hybrid. This was identified within the data as being “very useful in bringing together the full design as a visualisation.” The outcomes were in both 2D and 3D, and digital processes allowed the designer to consolidate the designs in a 2D format (see Figure 11). Digital methods also have the potential to bring a 2D design to a 3D format through the use of rapid prototyping. This would be more costly and time consuming but it would allow for the designs to be presented as a tangible object. Providing the viewer with more in-depth knowledge of that design.

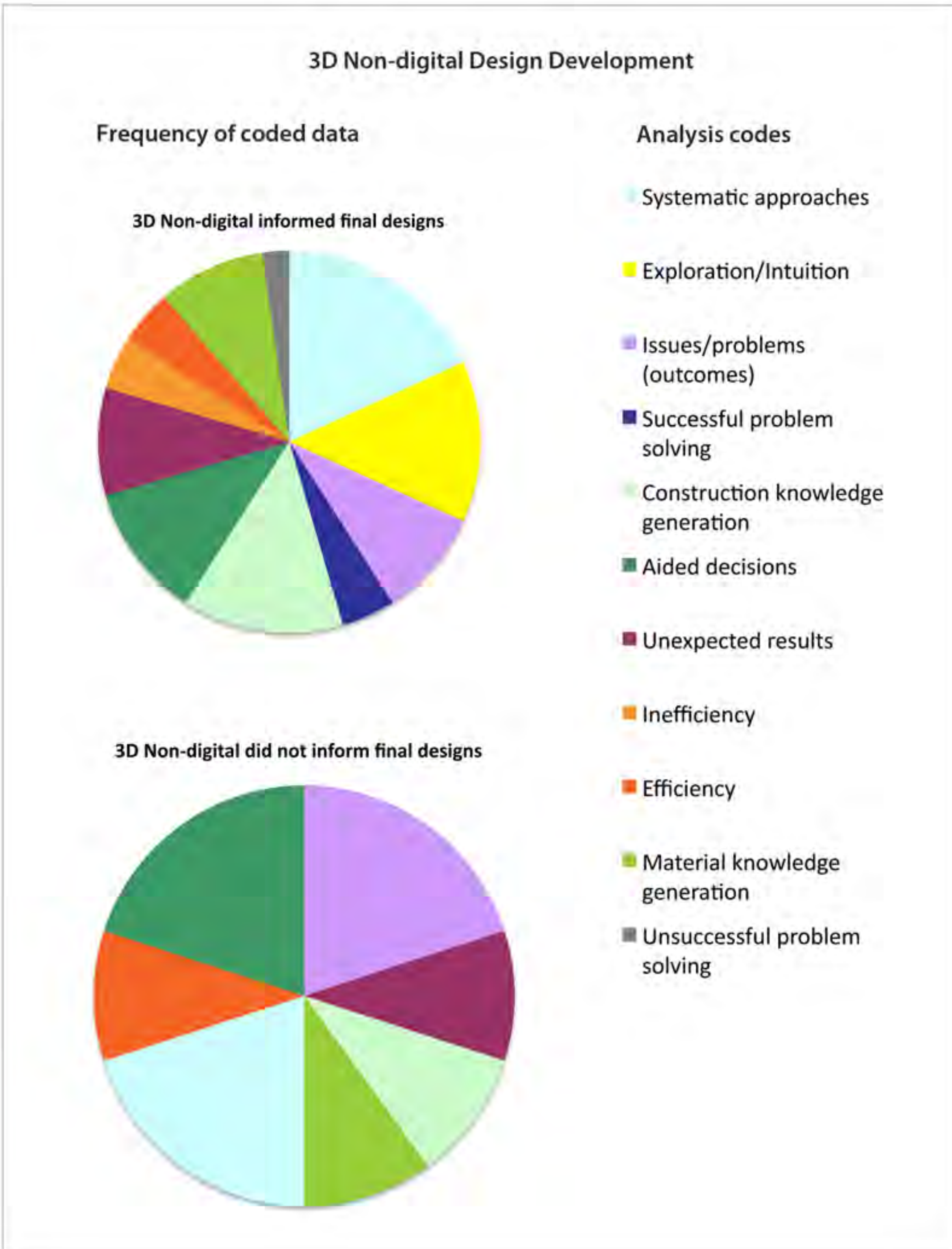


Figure 10. Two pie charts showing the distribution of analysis codes at the design development stage and whether they informed the final designs

Figure 11. Design sheet generated using 2D/3D hybrid approaches

Conclusions

One of the main challenges for a hands-on approach to sandal design lies in issues of cost and time efficiency. The use of weaving to test yarns at the in-depth research stage was time consuming and uncertain in terms of outputs. It was found that innovation may occur through unexpected results and this could be valuable to informing design concepts. This leads to the conclusion that in-depth research through interaction with materials has the potential to be suited to ongoing research that could inform concept development.

Another area of potential for a hands-on woven textile approach was at the design development stage. It required substantial time investment from the designer but the majority of 3D non-digital activities led to the final designs. Where issues and problems were encountered, the designer was able to gain a first hand understanding of the problem and decide whether to solve it or reject the design. The immediacy with which the designer was able to use tacit knowledge in order to do this was a benefit in comparison to more conventional footwear development. Sennett (2009, p.159) reports that through first-hand interaction with materials, flaws can be identified and adjusted by the designer. The findings indicate that hands-on processes have the ability to speed up the decision making process and provide the potential for subjective decisions to be incorporated alongside technical ones.

At the idea generation stage, quick methods of 3D modeling were used in conjunction with sketching. The literature indicates that design ideas can evolve through drawing and that was the case in this project. 3D Hands-on approaches were used to generate ideas and sketching evolved them. The ability to quickly generate new ideas appeared to be key at this stage along with the use of 2D and 3D approaches in conjunction with one another. This points to a need for drawing at this stage, showing that hands-on making could be integrated to inform new ideas, but not replace existing methods.

At the initial research and presentation stages digital approaches were used to consolidate the outputs of a number of different approaches. This was done in a 2D format, however, there is also scope for this to be applied in a 3D format through the use of rapid prototyping.

In summary, there is potential for hands-on interaction with materials to be utilsed in the form of a woven textile approach to sandal design. There are key considerations in efficiency within the context of commercial footwear design. The findings indicated that the potential benefits to be gained from hands-on interaction are generation of in-depth knowledge of materials, innovation and control/immediacy in decision-making. Hybrid approaches show potential in incorporating hands-on interaction into a more conventional design process.

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Context Construction through Material Perceptions: Experiences from an Explorative Workshop

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Abstract

This paper describes and reflects upon a design-led workshop carried out by design and science researchers in an interdisciplinary material development project. The aim of the workshop was to construct application context for the design of thermoelectric energy harvesting applications that combine textiles, thermoelectric materials, electronics, and additional smart materials. The experience of textiles is typically multi-sensorial as textiles are often close to the body or in the touching proximity to people. However, the development of novel textile materials and applications is often science-led resulting in extensive considerations of technical aspects at the cost of the experiential insights. The workshop was utilised to explore a way to engage technically oriented researchers into the consideration of material sensing and engagement as a resource for the ideation of potential application contexts. The approach was based on grounding the ideation of design concepts on sensory experiences rather than on technical considerations. The workshop was planned in a manner that relied heavily on personal exploration of the textile and other materials that the workshop participants were provided with. This would contribute to the creation of 'an experiential context' for the subsequent development in the project.

Keywords

textiles; materials; explorative workshop, sensory; context framing

Adank and Warell (2006) underline the importance of human senses as a source of knowledge within the product development process. Therefore, the material properties that influence human sensing can be defined as sensorial properties, a definition, which refers to the way in which users interact with material through their basic senses (Karana, Hekkert & Kandachar 2009; van Kesteren 2010). The scientific treatment of the sensorial properties of materials entails an objectivist approach, as the properties are based on the physical existence of the material measurable with scientific instruments. In contrast to the scientific approach, a design approach to the study of a material's sensorial properties and expressivity includes the examination of both the objective and subjective sides of the materiality in terms of embodied interaction. The sensorial properties and expressivity of a material are based on the intrinsic features such as the material's physical structure, and of extrinsic features that are influenced i.e. by the differences in human physiological conditions, feelings, previous experiences, use context, culture, and environmental conditions (Zuo 2010). Textiles are intrinsically multi-sensorial due to their placement in the close proximity of the human body and the use that typically involves direct touching. Textile perception is grounded in sensations of a physical material through the human somatosensory system that comprises cutaneous senses, such as touch, pressure, vibration and temperature; proprioception, or sensing of body position; kinesthesis, or body movement, as well as pain, tickle, and itch.

Materials are also becoming increasingly active, thus providing new possibilities for design. For example, some of the new materials can be stated to be able to 'feel' their surroundings and events in there (Lehmhus et al., 2013). They (ibid.) consider these kinds of materials as 'sensorial materials,' and define these as materials featuring integrated sensing, intelligence, and communication properties. These kinds of technologies can also be embedded into textiles, and these may be further constructed into smart textile systems (Berglin 2013). These kinds of systems provide novel and unanticipated sensory experiences and possibilities to interact, which make them fruitful for the kind of design exploration that we set out to conduct.

This paper reports on a workshop that was organised to envision novel applications for smart textiles under the theme of 'Internet of Textiles' (IoT^x). The workshop was part of a larger interdisciplinary research project with researchers of chemistry, electrical engineering, and design to investigate thermoelectric materials and energy harvesting technologies for new types of integrated energy applications. The focus of the project is to study the potential for novel heat harvesting technologies. Heat harvesting is based on converting heat energy into electrical current. Thermoelectric material, see e.g. (Tynell 2013), uses heat sources to generate electricity that may be used, e.g. to power wireless communications.

Our research contributes to existing research by describing a study where the exploration of experiential qualities of materials, especially textiles, was utilised to ground the ideation of novel applications with technically oriented researchers. The workshop design is explained and the problems related to the framing of the ideation are explicated. Challenges related to enabling technical experts to contribute to the exploration of experiential qualities of design are discussed.

Constructive Design Research as the Method

Our study was conducted with the Research through Design (RtD) approach, which is based on utilising design methods as legitimate method for academic enquiry (Zimmerman, Forlizzi, & Evenson, 2007). The approach is also called constructive design research (Koskinen, Zimmerman, Binder, Redström, & Wensveen, 2011).

The approach draws from designing, especially in the form of iterative reframing, as well as holistic and integrative consideration (Zimmerman et al., 2007). Reframing is the activity to critically reconsider what is the object of study by the means of restructuring how the object should be seen as (Schön, 1983). The constructive design research approach may utilise design idea generation as part of the forming of research questions, and rather than pursuing answers to already known questions, new research questions are also generated while the process is active (Ylirisku, Jacucci, Sellen, & Harper, forthcoming).

In the process of developing a new framing for the design object a design team needs to construct design resources that enable them to re-think what their challenge is truly about (Ylirisku et al., forthcoming). Dorst (2015) talks about this process in terms of frame construction and he argues that a frame construction approach is especially useful in tackling the open, complex, networked, and dynamic problems. Holistic and integrative aspiration pushes researchers to expand their thinking beyond what is initially connected to the focus of exploration. They typically work in a manner where new materials are generated in multi-disciplinary teams to attain a broader perspective on the topic. A common description of this approach is presented as the expansion and focusing cycle of designing, see e.g. (Laseau, 2001; Pugh, 1991). Divergent, expansive, and generative phases are followed by convergent and reductive activities.

The research project

The Heat Harvest project is one of in total nine projects within the Aalto Energy Efficiency Research Programme (AEF), which is an interdisciplinary programme conducted at the Aalto University (Finland) to improve energy efficiency. The 4-year (2014-2017) project involves researchers from the Departments of Chemistry, Electrical Engineering and Design. The Heat Harvest project explores new thermoelectric materials and seeks to discover new kinds of applications that utilise energy harvesting technologies. The research approach is multi-disciplinary, and this paper focuses on reporting one of the multi-disciplinary workshops that was organised in the project.

The aim of the studied multi-disciplinary design workshop was to produce ideas and considerations that would help focusing the work in the project towards the realisation of some of the design ideas as functional prototypes. The workshops were lead by design researchers and the participants were researchers of all disciplines of the project (chemistry, electrical engineering, textile design and interaction design).

A preliminary framing workshop

Prior to the studied workshop (which forms the data for this paper), a preliminary framing workshop was organised. The preliminary framing workshop provided resources that enabled to set the aims and direction for the second workshop. The preliminary framing workshop resulted 127 ideas of which 45 were defined as ‘scientific’, 52 ‘business,’ and 28 ‘artistic’ related ideas. The idea of ‘Internet of Textiles’ (IoT^x) was amongst the ideas presented in the preliminary workshop. IoT^x was considered as a broad, open-ended, and provocative-enough theme to yield further discoveries for potential applications. The notion of IoT^x borrows from the Internet of Things (IoT) more than its name. The IoT^x was explained to the workshop participants with the assistance of the concept of IoT. The definition was, nevertheless, somewhat relieved from strictly Internet technology considerations, i.e. we did not assume all textile nodes in the network to gain an IP address and communicate through TCP/IP, but accepted any means of networked interaction that could be wireless or embodied. We considered IoT^x to provide a means for seamless communicating and collaborating with users and with other devices and thus feasible for creating service-oriented networks in conjunction with the materiality of textiles.

The IoT^x workshop

The IoT^x workshop was organised on the 15th of April 2015 with in total 12 participants (6 from chemistry, 3 from electric engineering, and 3 from design). The workshop lasted in total for 6 hours, and the program was divided into four main phases: 1) presentations about the IoT^x concept, 2) situational sketching and idea elaboration, 3) persona development, and 4) presenting ideas through the form of short stories and building mock-ups.

Firstly, three presentations of the umbrella concept of Internet of Textiles were employed to set the scene and agenda of the workshop. We outlined three aspects for the participants of the workshop to consider on the concept of IoT^x: 1) interaction, 2) memory, and 3) processing. Due to the interdisciplinary nature of the project, each dimension (interaction, memory and processing) was highlighted through the disciplines involved in the project. A chemistry professor explained these aspects in terms of chemical technology. An electrical engineering researcher presented these in terms of distributed computing, logical processing, communication, and energy harvesting. A design researcher explained textiles, their sensory expressivity, added value, and physical actions that textiles enable.

The second phase of the workshop consisted of imagining users for the future applications. The participants were divided into three teams and each team was given provoking collages of pictures of 5 people on a single A4. They were asked to construct names, occupations, social circles, and attitude to textiles and to explain how the five random persons in their A4 were related to together. The idea was to ground the next phase of ideation on empathic conception of a small set of human beings.

The third phase focused on constructive work with different kinds of physical materials. The workshop space was set up with a variety of textiles with different tactile and visual appearances, and with materials that could be used in a textile-like fashion (e.g. films, tubes). Also additional material props had been brought available to sensitise and to provoke creative thinking. By placing the sensory expressions and properties of different textile material and additional props into the centre of the workshop space, we aimed to draw together the four areas of expertise, chemistry technology, electrical engineering, textile design and technology, and human-centred design, as shown in Figure 1. The use of tangible materials was expected to bridge the different fields of expertise and to create a shared platform for thinking out of the box. It also leveraged thinking with and through materials as opposed to thinking about technical aspects of materials that is customary to science researchers.

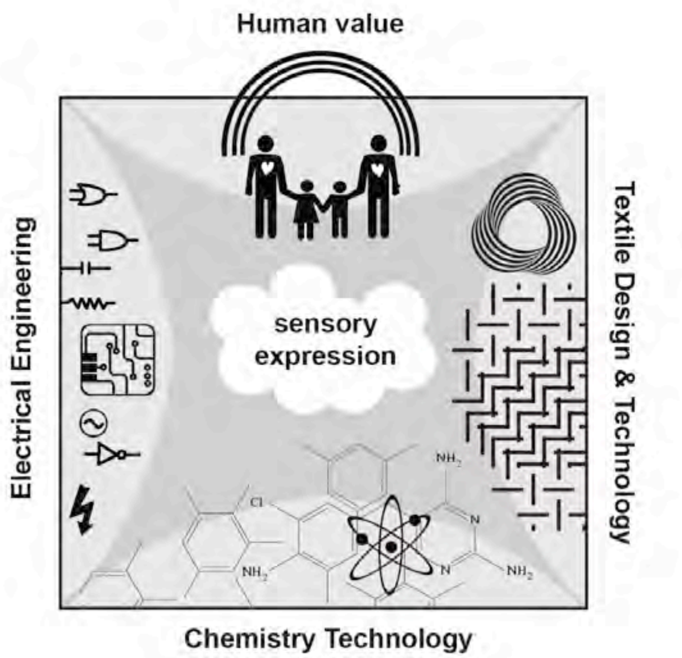

Figure 1. The domains that were brought together in the workshop

The aim for the third phase during which the participants explored the materials was to create situational sketches for the persons that they had imaged during the second phase. The situational sketches are enacted ideas that express concrete situations with specific materials and products that could be utilised for whatever purposes appeared meaningful in the situations. The sketching began with browsing the physical resources at the space, i.e. the textiles, etc. The participants had to envision new product functions, which kinds of external stimuli could trigger the functions of the product, how the product would respond, what types of data and how much data would be produced and used, the manner in which the data would be transferred, and to consider different ways to supply power to the product. Once expressed with the materials, the ideas were documented in a written format on sticky notes for quick reference.

The final phase of the workshop was building stories with the fictional characters that the participants had empathised with earlier. The stories amalgamated the personas with the mock-ups to communicate the ideas in a contextualised manner, so that the social setting motivated the value and benefits of the ideas. This way of working was aimed at constructing and evaluating the ideas with a human-centred focus, thus contributing to reflecting on the plausibility of the future-oriented ideas from the point of view of the potential users.

As the result of the second workshop, the project team created 12 new ideas, five of which were presented as physical mock-ups.

Findings from the IoTx workshop

The workshop was documented with video, which was then transcribed and analysed. The focus of the analysis was on occurrences of such interactions and exchanges where sensuous impressions between the participants of the workshop that could be said to be found and which appeared meaningful for the designing as exhibited by the participants. Below there are clustered according to discoveries on ‘encounters with materials,’ ‘idea development through material exploration’.

Material immersion and initial ideas

The fashion of how the participants interacted and engaged with the textile materials during the phase when the participants began to acquaint themselves with the materials was twofold. Primarily, the materials were approached in a somewhat conventional manner by touching the materials by hand holding the material between fingers without actually picking the fabric off the table or by letting the textile to hang against one’s body. A small group of the participants followed a line of enquiry where the textile materials were approached and explored in a versatile and somewhat unexpected manner by manipulating the materials and immersing themselves into the materials.

Excerpt 1

Researcher M: ((explores the mesh fabric that he took from the table earlier.

He squeezes it into a small ball form within his hands, opens it and puts it over his head in, see Figure 4.))

Figure 4. One of the participants of the workshop explored the sensorial properties of a metallic coloured mesh fabric by veiling his head and upper body.

They also made immediate associations to potential uses on the basis of how they configured their body in relation to the materials. The researchers used both the configuration of the body in relation to the material as well as the appearance of the material, e.g. ‘cloud-like’ to draw ideas for possible technological and usage contexts.

Excerpt 2

Researcher R: ((Takes a ball of wool and pushes her hand into the ball.))

"Look, it's a glove... and a mobile phone."

((Places her hand against her ear))

Researcher O: "And it has already a cloud-like quality!"

Researcher R: ((Changes the ball of wool to a legwarmer with tufted-like threads

across the surface. She swipes over the surface with her other hand, puts the material against her ear again, and imitates talking on the phone.))

Researcher L: "It could also be a hat with a phone that stays near your ear without

holding it with your hand."

Research O: "Hands-free!"

Researcher L: "And when you want to finish your call."

((Hits his head with his palm a couple of times quickly.))

Explicating knowledge through material exploration

It became also apparent how the technically oriented researchers were able to bring their technical expertise to bear on the decisions on which materials they would use for communicating their ideas. One of the ideas developed further in the workshop concerned a jacket (or clothing to be worn on the upper body) that regulates the body temperature according to the indoor ambience. The garment was envisioned to communicate with the ventilation or heating system of an interior. The target group is an infant or someone else without the capacity to either change their clothing themselves or lack the ability to communicate the thermal comfort of the body. The researchers imagined a thermal-responsive material with pores that could expand and subtract due to temperature change. When the body heat would rise, the pores would open enabling free diffusion of heat. A decrease in body temperature would shut the pores and simultaneously fill the pores with insulating air.

During the passage presented in Excerpt 3 the researchers are discussing about how the idea of 'pores' could be expressed with the available materials. They begin to think the materials as enlarged versions of the real materials, like watching through a microscope, and this leads to think of 'nanopores,' which become quickly abandoned based on their expert knowledge on heat dissipation.

Excerpt 3

Researcher A: "We need to somehow simulate either the pores or the other idea."
Researcher M: ((Takes a metal textile structure into his hands.))

"This is somehow really hard to realise!"

Researcher A: ((Lifts a bubble wrap as seen in Figure 5))

"The pores would be really small, like micro, or nano something. This would be just kind of a scale up."

Researcher M: ((Laughs, shakes his head))

"Nano? How effective is heat transfer through nanopores?"

Researcher A: "Very ineffective." ((Puts away the bubble wrap.))

Figure 5.Communicating a scale-up of nanopores with bubble wrap.

The exchange presented in Excerpt 3 was soon followed be what is presented in Excerpt 4. In this exchange Researcher M finds a material that can demonstrate the opening and closing of pores when manipulated in hands. He demonstrates this to his colleagues by holding the material clearly visible, folding it over itself, and showing how it might appear.

Excerpt 4

Researcher M: ((Picks up a woollen, loosely knitted, soft white scarf that he holds up

towards the light and looks through the structure. He then stretches the knitwear and presents it to the researchers as the material's porous, open state. Next he folds the scarf once and then again to imitate the material's pores closed and dense state.))

Figure 6. A researcher presented the idea of textile pores with knitwear. First, imitating textile pore's 'expanded state' by stretching the knitwear (left), and then presenting the material's 'contracted state' through folding the knitwear in half (right).

Thinking of appearances changes material focus

Later the team started to work on the overall appearance of their envisioned clothing. Their final choice of material was a golden coloured mesh fabric, which could better convey active and technological fabric capable of heat transmission than the knitted textile. The golden mesh fabric was described as having the capacity to expand and contract, and the role of the pores became less in focus of their discussion.

Figure 7. Placing the final presentation material for the product inside of the coat.

The team also had ideas about materials that they, nevertheless, did not try with the actual samples present. One such idea was a regulated textile material that could vary its proximity with the body. When the body needs warming, the fabric would have immediate contact to the skin, i.e. the fabric would rest tightly against the body, whereas when the body needs to be cooled, the structure of the fabric would become looser and expand. Another such suggestion was to alter the material's reflectivity so that it would either capture or release heat.

Infusing component thinking with aesthetic qualities

The team used the physical materials to express the technical functionalities that they were assigned with. For example, besides the thermal responsive material in the coat, the garment also included embedded technical functionalities, such as a thermal sensing, electric conduction, transmission and heat harvesting. These ideas were expressed through physical expressions, in terms of technical components, added to the structure one at the time. The conversations and the search for suitable materials to represent the technical components, however, displayed also non-technical properties, as the discussion shifted from to sensory and aesthetic issues concerning the presentation of the idea as depicted in figure 8 and 9.

Figure 8 (left) Exploring different materials to be used as a temperature sensor grid. The metal structure was dismissed as it lacked textile-like characteristics. Figure 9 (right) Suggesting plastic pipe and packaging material to be applied into the garment to add aesthetic value for communicating the idea of a thermal control coat. While the researchers looked for material to express both the thermal sensor and the material element for communication, the focus turned to finding additional material to make the coat visually more appealing while proposing textile-like qualities.

Reflection

Richer interactions with materials resulted in more creative ideas

The purpose of the workshop was to focus the research project through the construction of a 'context' for thinking more resourcefully. The 'grounding context' for the workshop, i.e. the materials, expertise, and presentations, comprised of human value, electrical engineering, chemistry technology, textile design and digital technology. The resulting 'idea context' was intended to serve as a ground for making more aware choices on what should be actually researched and prototyped in the project. We expected that sensing and engaging with tangible materials during the ideation process would contribute positively to the flow of idea generation and to provide means to move beyond ideating on the level of what is obvious to textiles. The workshop resulted in a total of 12 ideas, which were collaboratively discussed in the end of the workshop. Eleven out of the twelve ideas were either about clothing, accessories, or curtains that functioned as a platform for different types of communication purposes.

Based on our video analysis we discovered a relation between the way the participants engaged with the textile materials at the initial stage of the workshop and the characteristics of the generated ideas. Those ideas, which resulted from a more dynamical exploration of materials, i.e. beyond the mere looking at textiles as flat objects or as ready-made textile items, were much more imaginative in how textiles were incorporated in the final expressions of the ideas. On occasions where the researchers engaged in a more active and unusual interaction with the materials, e.g. crunching, stroking or just simply allowing the material to fall gently over the skin to touch and veil the body, as in Excerpts 1 and 2, the exploration resulted in novel types of uses of textiles even though not all of the ideas were brought into the final concepts. One such example is in Excerpt 2, where the participants associated the bodily configuration with the material with familiar situations (e.g. swiping over the surface of the interface of a mobile phone and lifting the phone against your ear to listen) with unconventional material (fluffy knitwear). The action to hit one's head to end a call was also a novel and unexpected feature, which was not used, but which inspired further playful exploration with the materials.

Idea development versus idea expression through material

The researchers employed the given materials in a versatile way to explore issues of different physical scales. The textile pores idea (in Excerpts 3 and 4) was approached with two different strategies to provide thermal responsive changes: 1) macro level changes that offered visual transformation to the textile and 2) micro level changes to the textile surface, which provided non-visual alterations. The idea of textile pores evolved in close connection with the handling, showing, and studying the materials, e.g. the expansion and contraction of material such as was experienced with the knitwear. However, considering the extent of the time spent on the textile pores idea, it astonished how the idea was left open-ended. While the ideation of temperature regulating material was developed from the initial inspiration, the representations of technical components remained vague and appeared as 'slapped on' features on the whole. The consideration of technical functionalities, such as the memory and processing, hence appeared to downplay aesthetic working with the materials. It was, nevertheless, surprising that these considerations also prompted discussion into aesthetic concerns that were reflected in search for materials to enhance the visual appeal.

Interdisciplinary challenges with ideation

The majority of the participants approached the materials with slight caution initially. Some participants remained entirely distant to the materials applying only visual contact. Nevertheless, as the workshop progressed, they became more active towards engaging with the materials. In particular, materials that had a strong visual impact, i.e. metallic or metallic-looking textiles and textile-related products as well as textiles with distinct textural surface or colour changing properties, captured the attention of these participants. Consequently, these types of materials provoked discussion, idea elaboration, and they were actively used to communicate ideas.

The participants integrated textiles in a rather passive manner as a platform for adding technology, rather than making use of textile’s inherent properties, both tangible and intangible, as means to create new innovative products or new functions to existing products. This may be an effect of the way through which the workshop was facilitated, i.e. the participants were enabled to construct their ideas, explore the materials, and integrate their ideas of the use of the materials freely. It could have been possible to instruct particular approaches to the materials in order to utilise those in a more resourceful manner.

Some of the challenges in ideation appeared to stem from the different foci of the disciplines that the participants of the workshop represented. This discrepancy of foci is visible especially in the event of communicating a scale-up of nanopores with bubble wrap (Excerpt 3). This discovery triggered us to examine the different research disciplines in regards to how they are positioned in comparison to each other in terms of scale of materiality, and the type of properties that are subject of focus. Figure 10 illustrates a few interesting aspects that highlights some differences between the disciplines of the project.

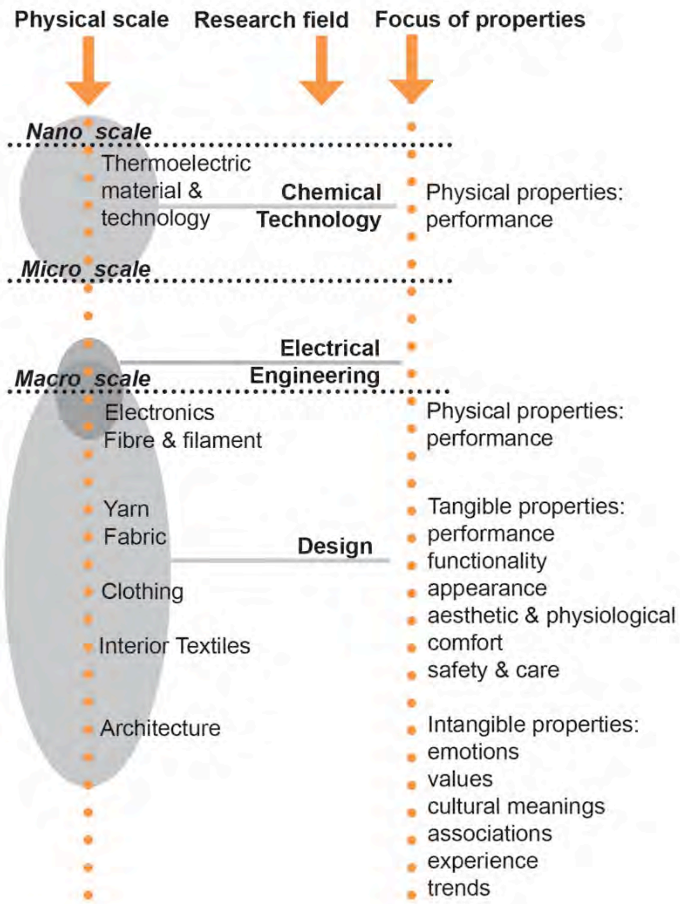

Figure 10. A map of the physical scales of materiality across the different research fields within the project.

Chemical technology and electrical engineering share a common science culture as they investigate scientific phenomena and the study of materials with an objective approach opposed to design that employs a subjective approach. The science disciplines are highly specialized with a relatively narrow research area, which entails studying material through additional material, devices and instruments to obtain the needed material knowledge. In contrast, design, especially textile design, engages and acquires material related knowledge with material directly, often without mediated material or instruments that uses the human senses. Chemical technology and electrical engineering study the properties of materials with the main focus on performance properties and the controlling of these through the material's nano- and microstructure. Design, on the contrary, adopts a much wider focus covering a broad range of relations with materials, such as performance, functionality, appearance, aesthetics, physiological comfort, safety, care, cultural meanings, associations, and trends. Consequently, this allows for design to develop a more holistic approach to the study and development of materialised ideas. Thus, this type of approach may impact on the utility of materials in particular applications and products and enable to build human-centred context for new materials research.

Conclusions

This paper described and reflected upon a design-led workshop carried out by design and science researchers in an interdisciplinary material development project. A procedure for facilitating materials-based ideation with multidisciplinary participation was presented and the key insights were explicated. One of the underlying goals of the studied project was to enable technical and scientific researchers to engage in creative ideation work on the basis of direct material exploration in order to let the materiality to guide and drive the thinking. We encouraged free exploration, construction and presentation of new ideas with a wealth of diverse materials that were provided to the workshop space.

It was found that scientific and technical researchers have a tendency to sit back and observe the textile and other materials from distance and treat them as ready-mades instead of creatively engaging directly with the materials. This ready-made character became enforced in the final idea presentations where the technical ideas were simply added on top of the existing textile products. We, however, observed certain examples in which the technical and science researchers studied the available materials in dynamic ways, and this not only triggered them to draw rich associations from their everyday experience, but also enabled them to bring their expertise to bear on the evaluation of the feasibility of the ideas. The researchers also displayed resourcefulness in playing with ideas of different scales with the materials. It appeared easy for them to consider a material object as a super-sized version of a nanoscopic phenomenon they were discussing.

The aim of the workshop was to construct application context for the design of thermo-electric energy harvesting applications that combine textiles, thermoelectric materials, electronics, and additional smart materials. The use of physical materials as catalysts for idea generation, discussion, and reflection appeared to work in many regards: 1) they served as common entities for reference for people from different backgrounds, 2) they allowed for playful exploration and idea generation while starting from the material perceptions, and 3) enabled also the scientific and technical researchers to go beyond their professional roles in exploring contextual associations for the applications of use.

The workshop, however, resulted in ideas that were not directly applicable in the project, but required a post-workshop reflection in order to re-frame the focus of the subsequent work. It is possible that with a different kind of workshop facilitation the resulting ideas may have become better actionable in the next steps. This, however, can only be known after the workshop is done.

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Epistemic mutations:
Material object engagement in exhibition making

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Abstract

The paper investigates how experimental design practices in pre-exhibition object handling can unfold the materially embedded knowledge production of museum objects. Even though material objects are recognized as key elements in museum practice, concerns for their specific material qualities, such as texture, color, weight, etc., seldom function as primary drivers during the curating and design phases in exhibition making. This is partly due to preservation issues – the fact that direct object handling must be limited – but is also a result of dominating textual practices. This paper argues that, if the materially embedded knowledge of museum objects is to be conveyed in an exhibition context, curators and designers must engage with the objects on *material terms*. Based on empirical analysis of a series of experimental object juxtapositions and display designs, the paper explores how experimental handling of material objects can unleash the experiential and tangible qualities of museum objects beyond the constraints of fixed, conceptual meaning. Sociologist Karin Knorr Cetina's thoughts on epistemic practice will serve as an analytical framework for this investigation. Thus, the paper places epistemic theory in a museum practice context and relates it to processes of practice-based design research.

Keywords

exhibition design; museum object; material presence; design experiment; epistemic object

Within museum studies and museum practice alike, current discussions about visitor experience at museum exhibitions and how to enhance it focus on the need for multi-sensory interpretation strategies. The distancing visual hegemony that has traditionally dominated exhibition aesthetics is being challenged by the call for touch and other types of close, sensory object encounters (Candlin, 2006; Classen & Howes, 2006; Levent & Pascual-Leone, 2014). Material object qualities – i.e., the actual physical properties, such as texture, weight, color, etc. of museum objects – and how these qualities can affect the museum visitor and bring about strong emotional and transformative experiences are increasingly emphasized and valued (Dudley, 2010, 2012). However, the main focus within these material and sensory turns in museum literature is directed towards the exhibition situation as such, that is, when the museum visitor encounters the objects on display or, preferably (some would argue), touches them. As a supplement to these studies, this paper will focus on material object engagement in the developmental phase of exhibition making and argue that, in order to create exhibitions that enable the visitor to engage with the material qualities of museum objects, you must first get to know what these qualities are. You must engage with the objects on *their material terms*. In the present study, those material terms have been established by employing an experimental, materially embedded design practice. In connection with the exhibition project *The Body Collected* at Medical Museion (University of Copenhagen), a series of experimental object juxtapositions and display designs were conducted with the purpose of probing the material qualities and display potential of objects from the museum's collection of pathological and anatomical specimens. Empirical analysis of these experiments will lay the ground for this paper.

In order to grasp and talk about the study's experimental, material processes, the paper will draw on sociologist Karin Knorr Cetina's theory of epistemic objects and practice that she puts forth in her essay *Objectual practice* (2001). Although developed in relation to natural science practices (meaning that this paper's adoption of the theory presents a significant contextual shift), Knorr Cetina's foregrounding of creative and constructive aspects within experimental practice makes her theory a useful conceptual toolbox for analyzing and understanding the particular epistemic dynamics of this study's design experiments. In order to connect ideas of scientific epistemic practice to questions of material practice in design, the paper will also draw on historian of science Hans-Jørg Rheinberger's thoughts on materially embedded experimental practice. The paper sets out to investigate the following questions: How do the design experiments unfold their epistemic functions, and what kind of materially embedded knowledge do the display experiments bring forth in the specimen objects? These investigations will contribute to discussions about object engagement and material design practices in exhibition making. However, before commencing the empirical analyses, some initial thoughts on the presence effect of material objects, as formulated by literary theorist Hans Ulrich Gumbrecht, and why contemporary exhibition practices fail to embrace its potential will lay the groundwork for the paper's epistemic investigations.

Epistemic presence

For preservation reasons, most museum objects can only be handled and touched to a very limited extent, meaning that the *material* encounter between curator/designer and museum objects often does not occur until rather late in the exhibition development phase. Curating and design processes will, therefore, typically be based on register information and photographic object documentation, which can never fully depict the three-dimensional material presence of the objects. The dominant textual practice in which you *first* develop an exhibition manuscript and *then* choose the objects that best fit the 'story' also contributes to the lack of actual material object engagement. In these cases, the storytelling and object *context* is put before the material objects themselves, and, in effect, the objects are turned into mere carriers of meaning, functioning "as props in the telling of a story rather than as the focus of the story themselves." (Dudley, 2012, p. 6). Despite a growing concern for the material presence of museum objects and for the nonrepresentational and non-narrative object qualities that this presence entails (Bencard, 2014), the curator/designer's material object experiences and how these shape their exhibition strategies (and, consequently, the visitor's experience) are rarely emphasized as primary drivers in exhibition making. Thus, it appears that it is not just the exhibition visitor's limited access to direct material object encounters that is problematic, as current museum literature tells us, but that the persons who are supposed to actually know the objects and, hopefully, not just for the immaterial stories they represent but for their actual material presence also, more or less willingly, have difficulties entering the material realm of museum collections.

Entering this material realm, however, might not just be a matter of taking the objects down from the storage shelves and placing them before us, which would be the spatial circumstance from which Hans Ulrich Gumbrecht develops his theory of presence: "What is 'present' to us (very much in the sense of the Latin form *prae-esse*) is in front of us, in reach of and tangible for our bodies." (2004, p. 17). Rather, as this paper argues, it is a matter of taking Gumbrecht's notion of the "production of presence" to its extreme and prioritize the dynamic functions of bringing forth and pulling forth that Gumbrecht associates with the word production, when he emphasizes that "the effect of tangibility that comes from the materialities of communication is also an effect in constant movement" (ibid., p. 17). The act of putting the object in front of you and engaging in its instant presence effect will, of course, be the first step. However, this study has set out to investigate the potential of a more radical approach to material object engagement, one in which the objects are seen not as self-enclosed unities (with self-enclosed presence effects) but as objects that transgress their own boundaries, unfold and evolve in the production of materially embedded knowledge – as epistemic objects.

Applying theories of epistemic objecthood and practice to this study's particular display experiments, however, has several conceptual implications. First of all, because the experiments involve medical specimens that, in themselves, can be seen as epistemic objects and the design experiments, therefore, must deal with different scientific logics and epistemic object understandings. Moreover, the general notion of the knowledge-producing potential of exhibition media complicates the matter, since it raises questions about the museum visitor's continuation of epistemic practices in the exhibition situation.[1] Although the paper's conceptual understanding of epistemic objects and knowledge production is, first and foremost, framed within the context of design practice and research, questions concerning the initial epistemic logic of the medical objects will inevitably emerge as the empirical analysis commences, as will issues of the museum visitor's perception of the experiential, materially embedded knowledge that the experiments seek to unfold. Thus, the paper necessarily engages in different epistemic frameworks but will keep its empirical focus on the epistemic objects as they unfold in the pre-exhibition design experiments. How, then, might one define the epistemic object within design practice and research?

Theories on scientific epistemic practice are currently gaining ground within the fields of art and design research. Hans-Jørg Rheinberger's thoughts on "experimental systems" (1997) have, for instance, proven useful for dealing with practice-based artistic research (Schwab, 2014). Even though Rheinberger primarily focuses on the practice field of molecular biology, he has himself associated art and natural science practices by pointing towards a shared "experimental spirit":

> …in my understanding of 'experimental spirit', the interaction of the experimenter with his or her *material* lies at the centre. If one is not immersed in, even overwhelmed by, the material, there is no creative experimentation. In the course of interaction with the material with which one works in an experiment, the material itself somehow comes alive. It develops an agency that turns the interaction into a veritable two-way exchange. It's both a forming process and a process of being informed (Rheinberger & Schwab, 2014, p. 198).

This idea of being immersed in and overwhelmed by the material itself – of being informed in the process of forming – lies at the center of the experimental design practice presented in this paper. Within this framework, the epistemic object can be understood as a material entity that fluctuates between modes of initiating and satisfying experimental inquiries while continuously mutating into new material compositions. The concept of epistemic objecthood, thus, offers a way of grasping the material aspects of experimental design practice, although it should be noted that epistemic objects might, in principle, be rather difficult to grasp in any clear-cut way. As Rheinberger points out, "epistemic things" "present themselves in a

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[1] For the point on combining the epistemology of the exhibition with that of the exhibited scientific object, I draw on discussions with associate professor and curator of the exhibition project Karin Tybjerg. See also Tybjerg, 2015.

characteristic, irreducible vagueness. This vagueness is inevitable because, paradoxically, epistemic things embody what one does not yet know. Scientific objects have the precarious status of being absent in their experimental presence" (1997, p. 28). The study presented in this paper reveals this paradox very well, since it insists on the "irreducible" and "vague" experiential knowledge that material objects produce while, at the same time, sets out with the purpose of *getting to know* the objects' materiality. However, the experimental system's ability to encompass both aspects, no matter how paradoxical, has been the very reason for employing an experimental method, seeing that it allows the kind of irreducible and vague material knowledge that otherwise risks being suppressed by fixed conceptual meanings to come forth. Thus, borrowing Gumbrecht's words, the experiments and, in turn, this paper's analysis of them seek to "reach and to think a layer in cultural objects and in our relation to them that is not the layer of meaning." (2004, p. 54).

Getting to know the objects

The series of design experiments started with quite simple set-ups in which human specimens were juxtaposed in different ways in order to see how they immediately affected one another. What, of course, became clear is that the different combinations of objects emphasize different material characteristics of the specimens by the simple effect of similarity and contrast. For example, the juxtaposition of a whole-brain specimen and a brain section with a massive blood clot emphasizes the copious three-dimensionality of the whole-brain specimen by its contrast to the flatness of the brain section and vice versa (fig. 1). Another experiment juxtaposes a whole brain with a small brain (cerebellum) and this creates a quite different effect (fig. 2). Due to their shared 'whole organ' appearance – their similarity – the two specimens in figure 2 call for comparison, which, in turn, makes their singular shapes and surface texture – by which they stand in contrast to each other – more evident. The branching blood veins in the small brain specimen compliment the twining curves of the whole brain's cerebral cortex but also differ from it, and this interplay of likeness and contrast is what makes the specimens appear the way they do in this particular set-up.

Fig 1. Juxtaposition of whole brain and brain section

Fig 2. Juxtaposition of whole brain and small brain (cerebellum)

In comparison to a single specimen set-up with only one whole-organ brain, the importance of this aesthetic interplay and how it might affect the perception of objects in an exhibition context become apparent. The juxtaposition in figure 1 accentuates the spatial analytics of dissection, since it presents us with both a brain seen from the outside and a section of a brain, which somehow destabilizes the completeness of the whole brain and makes you wonder how it looks inside – for instance, whether a dissection would disclose a blood clot in that specimen as well. In figure 2, it is the whole organ shape and the specimen's surface texture that is accentuated. By contrast, the single-brain set-up does not unfold the same kind of aesthetic interplay that analytically dissects the object *beyond* the surface of the glass jar, meaning that the object is allowed to close in on itself, affirming its own completeness, while proclaiming: *this is a brain!*

Building on Rheinberger's theory, Karin Knorr Cetina notes how it is exactly the "lack in completeness" that defines the epistemic object:

> I want to characterize objects of knowledge ('epistemic objects') in terms of a lack in completeness of being that takes away much of the wholeness, solidity, and the thing-like character they have in our everyday conception. The everyday viewpoint, it would seem, looks at objects from the outside as one would look at tools or goods that are ready to hand or to be traded further. These objects have the character of closed boxes. In contrast, objects of knowledge appear to have the capacity to unfold indefinitely (2001, p. 190).

Looking at the brain specimen set-ups in the light of Knorr Cetina's notion of epistemic objects supports the notion that the way in which museum objects are juxtaposed and displayed might reveal their epistemic qualities in different ways and to different extents. Whereas the solitary brain specimen closes in on itself, attaining the character of a "closed box" – effortlessly, you might say, since it inherently presents itself as a closed (glass) box – the same specimen, when juxtaposed to other brain specimens, seems to open up and extend itself into a materially-determined interplay, thereby exemplifying how display objects can function as "processes and projections rather than definitive things" (ibid., p. 190).

These initial experimental set-ups did not follow a fixed curatorial idea or categorization but investigated the objects in a manner that opened them up rather than pinning them down. In order to maintain and stay with the basic materiality of the objects, I deliberately refrained from seeking information about the specimens in question. As a result, many of them appeared to me as rather obscure pieces of unrecognizable human material, since I did not have the proper medical knowledge to decipher them or the necessary Latin skills required to read their labels. Instead of initiating the object engagement by putting the objects in intellectually meaningful categories, I explored the purely material characteristics of the objects with no regard to their specific function and meaning as part of an eventual exhibition display. This opened a path into the material realm of the objects that, even though the exact set-ups did not make their way into the final exhibition, presented a material concretization that contributed to the development of a key curatorial concept: that the production of human specimens – the particular way in which specimens have been cut and dissected to reveal certain anatomies or diseases – marks a crucial point in terms of how the objects can make their materially embedded knowledge tangible in an exhibition context. Moreover, they provided the groundwork for additional experiments that moved beyond the simple juxtapositions to search for ways to accentuate and extend the material qualities of the specimen objects by introducing *other* materials in their immediate display surroundings. Whereas the initial set-ups conducted their experimental investigations with a rather light touch, the following display experiments unfolded the objects' material knowledge in a more transgressive way.

Material layers

Display design will always entail some kind of added material, such as showcases, plinths and other mounting hardware, and the material used to construct this hardware will typically be chosen for its ability to present the object in 'the best way', which, in many cases, will be thought of as dependent on the material's unobtrusive background character. Unobtrusive, however, would not be the right word to describe the next experiment. Here, a heart specimen has been placed on top of a voluptuous plaster 'podium' into which it seems to sink as if the podium were a compliant, malleable cushion (fig. 3). This 'sinking into' reveals the rectangular shape of the specimen jar while also pointing towards its heavy weight. At the same time, the podium with its softly rounded folds and beige color mimics the layer of fat on the heart specimen, which has the effect of making the specimen's materiality seem to extend and flow outwards into the object's surrounding space (fig. 4).

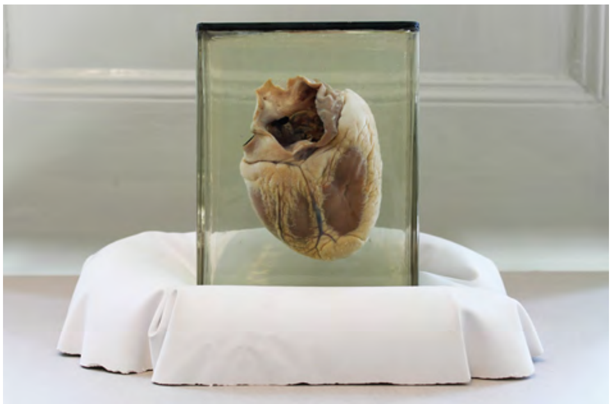

Fig 3. Heart specimen 'sinks into' plaster podium

Fig 4. The soft folds in the plaster mimic the layer of fat on the heart specimen

This ‘new’ object, composed of the specimen object and the plaster podium together, destabilizes the completeness of the specimen object and provokes a shift from its original epistemic construct. Knorr Cetina describes epistemic objects as “things that continually ‘explode’ and ‘mutate’ into something else” and develops her idea of the temporal structure of epistemic objects – the fact that they are “always in the process of being materially defined” – by describing this process as an “*unfolding ontology*” (ibid., pp. 190-191). This idea of an object construct mutating into a new object construct seems to capture the dynamics of this display experiment very well. In order better to grasp the mutation from medical science object into display object, let’s take a closer look at the epistemic unfolding of these particular specimens.

When considering the epistemic nature of human specimen objects, the detection of their “unfolding ontology” seems quite straightforward at first: Tissue, organs and body parts were extracted from the human body in order to produce knowledge about certain anatomies or pathological diseases and then placed in preservative liquids and glass containers to stabilize and arrest this knowledge in time – a stabilization that, in turn (once their initial relevance as knowledge producers in the context of the medical professional expired), has enabled them to function as museum collection objects. Thus, stabilization over time is at the core of these object’s ontology. At the same time, however, the preservative liquids and hermetically sealed glass containers seem to turn them into perfect “closed box” objects, preventing, it would seem, the further unfolding of their ontology. If epistemic objects are indeed characterized by their continuous mutations, as Knorr Cetina argues, then these objects might have ceased to be epistemic at the very moment the glass container lid was glued on. However, the knowledge-producing potential of the specimen objects depends, of course, on the specific epistemic purpose and approach, and, in this case, the experimental juxtapositions and display designs have been a way of placing the objects in different experimental settings, thereby unfolding them anew. Rather than asking the object ‘what does a blood clot in the brain look like?’, the questions posed by this study’s experiments have been: ‘how does the initial scientific question manifest itself materially in the way the specimen has been dissected and preserved? And how can this material manifestation, along with other particular material object qualities, be made tangible in an exhibition display?’ Thus, it is not only the materiality of the specimen inside the glass and its medical scientific value that matters. Rather, body object, medical object, and museum object function as *one* specimen object, and the display experiments have engaged in this object’s total materiality: human body material, preservative liquids, and glass container. Even though the human material inside might be the primary reason for exhibiting these objects, the liquids and glass containers are as much a part of their material presence.

The experimental idea has been to open up the specimen objects anew – not by removing the lid of their glass container but by transgressing their material boundaries and picking up on “the pointers they provide to possible further explorations” (Knorr Cetina, 2001, p. 192). The explorative purpose has changed from a medical-scientific to a design-experimental one, and the pointers that have been picked up on have been of a predominantly aesthetic character, that is, pointers that have to do with materially-initiated sensory stimuli. Which is not to say, of course, that material stimuli were not relevant for the medical scientist but only that the purpose of unfolding the materially embedded knowledge of the objects has shifted. This is exemplified, for instance, by the ‘picking up’ on the rectangular shape and heavy weight of the heart specimen object as an aesthetic cue for the casting of the plaster podium. Importantly, however, at this point in the series of experiments, picking up on aesthetic pointers was, to a greater extent than the juxtaposition experiments before, steered by curatorial ideas of letting the exhibition design connect to and reflect the initial scientific knowledge production. This is particularly apparent in another experiment in which the display design seeks to accentuate the particular act of extracting organs and tissue from the human body in order to turn it into a specimen (fig. 5). In this display, a specimen object is displayed in front of a plaster cast that reveals the object’s ‘negative space’, which points toward the production logic of the object: that it is a *positive* material volume that has been excavated from the human body, thereby leaving its own *negative* space behind. However, by picking up on the glass canister’s aesthetic pointers and not showing the negative space of the specimen lump itself, the display evokes this notion of excavation by embedding the specimen object in a material setting that unfolds its total exhibition object materiality.

Fig 5. The ‘negative space’ of the plaster cast reveals the shape of the canister

Even though the way in which these ‘new’ epistemic object mutations connect to the specimen objects’ initial epistemic functions is somewhat abstract, its material presence is, nonetheless, quite concrete. By supporting the material concreteness of the objects and their display setting the experiments have accentuated and unfolded different material layers in the specimen objects. As such, they have functioned as a design researcher’s privileged object engagement practice, involving the possibility of direct touch. However, the experiments have also set out to investigate how display design might strengthen the experience of an object’s tangibility, i.e., its material concreteness, without depending on direct touch. Thus, despite the paper’s focus on pre-exhibition object engagement, the idea of unfolding the museum object’s epistemic materiality in the exhibition development phase cannot be completely delineated from ideas of the museum visitor's perception of the exhibited objects. In order to illuminate this epistemic transfer from touching exhibition maker to non-touching exhibition visitor, let me now turn to questions of tangibility and material handling as they have occurred in the process of making the experimental displays.

Epistemic transfers

When seen in the context of museum exhibitions, the specimen objects seem to present an additional distancing layer than the typical exhibition object placed inside a glass showcase. Thanks to their glass containers, the specimens have a showcase of their own, and the question of touching these objects and thereby, presumably, deepening one's experience of them is, therefore, problematic. For do they not all feel somewhat the same? And does the act of touching the objects even make sense if you cannot touch the specimen inside but only the surface of the glass that contains it. The experiments presented in this paper, however, have made a point of engaging in the total materiality of the objects, including their glass containers, since they are an integral part of the object's epistemic construct. Yet, the experiments have also tried to overcome the limits of these containers by investigating how their display might extend the specimen materiality, so that it 'spills into' the surrounding space. In the design process, therefore, it has been a question not only of touching the objects themselves – feeling their weight, their cold, hard, yet smooth surface and letting the fingers decipher their rounded or rectangular shapes – but also a matter of touching materials that connect to the specimen material *inside*, albeit, in a more indirect way. For this purpose, the plaster came into play, since it shares some fundamental material characteristics with human body tissue: malleability and liquid flux. Of course, plaster hardens in time, which is a crucial aspect of its efficiency as a construction material. However, in the initial process of making the casts and handling its fluid mass, the plaster has had the effect of connecting to the malleable tissue inside the glass containers.

Fig 6. Handling and shaping liquid plaster using silicone cloth

Thus, the material object engagement entailed a fluctuating interplay between the objects as such and the material used for their display design, mediated by the material handling of the designer (fig. 6-7) – an interplay that foregrounds the question of subject-object relations, which is also a central concern for Knorr Cetina, who argues for a "relational idiom" in epistemic practice discourse. While rejecting the performative idiom's focus on habit, skill and "procedural routine" (ibid., pp. 187-188), Knorr Cetina emphasizes the importance of the "dissociation" between subject and (work) object that arises when a work practice is new to a researcher. This notion of dissociation that "inserts moments of interruption and reflection" into research practice (ibid., p. 184) captures very well the dynamics of the experiments presented in this paper. It stresses the constructive and creative potential of non-routine practices that arose not only with regard to the ‘unknown’ medical details of the specimens but also during the process of plaster-casting. Had plaster been a material that I, as a designer, had worked with before (thereby acquiring skill and routine in handling its particular material flux and sensing its smooth surface texture), it would escape my attention as a work object and lose its power to push and affect the material interplay that the experiments sought to unfold.

Fig 7. Making a plaster cast

While the breaking of habits has shown a constructive effect in terms of interrupting routine engagements with the material at hand, thereby making its material characteristics appear, it seems futile, nonetheless, to reject completely the function of skill in relation to this paper’s notion of epistemic practice. Knorr Cetina maintains the importance of expert experience, which she defines as “an arousal of the processing capacities and sensitivities of the person” (ibid., p. 195). However, regarding habitual skill and expertise as two different things, as Knorr Cetina seems to propose, proves difficult in relation to this paper’s investigations not only because it involves the experimental practice of a designer whose skills are tightly connected to processes of sensory stimuli sensitization but also because the question of skill becomes crucial when it comes to speculating about the exhibition visitor’s perception of the material objects on display. For, whereas the designer’s skills are based on an attunement towards the aesthetics of material qualities, the skills of the museumgoer have long been cultivated towards the expectation that the production of meaning in exhibitions is based on language and narrative rather than material object presence.

Dealing with this epistemic transfer from one type of ‘skilled expert’ to another raises several questions. For instance, how can the museum visitor be supposed to pick up on the aesthetic pointers that the curator/designer experienced when handling and touching the objects in a much more direct way than would ever be possible at a public exhibition? And how will the visitor be able to pick up on the material pointers that the display has been designed to trigger when the design of the display’s material interplay were based on a specific dissociative subject-object relation and on one individual expert’s sensitivities? This set of questions could, in fact, be extended to include the initial medical scientist’s expert handling of the objects as well, since the curator/designer’s picking up on the medical-scientific pointers, of course, presents a similar transfer of expertise. Answering or finding solutions for these questions lies beyond the scope of this paper, but a starting point might be, first of all, to recognize the experiential determining factors within different habitual skill sets as well as the productive potential of breaking with these habits – not only the designer's habitual use of 'unobtrusive' background materials (a habit that might be detected in the extensive use of flat plane materials in contemporary exhibition design, such as MDF board and plywood) but also the museumgoer's habits of relying on exhibition texts to make sense of material objects. Even though the material object engagement and epistemic practice that might take place during an exhibition's development phase will necessarily differ from the ones taking place in the final exhibition, it does not mean that the unfolding of the material object does not continue beyond the exhibition's opening date – only that it happens on different terms, based on the experiential processes of the visitor. Processes that might hopefully be materially tuned – or sensitized, if you will – by the material presence of the objects and their display.

Conclusion

The experimental object juxtapositions and display designs presented in this paper have concretized the potential for pre-exhibition object engagement as a way of unleashing the materially embedded knowledge of objects. Thus, remembering Gumbrecht's words, the paper has presented a possible trajectory for reaching a material object layer that is not the layer of meaning. Although it should, of course, be noted that the particularly strong material presence of the human specimens involved in this study, as well as the opportunity they have offered for extensive, direct touch, might not be directly comparable to all other museum exhibition productions – just as the implied loss of conceptual meaning might not fit all curatorial purposes.

In pointing to the loss of meaning, however, I do not wish to say that the study has completely abandoned any notion of meaning. After all, it is the epistemic sense-making of the experiments that has produced this paper's arguments. However, one should not assume that the transfer from experimental practice to conceptual word has resulted in a 1:1 account of the study's material processes, just as the image material presented in this paper does not capture the full three-dimensional materiality of the experimental practice. In that sense, the images have functioned – and lacked – in the same way that photographs of museum objects do when they are used as substitutes for actual material object engagement in pre-exhibition development. Although epistemic theory has presented a way of grasping the material processes and its concepts have made it possible to formulate this grasping, the material complexities of the experiments have not been comprehended in any exhaustive way. Hence, the sense of loss goes both ways. While the emphasis on the material presence of museum objects entails a loss of conceptual meaning, the sense-making that has taken place by putting the study's experimental processes into words and images has lead to the exact reverse: a loss of material concreteness. However, what is gained – the possibility of taking advantage of the rich experiential and tangible knowledge potential of museum objects and exhibition media and, quite importantly, finding ways of talking about it – fully compensates, I believe, for such losses.

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Designing with an Underdeveloped Computational Composite for Materials Experience

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Abstract

In response to the urge for multidisciplinary development of computational composites, designers and material scientists are increasingly involved in collaborative projects to valorize these technology-push materials in the early stages of their development. To further develop the computational composites, material scientists need designer's inputs regarding the physical properties and temporal behavior of the composite, as embodying an application in a context of use. Effective communication of material knowledge and design knowledge between the two disciplines (material science and design) has proven to be challenging due to their different perspectives on materials. Designing appropriate product concepts requires understanding of composite's unique characteristics and creating aspired value closely linked to those characteristics. Our design case shows that designing for materials experience can provide a useful framework to organize the design activities around understanding the technical and experiential characteristics of underdeveloped computational composites. Collecting and making tangible samples, outlining and simulating possible physical and temporal behavior and discussing them with material scientists and users improved designer's understanding of the underdeveloped computational composite. Our study points out the need for clarification of possible aspired values in designing with computational composites and discussions on those, prior to determining the design/development path. Further, it underscores the multifaceted role of prototypes in resolving uncertainty associated with material knowledge and a preferred design path and mobilizing design actions, that entails further investigation.

Keywords

design process; computational composites; materials experience; design-driven innovation; smart materials

Recent advances in material engineering and manufacturing techniques, and miniaturization of electrical components have given rise to a large number of technologically viable as well as large-scale producible material compositions. So-called 'computational composites' (in short CCs) (Vallgårda & Redström, 2007) are possible assemblages of smart materials with embedded electronics that are able to convert particular forms of energy reversibly (e.g., to/from electrical energy). They can be programmed to dynamically change their physical features, such as color and texture, in response to external stimuli (e.g., touch, temperature, etc.).

A large number of future CCs are still in the early stages of their development (i.e., underdeveloped; Fig 1), meaning that their components are rather experimental and not yet integrated in materials of applications. Recently, there have been systematic efforts to produce CCs made of smart materials in collaborative projects between designers and material scientists (e.g., Light-Touch-Matters (http://www.light-touch-matters-project.eu/), Project Solar-Design (http://www.solar-design.eu/project)). The underlying goal of early collaborations and consultations with designers is to guide the development of smart material composites according to both experiential and functional advantages (Miadownik, 2007; Wilkes, Wongsriruksa, Howes, Gamester, Witchel, Conreen, Laughlin, & Miodownik, in press; Karana, Barati, Rognoli, & Zeeuw van der Laan, 2015). Communicating the potential of new technology, exploring and demonstrating applications for new technology are among variety of ways that designers can benefit co-development of new technological materials (Nathan et al., 2012). Understanding unique characteristics of the composite (both technical and experiential) and creating aspired value (e.g., certain experience) closely linked to those characteristics are critical steps in designing appropriate and meaningful applications (Karana et al., 2015).

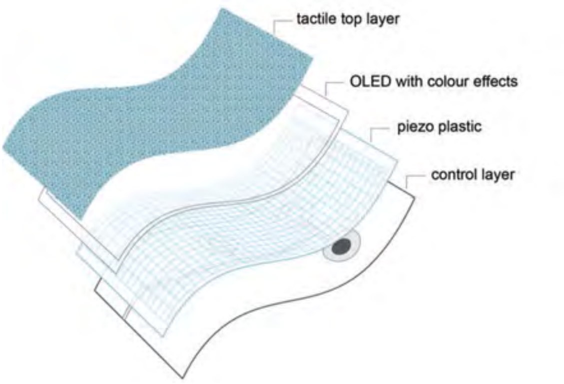

Fig 1. Schematic representation of an underdeveloped CC, Light.Touch.Matters (source: Miodownik and Tempelman, 2014)

Regardless of how CCs are labeled, as physical/digital materials or technologies, designing with them is phenomonologically similar to other material or technology-driven situations, with a difference that early in their development process CCs are hardly available to be directly experienced and tinkered with. So the questions raised are: how can designers explore CC's potential and design with it based on material information provided by material scientists? What strategies can designers rely on to improve their understanding of the CC and its unique characteristics? And what design activities or tools can support them through the process of understanding and designing?

In an earlier study, we suggested the logical equation of 'what' +'how' leads to 'why' as a basis to analyze the design situations starting from an underdeveloped CC (Barati, Karana, & Hekkert, 2015). Our three cases showed that designers relied on 'framing' and 'analogical reasoning' to bridge between the CC's properties (e.g., producing electrical current when deformed) and an aspired value. Analyzing the CC in terms of its functional and experiential qualities supported designers in building such bridges. Adopting the model of product impact (Fokkinga, Hekkert, Desmet, & Özcan, 2014), we explained how the three levels of property, user-product interaction, and overall effect encompass the designers' activities concerning the completion of the equation.

In this paper, we present a six-month journey of a Master's graduation project departing from an underdeveloped CC, Light.Touch.Matters (LTM materials), and finishing with a demonstrative application. We look into the design activities she carried out for bridging between and across the levels and determining the aspired value, and discuss the tools and strategies she relied upon. Our insights on her process help us identify areas that need further in-depth research.

Challenges of Designing with Computational Composites

Designing with CCs in collaborative projects imposes multidisciplinary challenges as well methodological challenges (Redstörm, 2005). Coming from very different backgrounds, designers and scientist have different perspectives on materials, properties and technical limitations, and use different language to communicate. Particularly in the early stages of development, designer's understanding of what the technology is and is capable of is mainly through the material science channel. Such understanding is possibly limited to material's main technical characteristics, functional principles, existing processing/manufacturing techniques and applications. In order to design for materials experience, designer's understanding of CC should encompass not only *what it is* and *what it does,* but also *what it expresses to people, what it elicits,* and *what it makes people do* (Karana et al., 2015). In other words, designers need to make sense of the CC information both as a design material (which needs to be shaped/integrated into a product) and as experienced in use (supporting/hindering certain actions and values).

Methodological challenges of designing with a CC are concerned with the digital-physical nature of CCs and their dual citizenship in embodiment and function of the application (Wiberg & Robles, 2010; Redstörm, 2005). In addition and in relation to the static physicality, CCs also characterize certain temporal behaviors that need to be defined. Designing with CCs is, therefore, not only a matter of giving them physical form, but also envisioning their temporal characteristics as situated in the social, cultural and behavioral context of use (Rosner, Ikemiya, Kim, & Koch, 2013)—within a 'situational whole' (Karana, 2009). Over the past decade, many design researchers have invested a great deal of effort in exploring affordances and expression possibilities of programmable materials (for a review see Wiberg, 2014). However, horizontal material explorations, reported in many of material-related studies in the field of interaction design lack what Wiberg (2014) calls 'the matter of purpose', i.e., value and meaning creation as the ultimate aim of design.

Recently, Wiberg (2014) proposed a methodology for material-centered interaction design research that emphasizes a back and forth thinking between 'materials' (i.e., material properties and character) and 'wholeness' (i.e., way in which the material is approached from the perspective of the user, and appraised within a composition). Through designing material surface, particularly texture and by elaborating on aesthetic details, designers organize the material properties into applications, and communicate certain qualities and values (Wiberg, 2014). Iterative cycles of making material samples and testing with users allow designers to explore material's experiential qualities (Karana et al., 2015) and verify their success in communicating the intended qualities and values. Tinkering with the material is also encouraged to obtain practical knowledge on its main technical properties, limitations and possible manufacturing processes (Karana et al., 2015). In designing with CCs, designers need additional technical competences such as programming and working with electronic component such as sensors and actuators to embody the temporal characteristics (Bergström et al., 2010; Vallgårda & Sokoler, 2010).

From Underdeveloped Computational Composites to Aspired Values

Any purposeful design process aims to close the logical equation of 'what' +'how' leads to 'value' (Dorst, 2011) and the situation of designing with an underdeveloped CC is no exception (Barati et al., 2015). In an open technology-driven design brief, the starting point and the only constraint is the technology itself (i.e., a fraction of 'what', in this case properties of CCs) and designers have freedom to designate virtually any aspired value as long as the proposed design exploits the unique characteristics of the technology. But where does designer's intended aspired value come from? Is an underdeveloped CC a neutral object or does it invite certain ways of dealing with it (Ihdle, 1990)? In order to design meaningful applications, looking exclusively at either the human or technological side would not suffice, instead the designer require consideration of the complex relations that the technology makes with other artifacts or the context of its use (Jung & Stolterman, 2012). Designing with a technology to create value involves three types of investigations, as discussed by Friedman et al. (2013): technical, conceptual, and empirical investigations. Technical investigations aim for understanding the technology in the light of its 'value-suitabilitie' (i.e., the range of activities and values a technology supports or hinders). To discuss and assess an aspired value of an application the central constructs of 'what values' and 'whose values' should be first conceptualized (i.e., conceptual investigations). Empirical investigations comprise surveys, observations, and experimental studies that help designers study the human context in which the technical artifact is (or will be) situated.

In case of CCs, the communicated properties, characteristics etc. are the only given inputs. As a result sooner or later designers reason from them (or link to them) to the two unknowns of the equation, namely 'how' and 'why'. In order to be able to design with a technology, designers need to interact with it and make sense of it (Orlikowski & Gash; 1994). In this sense-making process, they develop particular assumptions, expectations, and knowledge of the technology, which then serve to shape subsequent actions toward it (Orlikowski & Gash; 1994). In our earlier studies, we realized that design students adopted frames of reference in absence of the actual material, for example an activity like CPR, to explore CC value-suitabilities and to complete the logical equation (Barati et al., 2015). Established activities such as Yoga and boxing, encompass the 'how' and the 'why', and make designer's life much easier in coping with uncertainties regarding CC value-suitabilities. We also observed that a frame of reference could be a theme, which is not associated with a definitive context, such as "way finding in the dark" or even a metaphor such as "parasitic". The important feature is that it helps a designer to build a hypothesis which brings the properties of materials forward: IF this combination of properties are seen from this particular lens THEN they may elicit such aspired value and applicability. In the case presented in this paper, we encouraged the student to design for materials experience through exploring and reflecting on the CC's experiential qualities at sensorial, affective, interpretive and performative levels (Giaccardi & Karana, 2015).

A Case: Interactive Cape Jacket

Our case was defined in connection to a EU project, the Light.Touch.Matters, which brings together designers and material scientists for the goal of design-driven material innovation (Verganti, 2009). The underlying goal of design-driven material innovation is to explore potentials of the technology in opening up new experiences and to further develop the composite according to the design requirement. The LTM materials are composites of two main components of flexible OLED and Piezo electric polymer. The LTM materials feature some main characteristics due to their thin and flexible structure and their pressure and position sensitivity and surface lighting. Since the composite is still in the early stages of its development, it can be merely communicated through description of its components and main characteristics and limitations (provided by material scientists).

In a 6-month graduation project, a Master's design student was asked to (1) explore and communicate unique characteristics of the LTM material and (2) embody the LTM material in a product concept that stands out from its categorical benchmark due to a creative use of the identified unique characteristics.

In order to map the designer's journey from the introduced LTM material to an interactive cape jacket concept (Fig 2), we use the mapping tool we developed earlier in Barati et al. (2015) (Fig 3). The mapping tool consists of three main levels: property level, interaction level and overall effect level which provide a useful landscape of design activities with the aim of navigating design possibilities of an underdeveloped CC. Design activities at property level correspond to 'what' a material/ or future product and their properties are (i.e., descriptive). Design activities at the interaction level correspond to 'how' a material and its properties afford certain forms and functions, how they gratify senses, evoke meanings, elicit emotions and facilitate unique actions/performances (i.e. *materials experience*; Karana et al., 2008; Giaccardi & Karana, 2015). Design activities at the overall effect level encompass any other explorations and investigations regarding the purpose of the material/product (why) and the context of use (where and when).

In addition, the mapping tool supports capturing how various frames of references and eventually design intent facilitate bridges between the property level and the other three levels (dashed line in Fig 3). The connection between the levels is thus used to discuss the aspired value in relation to what ultimately the designed application intends to offer, including value in changing the appearance and adding new functions, value in changing experiences of existing products, and value in changing the purpose for which the existing product are used or in unfolding unforeseen practices. It is important to note that changing the appearance/function, for example, could be a means for reaching to an intended experience or changing the product purpose. The model try to capture to what extent the designer is aware of these moves and influences them in the design intent.

Fig 2. The final concept and prototype

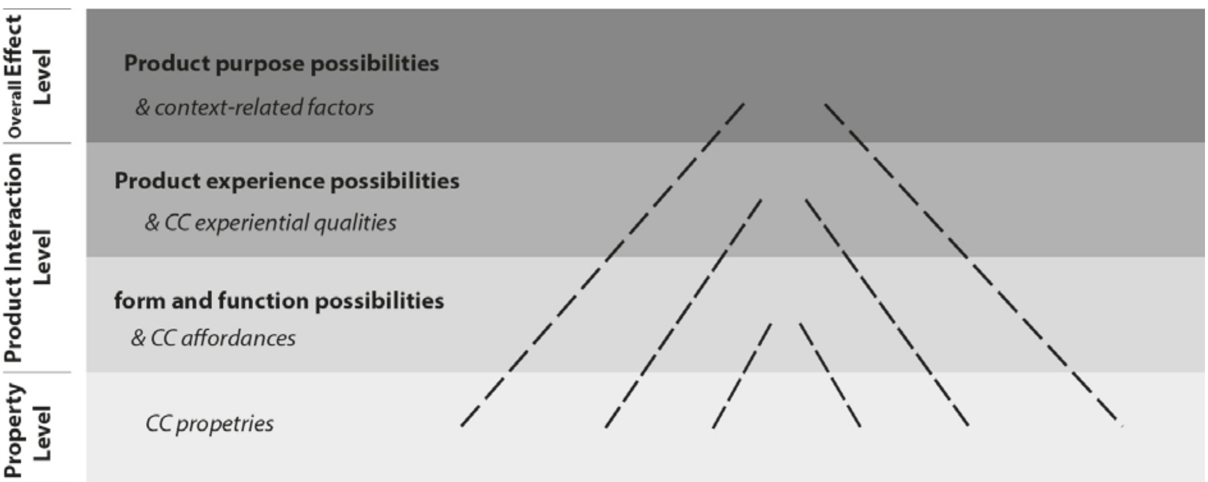

Fig 3. Mapping tool (source: Barati et al., 2015)

Fig 4 illustrates the sequence of designer's activities in connection to the levels presented in the mapping tool. In the following paragraphs, we first report on the main design activities, including mapping the properties; exploring the promising application areas; hands-on material exploration and simulation; materials experience investigation; vision creation, and iterative concept development. While all these activities supported the designer to approach the design assignment systematically, some activities were more critical in addressing the challenges of designing with the LTM materials as underdeveloped CC. We explain the necessity of those activities in material understanding and characterizing, when dealing with information, rather than an actual material.

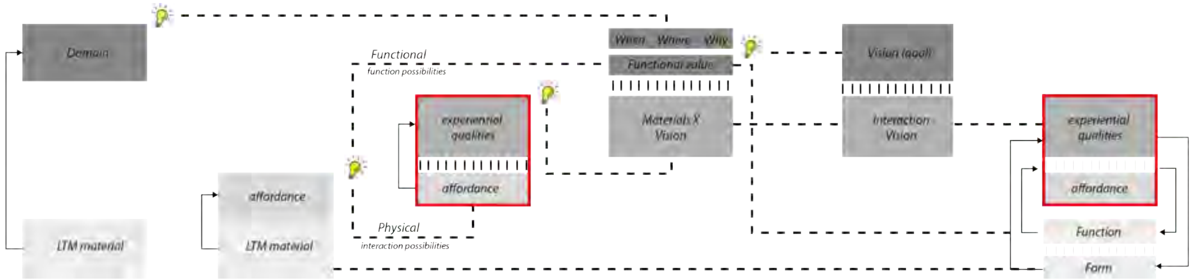

Fig 4. Sequence of designer's activities according to the levels of the mapping tool

Mapping the properties

The designer started the journey by mapping the properties of the two main components of the LTM materials and their overall characteristics according to the information inquired from a material expert. She developed pictograms of the properties and a video showing the main components emphasizing their particular properties (e.g. water resistant) (Fig 5) to map and communicate the material information.

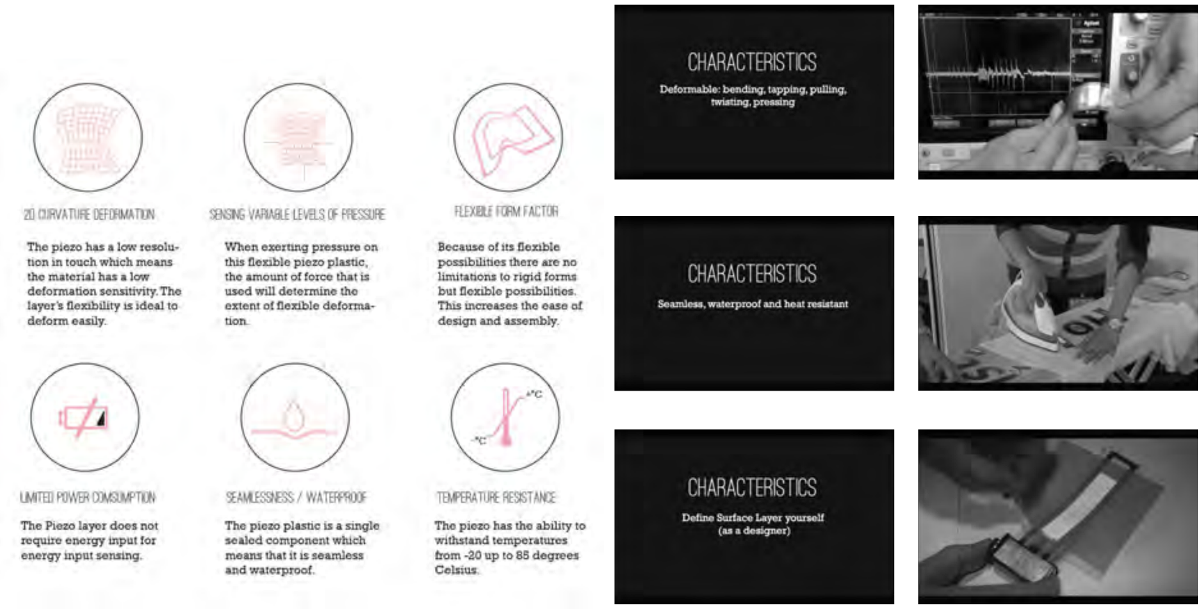

Fig 5. Examples of the pictograms (left), screenshots of the video (right)

Exploring the promising application areas

In a generative session, she invited 5 other design students and designers to identify the promising domains of application based on the provided information. She then cross-related the identified areas to the pictograms and ranking the application areas according to the number of properties that could come into play (Fig 6). The generative session, discussions and reflections on the application areas in relation to the mapped properties helped the designer realize the landscape of competing values (e.g., autonomy vs. security). Such thoughtful consideration of how people might be personally/socially impacted by a technological design involving the LTM material, are the initial steps towards conceptualizing specific values (e.g., conceptual investigations; Friedman et al., 2002). In Fig 4, the designer's first move between the levels is shown using an arrow from mapping the properties to the domains/context of application. By this move, the designer reached out for existing product categories, trends, activities, themes and domains (e.g., rehabilitation) to reflect on the overall effects and purpose of the LTM material in composition.

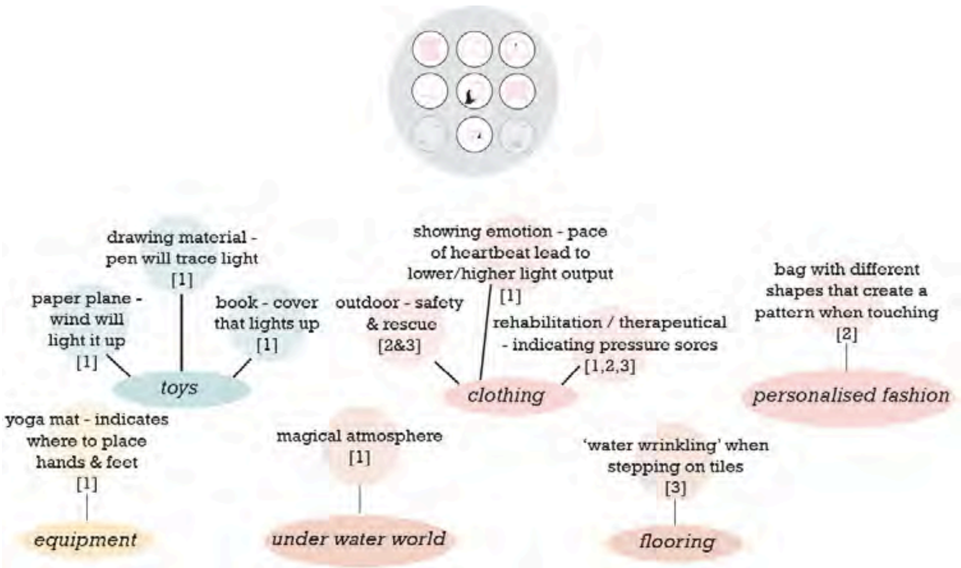

Fig 6. Mapping possible connections between the properties and application areas

At the end of the generative session, the participants were asked to describe their experience of the assignment and discuss the role of pictogram and video in understanding the LTM material. According to the discussions, it is concluded that:

(1) Designers experienced high level of uncertainty regarding what exactly the technology is in terms of feel and experience. They believed that having no material sample hinder an understanding of the LTM material that can be operationalized and readily translated to what can be done with it.

(2) The video, compared to the pictograms, was more successful in sparking a tangible manifestation of the LTM material, however, designers could not transcend literal translations of what they saw in the video.

She deliberately decided to postpone any context-related fixations in the early stages of design process since they could narrow down the design possibilities up front. Instead, she focused again on understanding the LTM material and helped herself (and other designers) understand it in terms of what could be done with it (i.e., affordances) and what experiences it could elicit (i.e., experiential qualities). She hoped that by gaining insights on how the material actively operates, a cohesive design goal, encapsulating the desired impact, the experience and interactions, could be formulated.

Simulating the LTM material and exploring form and interactions

Designer’s next activity towards understanding what can be done with the LTM material was to simulate it according to the given specifications, namely the thickness and the radius of flexibility. She made a small tangible library (Fig 7) exploring various textures, forms and printed light patterns (in connection to printability of OLED) and tried to connect the physical aspects of the LTM material to the possible forms and actions they afford (both the actions and how they are performed, i.e. performative qualities; Giaccardi & Karana; 2015). As indicated with an arrow in Fig 4, her hands-on approach enabled a move from material descriptive properties to navigating form and action possibilities of the LTM materials. It was also a takeaway for the designer toward further exploring the experiential qualities that those actions might elicit. The collection of samples formed in different ways not only gave a tangible manifestation to myriads of properties, but also facilitated a more factual and detailed communication between the designer and the material expert. As a result, a more elaborated understanding of the LTM interaction possibilities in connection to the properties and its functional principle was developed.

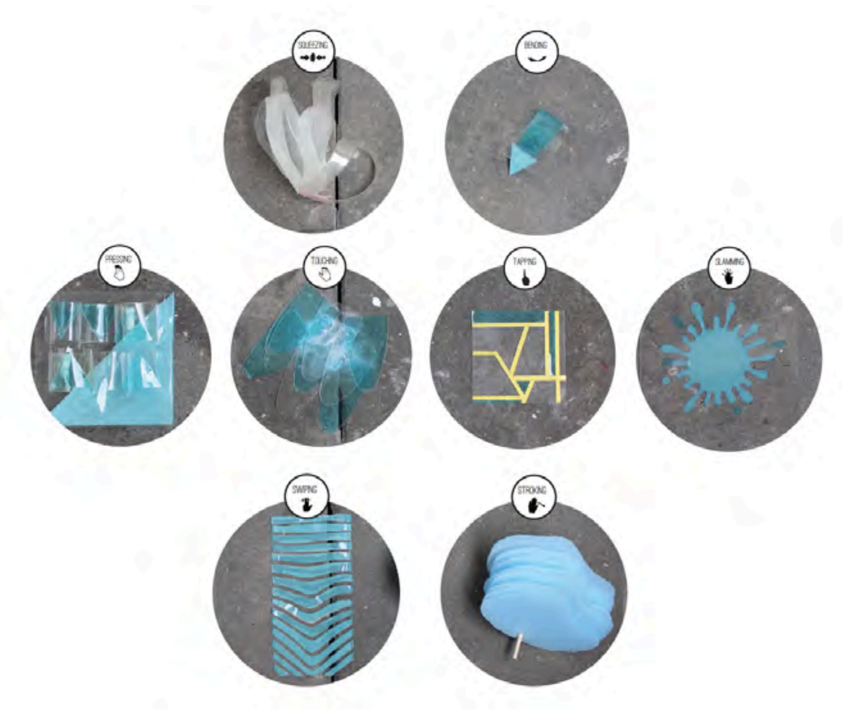

Fig 7. Exploring textures, forms and printed light patterns in tangible samples

Investigating the experiential qualities

Although her understanding of form possibilities with the LTM material had improved considerably, as a result of her hands-on explorations and discussions with the expert, to be able to design she needed to understand how the LTM material and its sensorial properties would be experienced. Karana et al. (2015) emphasize the importance of such understanding and investigating the interrelationships between experiential qualities and the formal properties of the material. Formal properties of a CC include the physical form as well as the temporal form (i.e., the pattern of the state changes that the controller will produce). The designer’s next activity was concerned with an understanding of the negotiation between the two form elements (i.e. physical and temporal) in relation to the possible/ promising experiential qualities.

She created a matrix of actions (e.g. stroking, squeezing) and temporal behaviors of light output (e.g., dimming, flashing, pulsating) corresponding to the functional principle of the LTM material (Fig 8). In an online questionnaire, she asked 20 participants (male and female between 24 and 65 years old) to choose the two ‘intuitive’ combinations and describe aesthetic qualities, meanings and emotions the combinations elicit (e.g., ‘creating powerful rhythm’, ‘feeling alive’ were associated to squeezing/pulsating). Result of the study showed that input/output couplings could readily signal to a broad range of functional values (e.g., light as illumination vs. light as carriage of information) and emotional experiences (e.g., relaxing and reassuring in stressful situations). Investigating the associated experiential qualities offered understanding of how the LTM physical and functional affordances may support or hinder certain experiences (and values). Such understandings when combined with the values identified in connection to the domains, worked as a compass towards certain applications.

Fig 8. Matrix of actions as input and temporal behaviors of light output

Creating an inclusive vision

All her explorations and investigations provided means to move from property level to affordances and experiential qualities and eventually shaped her understanding of the LTM material and its potentials. In order to bring the various findings under a cohesive intentional whole and to have a clear guide for making further design decisions, she articulated the design intention through a two-level ‘vision statement’ (Hekkert & van Dijk, 2011). In her vision statement (Fig 9), she specified why people would find her to-be-designed application valuable and meaningful by elaborating on the use purpose, context and qualities of interaction. By further analyzing the promising domains of application and functional values of light, the designer elaborated on when, where and why the unique technical properties and experiential qualities of a material may come forward (Karana et al., 2015). Fig 4 depicts how designer’s move between the levels are fused and intersected, to enable the designer form an inclusive design goal (using dashed-lines and lamps).

DESIGN GOAL

‘ I want people in unclear weather conditions to communicate their presence to the people around them for extra safety and visibility.’

INTERACTION VISION

‘ The interaction with the material’s tactile and visual possibilities should be dynamic and mystifying. It should feel like expressing oneself when on the move, but at the same time ensuring personal safety. ’

Fig 9. Designer’s vision statement including the design goal and interactions

Iterative concept development

In an iterative making/testing process, she elaborated on the physical and interactive aspects of a cape jacket for outdoor activities, focusing on the texture and light expression. In an experimental study, she showed multiple material samples and 8 texture probes (a ribbed, a woven, a flowing, a facetted, an irregular, a smudged, a wrinkled and a studded texture) to 5 participants and tested which ones could evoke the intended qualities of ‘intuitive’, ‘alive’ and ‘dynamic’ (Fig 10). By playing with the frequency, power and rhythm of light feedback, through programing, she finalized the LTM temporal expression corresponding to the intended interaction qualities.

Fig 10. Experimental texture test (left), programing the light feedback on the shoulder piece and sleeve (right)

Incorporating the LTM material in a wearable jacket made a good use of LTM unique characteristics including waterproofness, flexibility, portability and thinness. Similar to other multifunctional jackets, the concept features an additional functionality to provide visibility (due to OLED bright surface light). What makes the concept different from other existing jackets is the possibility to personalize the light patterns in relation to users' pressure inputs. Particular attention to texture and appearance of the jacket intends to encourage certain performances and actions to activate the sensing Piezo electric layer. But it does not stop there. The concept benefits from the LTM's programmability to allow users personalize the light output beyond a basic function of keeping them safe and making them visible. It unlocks unpredicted practices (e.g., new ways of communicating street/privacy intrusions) leveraging on the sensorial, affective, interpretive, and performative qualities of LTM material. Although the concept has the potential of intending and reaching such overall impacts beyond product experience (Fokkinga et al., 2014), to get there from what it currently is, more iterations of user testing and modifying will be needed.

Discussion

The process presented in this article provided further insights about the situation of designing with underdeveloped CCs. The structured approach highlighted the important components and activities, the designer incorporated to bridge between the given properties and a purposeful application. Our observations and analysis of the design process showed that the uncertainty rising from immaturity of the technology is a challenge and hindrance in designing appropriate application (Shrivastava & Schneider, 1984). However, simultaneously, such uncertainty brings about a unique opportunity for designers to challenge the dominant 'technological framings' (Orlikowski & Gash, 1994)—i.e., dominant conceptions of technology value-suitabilities and already-existing meanings. It gives designer a scape from conceptual limitations induced by an established body of knowledge, and a chance to reinterpret proper meanings and functions of a *becoming* material (Bergström et al., 2010; Sengers & Gaver, 2006). To advance the benefits of uncertainty in collaborative material development, designing for materials experience provides a flexible framework focusing on the understanding of technical and experiential characteristics.

One area that needs clarifications is the quality of applications in terms of value. Designing for materials experience although helped with the CC's understanding in connection to other materials, users and the context of use did not indicate what aspired value to designate as the ultimate design goal. Conceptual investigations on which aspired values are preferred for development of a particular CC and reflecting on them (between the stakeholders) help to explicate what is expected from a proposed application and how it is assessed.

Looking at the product concepts proposed in this paper and our earlier study (Barati et al., 2015), namely an interactive CPR trainer, Yoga mat, punching bag and finally an interactive cape jacket, it is clear that they posit very different 'raison d'etre' (reason for existence), even though they all exploit LTM's technical characteristics. What interests us is the manifold role of the LTM material in embodying these concepts, contributing to or improving their utility, shaping user-product experiences, unfolding unseen and unforeseen practices, and even touching upon ethical issues (saving human lives). These roles are consequences of a set of decisions made throughout design process, including design motivation and inspiration as well as rationale drawn by the functional principle of the LTM material, its characteristics and limitations. Jung and Stolterman (2012) suggest that quality of designs can be discussed based on (1) how aesthetic and functional potential of the technology are illustrated, (2) how meaningful a design intention is from social and cultural perspectives, and (3) how design references are properly surveyed, selected, and applied. Looking into the relationship between materials, their properties and practices developed around the products (made of those materials), Giaccardi and Karana (2015) elaborated on the role of materials experience in shaping our (everyday) practices. Accordingly, the quality of designs might be also discussed with respect to the role of CC's experiential characteristics in unfolding unseen and unforeseen practices.

It is suggested that designer's naïve perspective with respect to every technical details of a technology allows them to see new applications (Dunne & Raby, 2014). Our observation shows that this proposition is true if the designer is keen on attuning her conception of the CC's technical properties and functional principle to what material scientists take for granted about it. Gathering material samples and prototyping in the process of designing with the LTM served both as a way of understanding the given properties and a means of communication (Henderson, 1991). Without such physical representations, it would have been very difficult to verify designer's conception of the LTM material and its aesthetic and functional potential. Our observation confirms that physical probes and prototypes made along the process are viewed as 'boundary objects' (Star & Griesemer, 1989) to resolve uncertainty associated with material knowledge and a preferred design path (Mark, Lyytinen, & Bergman, 2007). Boundary objects are defined as "objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star & Griesemer, 1989, p. 393). But what features of a physical probe/ prototype make it an effective boundary object to facilitate communication across designers, material scientists and users (i.e., participatory design)? What features of it contribute to the understanding of a particular CC (e.g., inspirational bits; Sundström et al., 2012) and inspire design ideas? In our next study, we will elaborate on these questions.

Conclusion

This paper presented a design case study with an underdeveloped computational composite. Explaining the methodological and communication challenges of designing in the context of material co-development, we showed an approach to tackle the challenges along the design process. The approach particularly focused on qualifying the properties in relation to actions, emotions, associations and performances and investigating the user's experience patterns. Designing for materials experience provides a flexible framework to organize the design activities around understanding the technical and experiential characteristics of an underdeveloped CC. However, conceptual investigations concerning the aspired value should be taken place and discussed prior to determining the design/development path. Making physical probes and prototypes helped with understanding the CC and mobilizing further design actions while those intermediate prototypes can be used to communicate, discuss and transform material and design knowledge. The multifaceted role of prototypes in addressing/resolving uncertainty associated with material knowledge and a preferred design path should be further investigated.

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Open Structures: designing 3D printed alterable textiles

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Abstract

The design of textiles is flexible. The soft, pliable nature of textiles means that their expressiveness and physical properties can be altered long after the material has been produced, by e.g. adding or removing colour, pattern, density, or by printing, laser-cutting, etc. This transformability means that the design of textiles can be further developed in another design process in relation to a specific product or context. In the emerging field of textiles produced using 3D modelling and additive manufacturing, structures can be defined in detail and, later, altered or completely redesigned in CAD programs. However, the designs of these textiles are generally fixed when the structures emerge from the 3D printer. This paper describes a practice-based project that explores the transformability of 3D printed textiles, considers the question of whether some of the openness that characterises their digital form can be introduced to their physical form, and then explores what form this could take. It begins by describing the project which forms the basis for the exploration, the outcome of which thus far consists of two experimental 3D printed textiles with changeable physical structures. It then discusses the considerations and decisions involved when designing for such transformable textiles, proposing ways to understand and describe what is taking place: First, by relating them to the considerations made when defining open design systems; second, by introducing two types of design decisions, which together define which aspects of the textile's design are closed to further development, and which are open for others to develop.

Keywords

textile design; 3D printing; transformable materials; design process; open design.

Conventional and new forms of transformable textiles

Textile design is not fixed, but rather flexible. The soft, pliable properties of textiles mean that their visual and tactile expression and behaviour can be altered after the material has been produced by adding or removing colour, texture, pattern, density, or by pleating, embroidering, printing on it, etc. Wolff illustrates this potential by describing the ease with which the expression and behaviour of a single piece of textile can be altered by someone with a needle and thread: "They texturize, embellish, inflate, and support. They create puckers, folds, waves, puffs, projections, and openings. With stitching by hand or machine, they resurface, reshape, restructure, and reconstruct a flat, supple piece of cloth into cloth with an entirely different disposition" (Wolff, 1996, p. vii). The physical properties and visual and tactile expression of a textile are defined by the numerous interrelated decisions that the textile designer makes when defining the material (Wilson, 2011).The overall textile design influences what can be created with it, as well as how it can take part in another design process. This can be described as the textile's 'design affordances', a term originally introduced by Nordby and Morrison (2010) to discuss technology in relation to the design process. The term can also be used to describe what the material designer's decisions allow for in relation to another design process, e.g. what the properties of a textile bring to the table when designing. The transformable qualities of textiles are here a central element, as they facilitate the further development of a textile in relation to a specific product or context through e.g. physical manipulation of the material. As such, the final version of a textile design is not necessarily defined by the person who created the original material; rather, as the design can be involved in another design process, it can be finalised by those people working with the material as part of this other process.

New techniques and material developments have expanded the range of possibilities of not only what textiles can be but also what they can do, both changing and exaggerating some of their inherent characteristics by making them even more transformable and open to alteration. This can be seen in, for example, some of the so-called ‘smart textiles’, which have surfaces which can be programmed to repeatedly change their expression and adapt to different contexts. The new transformations offered also open up for new ways of interacting and sketching with material during the design process, and facilitate the exploration of anything from multiple expressions in one piece of material with reversible transformations to gradual development through permanent changes to the material’s design (Dumitrescu, Nilsson, Persson, & Worbin, 2014). The exaggerated properties of this category of textiles also influence the design decisions that are made when defining these materials: some become more complex (e.g. colour palettes expanding to include multiple states), whereas others which are not ordinarily considered to be central can become essential to the design process (e.g. how textiles change their expression over time) (Nilsson, Satomi, Vallgårda, & Worbin, 2011; Worbin, 2010).

Transformability is also a strong feature of the emerging field of CAD-modelled and 3D printed textiles. This new type of ‘textile’ material is currently made primarily from jointed structures of stiff material, such as digitally modelled knitted or woven textile structures (see e.g. Desbiens, 2013), and structures which mimic or are inspired by how fabrics are constructed, e.g. Pringle of Scotland (Beckett, 2014), Bingham et. al (2007), and Nervous System’s ‘Kinematics Dress’ (2014b). With this type of structure, the visual expression and construction of these materials can initially be defined in extreme detail, and later altered or completely redesigned in its digital form in relation to the object it is to become a part of. However, their design is generally fixed when they come out of the 3D printer, with a few exceptions - notably Translab’s materials (2014).

Aim and scope of the paper

The aim of this paper, and the practice-based project on which it is based, is to explore the transformability of 3D printed textiles in order to ascertain whether some of the openness which characterises their digital representation can be introduced in a physical form, and to then explore how this might be realised. The paper also considers the implications of this transformability with regard to what a textile designer must consider during the design process. Does this technique, like smart textiles, introduce new or more complex considerations to the process? Moreover, what might they look like?

Working in a hands-on manner with a design, e.g. by dealing with real materials and circumstances, can facilitate an understanding of the dynamics of design practice, which can be difficult to achieve through other research methods (Vallgårda & Bendixen, 2009). This is particularly the case when researching new materials; thus, the potential of transformable 3D printed structures was explored by designing and creating 3D modelled and printed textiles, documenting the design process, and studying the nature of the decisions made along the way. The paper continues with a description of the project that makes up the basis of the exploration, and then presents the resulting two examples of transformable 3D printed structures. Finally, the considerations and design decisions that arise when approaching this kind of textile design process are discussed, and ways to understand and describe what is taking place are proposed.

The Open Structures project

The Open Structures project developed transformable 3D printed textiles by alternating between modelling structures in Autodesk's Maya software and printing samples using the PolyJet additive manufacturing technique, as well as working hands-on with the printed prototypes. First, an overall construction system was created to facilitate alterations to the character and properties of a textile. It was important to create stable elements that could be connected to and disconnected from each other. To accomplish this, a rubber-like polymer, sourced from Stratasys, was used, and different types of connections were tested with it. The resulting construction system formed the foundation of the rest of the project, and consists of spherical nodes and links which can be permanently or temporarily connected in order to construct elastic structures. Using these basic elements, it was possible to explore how they might be used and what possibilities they might allow for with regard to further alterations to their structure.

The initial characteristics and properties of the textile structures that were created using the system, as well as their alterability, were defined by the nature of the links and nodes, as well as by how the latter were combined in the CAD model. These printed structures can, depending on the original design, be altered by someone else, who can replace, remove, or add components. The structure can, for example, be made more rigid by adding stiff elements, or become more colourful or more sculpted by adding other nodes and links which afford such qualities. The openness of the original design makes it possible for other designers working with the textile to develop the design quite freely, testing different options in the same piece while still making definite decisions about the final design. When defining the initial structure using CAD, it is possible for the textile designer to limit the ability of others to change links and nodes by either removing the opening function on the nodes or by merging them together with the connecting links. These options make it possible for the textile designer to define which parts of the overall structure should be built to allow for alterations, and which areas or individual elements should remain fixed.

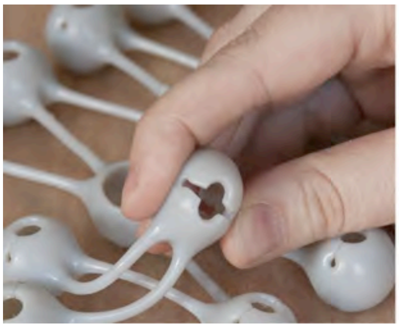


Figure 1. Node opening function. Squeezing the sides of the node creates a large opening, making it possible to attach or detach links that have different properties. Figure 2.The possibility to alter the design can be limited in the CAD model by removing the opening function in the nodes or merging links and nodes together. Figure 3. Examples of 3D printed prototypes and tests from the Open Structures project.

Based on this system, two alterable textiles were designed which offered two different kinds of alterability. This was carried out so as to obtain a broader understanding of the considerations and design decisions that a textile designer deals with when designing this type of textile. The framework of Dumitrescu et. al (2014) explored the use of smart textiles as a sketching material, examining the potential of transformable textiles as tools in a design process. The authors defined both the basic form of transformation that takes place in the material, and the ramifications of using it in a design process. This approach was used to frame the use of transformable materials in the Open Structures project. Firstly, the type of interaction the materials should introduce was considered; secondly, what specific alterations to the design this should involve:

Version A

The first textile was designed to allow for invasive alterations, so that the material's basic character could be explored and developed with few limitations. To do this, the material was built using separate nodes and links, all of which could be replaced or rearranged. The initial design consisted of two areas with different types of construction, which could be retained, altered, or removed by another designer as part of another design process. Other types of links, made from both stiff and elastic raw material, were also provided with the original textile, allowing for different construction techniques and properties to be added to the textile.

Version B

The second version was designed to allow for far fewer alterations, where the primary characteristics of the material were kept but alterations could be made in relation to a specific context. To accomplish this, the textile was designed in the form of a mesh structure with links permanently merged to the nodes, providing basic structure and materiality. The extra links and nodes provided can be used to restrict the elasticity of the structure, but also to change the character of the textile by adding colour, weight, texture, and pattern. This material is designed to have fewer possible alterations as compared to Version A: Some nodes in the mesh are split on one side, restricting the number of extra elements that can be attached, and only a small number of extra elements are provided with the original design – two types of links and one node. Each element introduced into the structure leads to broader consequences for the design; adding, for example, stabilising elements also results in the addition of threadlike extensions to the material, and extension nodes inserted into split nodes add colour but also increase weight.

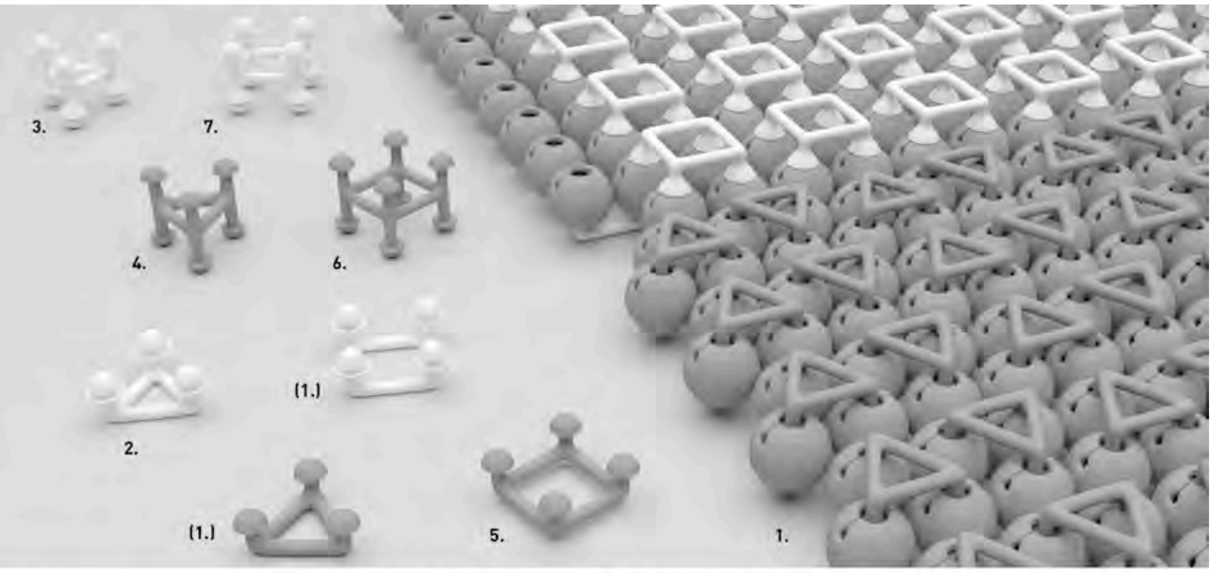
Figures 4-9. Photos of Version A (top) and B (bottom), shown in their respective original design configurations and then in two of their possible variants.

The nature of design decisions in alterable 3D printed textiles

The experimental examples created in the Open Structures project illustrate the fact that 3D printed textile structures can be designed to be physically altered and re-designed – the system of nodes and links is only one example of how this can be achieved. In conventional textile production, basic techniques such as weaving or knitting can to a great extent define the nature of the final textile structure and its inherent transformability. With 3D printed textiles, the way the structure is built is less determined by a specific technique; therefore, the construction can be designed in very different ways and can be made to differ significantly between sections of the material (Bingham et al., 2007). This possibility extends to not only how textiles can be designed, but also to how they can be altered. It opens up for new types of substantial transformation to the textile's design, e.g. by making it possible to alter not only visual appearance and construction, but also the raw materials that the textile is made from. Moreover, and as a result of 3D printing, a textile's alterability can be designed in great detail. Open Structures uses these possibilities to define the type of transformations that the textile should facilitate, as well as in which specific part of the structure this change should be possible: e.g. in Version A, they are used to allow change throughout the structure and, in Version B, they enable alterations at many, but not all, intersections between links and nodes.

What does the possibility to define in great detail a textile's alterability mean for the considerations and design decisions that are made when creating this type of structure? To better understand and reflect on how design decisions frame both present expressions and their possible developments, the textiles created in Open Structures were compared to examples of 'open design'. This term is currently used in several different ways, from promoting transparency in consumer relations to describing open source designs with distributed development to referring to open access to knowledge and blueprints (Avital, 2011). However, the definition followed in this paper relates to designs that are not fixed in their composition. This form of open design introduces a shift in thinking, from working with something which is or has been completely defined to something that can be explored, extended, and re-defined by someone else (Lamontagne, 2013). One of the recurring ideas used when discussing this form of open design relates to considering the design to be a system or meta-design (Stappers, Sleeswijk Visser, & Kistemaker, 2011; de Mul, 2011). From this perspective, the designer's task is to create an 'envelope' which contains several options for the user, but which does not dictate an outcome. Atkins (2011, p. 32) elaborates: "The challenge will be to create systems that enable the design integrity of the end result to be retained and perhaps the identity of the original design intention to be perceived, while still allowing a degree of freedom for individual users to adapt designers' work to their own ends".

This form of open design thinking can be found in several of the digital design systems created in relation to additive manufacturing. One example is the software interface Automake, which Marshall, Unver, & Atkinson (2007) used to explore generative systems for creating numerous unique designs. The system provides a number of simple geometric forms which can be overlapped to create stable structures. The first iterations of the system were to a large extent controlled by algorithms. Users watched a continuously evolving combination of forms and selected their favourite version. As the project developed, the system's designers opted to give the user more and more control over the final design, e.g. letting them freely place forms rather than only relying on algorithms. Another example of open design comes from Nervous System, a design studio which has developed a number of interactive design systems; the digital interfaces of these systems allow users to design and order unique versions of their products, e.g. customising jewellery by changing certain parameters such as the number of holes or layers in its structure, its colour, raw material, etc. (Nervous System, 2014a). The design decisions that define the Nervous System and Automake systems do not specify a final outcome; instead, they frame the original versions of the design and how users can interact with them, e.g. by deciding in which directions the designs can be developed. In some of these examples, the systems' designers quite strictly direct the possible outcomes of their systems, but in others the power over the final design is mainly handed over to the users of the system. Together, these examples highlight the fact that one of the most important aspects of defining the character of this type of open system is to decide how much freedom should be given to the user, and what the boundaries for the design should be (Atkinson, 2010). Exploring what these considerations can mean in relation to 3D printed textiles was an important part of the Open Structures project. Both structures were designed to be alterable; however, the degree to which the two original designs could be transformed differed significantly. Version A was intended to be more open, and therefore contained fewer limitations and greater customisability, whereas Version B was designed to provide more limitations and to restrict possible design decisions to a greater extent. Moreover, the boundaries in an open design can take on many forms – in the previous examples, they were defined in the digital interface. In Open Structures, it was primarily the material's properties and expression which framed possibilities and boundaries for further development. Each version was built from a specific combination of nodes and links, as well as additional elements provided with them, and together they set the stage for not only the initial design, but also what can be created using them. The following diagrams describe the composition of the material systems for Versions A and B:



1. Version A
The original design consists of two areas with different properties and characteristics. Both areas are built from loose spherical nodes with two openings, which can be connected to any type of link. The section made from triangular links with loose connection points has a very elastic structure. The section made from square-shaped links with stable connection points is more stable and even in its construction. Grey material: Rubber-like polymer (Tango from Stratasys). White material: Stiff polymer (Vero from Stratasys).

2. Triangle link Stable
A link of triangular shape and with stable connection points. This link can be used to connect three nodes in one plane and create a stable connection between these points in the structure. Material: Stiff polymer.

3. Triangle link 3D Stable
A link of triangular shape and with stable connection points on the top and bottom of the triangle. This link can be used to connect six nodes in two planes and create a stable connection between these points in the structure, which makes it possible to add three-dimensionality and layering to the structure. Material: Stiff polymer.

4. Triangle link 3D Loose
A link of triangular shape and with loose connection points on the top and bottom of the triangle. This link can be used to connect six nodes in two planes and create a loose, quite elastic connection between these points in the structure. Material: Rubber-like polymer.

5. Square link loose
A link of square shape and with loose connection point. This link can be used to connect four nodes in one plane and create a loose, quite elastic connection between these points in the structure. Material: Rubber-like polymer.

6. Square link 3D Loose
A link of a square shape and with loose connection points on the top and bottom of the square. This link can be used to connect eight nodes in two planes and create a loose, quite elastic connection between these points in the structure. Material: Rubber-like polymer.

7. Square link 3D Stable
A link of triangular shape and with stable connection points. This link can be used to connect three nodes in one plane and create a stable connection between these points in the structure. Material: Stiff polymer.

Figure 10. Overview of the material system for Version A, including the original design and the additional links.

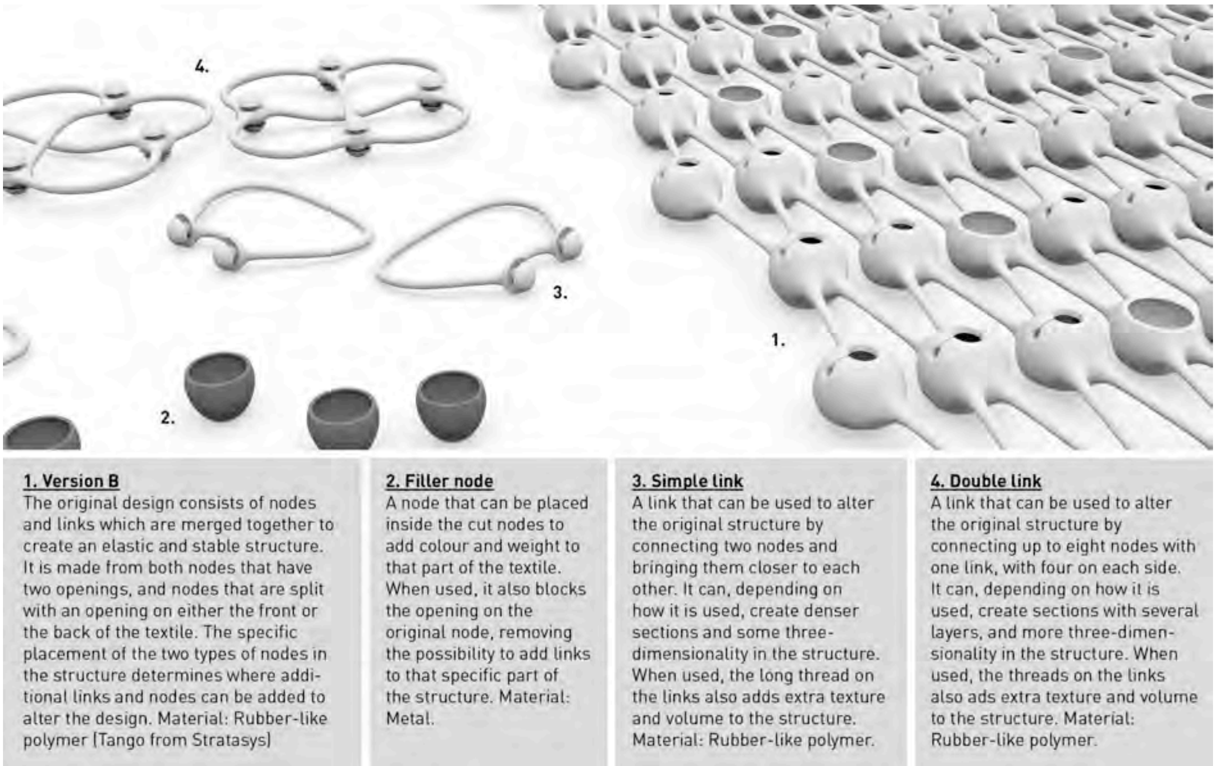


Figure 11. Overview of the material system for Version B, including the original design and the additional links and nodes.

Examining the design decisions made for Versions A and B, it becomes clear that there are two different types of decision that together frame the open textile systems. Firstly, ‘closed decisions’; those that are fixed in the material design, and which cannot be altered by physically manipulating the material. Secondly, ‘open decisions’; these are defined in the original material but, when printed, can be removed or altered by another designer. The design of the basic construction system made it possible to decide whether each element and intersection in the material would be either open for alteration or closed, and doing so made it possible to decide what was central to the design and should be kept, and what could be defined by others. For example, in order to keep the character of Version A but simultaneously allow for major re-construction of the textile, the shape of the links and nodes were made to be closed decisions; however, how they could be combined was open and so alterable. Contrastingly, in Version B, the shapes of the links and nodes were made to be closed decisions, as was how they could be combined – they were fixed into a mesh which provided the textile with a basic structure that, regardless of alterations, was present in the design. However, in a discussion regarding open textiles, one cannot talk of purely open or closed decisions; open decisions can come with limitations, and the same goes for closed decisions. The open decisions found in Versions A and B mean that certain nodes and links, and how they are connected, can be changed. In such cases, sets of alternatives are provided and each, if used, influences the material’s behaviour and expression in a specific way. The open decisions in these materials are as such open for alterations, but there are restrictions on which other decisions can be made regarding the material’s design, as set out by the material’s designer. This way of restricting openness by providing a limited set of options, and thereby still controlling what the changes can be, resembles the systems of Nervous System, where product type and some aspects of the design are left open to change. However, these choices are still quite limited; e.g. it is only possible to change a ring into a bangle, cuff, or sculpture, and not into anything else (Nervous System, 2014a).

In addition, the type of raw materials used to print 3D modelled structures can influence the nature of closed design decisions. The main material used in Open Structures was a stable but slightly elastic polymer, which made it possible to create an alterable structure, but it also put limitations on the permanence of closed decisions. In Versions A and B some decisions were considered to be closed, e.g. the shape of the components and the connection between merged links and nodes. However, with enough force, some of these decisions could still be altered, e.g. by using sharp tools to remove sections from the shapes or to cut links. Pieces of the structure that are printed with stiff and hard materials, such as metal and ABS plastic, are, on the other hand, much more difficult to deform or manipulate. The choice of raw materials in 3D printed textile designs is thus an important part of framing the material system, as these material choices not only define the properties of the material's structural elements, but also have an effect on just how 'closed' a closed design decision can be. Thinking in terms of open and closed decisions can, regardless of the raw materials chosen, be of assistance when designing this type of structure, as it calls attention to how design decisions define both the material's original design and its alterability. However, when working with soft materials, such as the rubber-like polymers in the prototypes, perhaps it is best to think of the open and closed decisions in the design as a form of invitation to collaboration, with soft boundaries rather than strict and unchangeable rules.

Alterable digital and physical 3D printed textiles

The focus of the project presented in this paper has been to explore the openness of transformable 3D printed structures in their physical form. However, with this new textile technology, open and closed decisions can also be defined in relation to digital interaction with the material. As in Nervous System's (2014a) interactive systems, this can take the form of digital interaction, controlled by clearly defined parameters. It could also be kept freely transformable, limited primarily by the capabilities of the software, leaving the physical form as the state in which limitations are introduced. Regardless, digital alterability is an interesting possibility to consider for future work, as it opens up for designing the material and its alterability in both possible forms; the printed physical state, and the 3D modelled, digital state.

Open conventional textiles

Thinking of textile design as a form of open design, with open and closed decisions, does not relate solely to 3D printed textiles. It could also be relevant to other forms of textiles, as most can be altered and re-defined after they have been produced. Considering conventional textiles in this way may not be relevant when designing for a specific context (e.g. upholstery for a specific model of car), as the properties and visual and tactile expressions of these textiles are, already in the design process, adapted to a specific use. However, many textiles are designed without a specific application in mind, such as those simply sold by the metre. In this case, the design may not be aimed toward a specific product, but rather intended for a certain application or market, and can be applied to a wide range of contexts. These materials will somehow, on their way to their various applications, participate in other design processes, become part of a dialogue with other elements of a design, and be adapted in terms of both their expression and properties. Similar to the designs created in Open Structures, a fabric's initial design and the way it can be altered is framed by the textile designer's decisions. Conventional textiles can from this perspective also contain elements that are open for alterations, as well as characteristics fixed in the design, and as such also contain open and closed decisions. For example, in a woven piece of cotton fabric with a squared printed pattern, the surface design, i.e. colour and pattern, can be changed by pleating the material, dyeing it, adding additional elements to the prints, etc. The design decisions that together shaped these aspects of the textile are as such open for change. However, the fact that a fabric is woven, constructed with a satin binding, and made from cotton yarn cannot be removed or altered in the fabric's design, and it can therefore be considered to be closed to further development. In conclusion, the open design approach discussed in this paper can be a platform for exploring and designing alterable 3D printed textiles, but it can also be a perspective with which to rediscover and develop the openness of conventional textile materials.

Conclusion and future work

This paper and the Open Structures project explored the possibilities of designing 3D printed textile structures that can be altered in their physical form, and provided two early examples of what this kind of textile could look like. The alterability of 3D printed textiles has primarily been discussed in relation to how textile designers can define the scope of the possible design decisions that the material allows for. However, these structures only reach their final form in other design processes, when designers redesign, explore, and adapt these textiles to a specific context. In addition to developing the Open Structures textiles further, future work should also explore what the extended transformability of 3D printed textiles can mean for other design processes, e.g. by creating and observing workshops in which designers work hands-on with these structures. So far, only a handful of designers have worked with small pieces of Versions A and B. However, the reversible decisions that can be made when redesigning them have demonstrated the potential for both free experimentation and more detailed decision-making. The qualities of this type of design material could, with further development, open up for new ways of interacting with textiles in the design process; they could e.g. open up for design processes in which the properties of the textile design are re-defined in detail in relation to the requirements of the product, or those where interaction with the material design can take place in both physical and digital settings. However, further exploration and development of the textiles themselves, as well as methods and tools which could enable them to become part of and influence other design practices, is required in order for this way of designing with textiles to be possible.

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How to visually represent the colour theory of thermochromic inks

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Abstract

Colour theories have been established in order to allow artists and designers to understand the relationship between colours, and to determine how a chosen colour will react or interact with another. Smart colours - such as leuco dye-based thermochromic inks - have entered into the textile and fashion design world, bringing with them new challenges. This paper stresses the fact that, in order to demonstrate and describe the behaviour of these inks at different temperatures when printed on textiles, a new colour system is required. Four design experiments using thermochromic inks are described and these, along with the discussion presented, highlight the need to develop a thermochromic colour system which can not only visualise and describe the behaviour of these inks in relation to other static pigments and temperatures, but also assist textile designers in making informed decisions during the design process.

Keywords

leuco dye-based thermochromic inks, colour system, textile, design, surface pattern

This paper is a part of an experimental design research programme which explores the design properties and potential of using leuco dye-based thermochromic inks on textiles in order to facilitate the understanding and design of dynamic surface patterns. The research was undertaken in the context of textile design, and carried out using textile-printing techniques, in particular hand screen-printing.

In short, each series of experimentation began with the testing of ideas generated by literature studies and sketches of ideas and continued through the development of expressions in fabric samples, which suggested alternative ways of achieving colour-changing effects on textiles. At each stage, fabric samples were gathered and analysed so as to create a foundation for future exploration. The outcome of this process was a series of working methods which offered the insight and depth of understanding required in order to design dynamic surface patterns through the use of thermochromic inks (Kooroshnia, 2015).

As a result of the analysis of the experiments, it became increasingly evident that existing colour systems and their terminologies were unable to describe the expressions achieved during the process. Therefore, this paper stresses that, due to the absence of a thermochromic colour theory that can visually and verbally describe the colour-changing effects offered by thermochromic inks, it would be difficult for textile designers to fully grasp the logical foundations of the proposed design methods and, as a consequence, these designers are unable to internalise the methods thoroughly enough to use them for further investigation through design.

Background

Leuco dye-based thermochromic inks

With the technological progress of materials science, the palette of colours with which to print on textiles has expanded beyond those with known properties and expressions to a new generation, with more advanced functionality and expressive properties.

This new range of colours is characterised by their ability to change colour in response to external factors. Often referred to as 'smart colours', these include thermochromic inks, photochromic inks, photoluminescent pigments, etc. Leuco dye-based thermochromic inks are colouring agents characterised by their ability to, when printed on textiles, change colour in response to temperature fluctuations (referred to hereafter as 'thermochromic inks'). Below their activation temperature they are coloured, and above their activation temperature they are clear or have a light hue (cf. Bamfield & Hutchings, 2010). They are usually blended with static pigments, allowing them to change from one colour to another. The activation temperature is defined as the temperature at which the ink has almost achieved its final state - transparent or lightly coloured.

These reversible thermochromic inks have attracted the interest of experimental textile practitioners and researchers because they can offer new forms of communication and expression (Orth, 2004; Berzowska, 2005; Worbin, 2010; Calder, Robertson, Louchart, 2013). In all of these examples, the colour-changing effects have been explored mostly through experimentation with blends of thermochromic inks and static pigments, which allow prints to change from one colour to another in different contexts. The colour-changing effects thus illustrate transitions from Colour A to Colour B, and back again to Colour A. For example, the prototype entitled *Touch Me*, created by Berzina (2004), is a colourful, striped pattern wallpaper, printed with thermochromic inks with activation temperatures of either 26 or 31°C. By touching a violet stripe on the wallpaper, for example, a temporary white-ish handprint appears, and the phase change materials incorporated in the wallpaper release heat so as to extend the effect produced by the thermochromic ink. Another example is a set of furniture, printed with magenta thermochromic ink, which is able to respond to the presence of a person by changing to a white-ish colour in response to the heat of a human body, and to retain this colouring for several minutes after the person has left (BAN, 2007; also cf. Ritter, 2007).

Despite the fact that these and other research projects are successful examples of how these inks can be used on textiles, research into creating dynamic patterns for textiles has progressed relatively slowly. This may be due to a lack of exploration into the complete range of design possibilities afforded by thermochromic inks, as well as a lack of documented information to guide textile designers with regard to how these colours may be applied in textile practice. This lack has thus led to more emphasis being placed on how to activate or control printed patterns produced by thermochromic inks than on exploring what the complete range of design possibilities could be. Consequently, the practical experiments on which this paper is based were directed towards exploration of the complete range of design properties and potentials of leuco dye-based thermochromic inks when printed on textiles, with the aim of creating a wider range of colour-changing effects.

An analysis of all the experiments, however, indicated that, although they offered insights into and an understanding of the behaviour of thermochromic inks, they also emphasised the fact that exploring the design properties of thermochromic inks is not concerned solely with the discovery of new design possibilities; rather, the experiments demonstrated the need for the creation of a new terminology with which to discuss these design possibilities (cf. Manzini, 1998). Based on this, it was decided that a detailed theoretical and practical investigation into other existing colour systems was to be carried out. As a result, a number of important issues arose:

- Whether the existing colour systems were capable of describing the colour-changing effects offered by thermochromic inks on textiles.
- How a certain colour combination or colour transition created through the use of thermochromic inks could be defined using existing colour systems.
- How existing colour systems deal with temperature when describing colour transitions on textiles.

Colour systems

In practice, when any type of pigment, such as textile pigment paste, is used, the primary colours are considered to be yellow, red, and blue, as these hues cannot be produced through any combination of other colours. Equally, all other colours can be produced through the combination of two or more primary colours: orange, violet, and green can all be made by mixing two primary colours in roughly equal amounts (Osborne, 2008, p 4). Tertiary colours are a mixture of a primary colour and a nearby secondary, e.g. yellow-orange, red-orange, red-violet, etc. (Feisner, 2006, p. 9). In addition, colours that oppose each other directly on the colour wheel are called 'complementary colours'; e.g. red is the complementary colour of green, orange of blue, yellow of violet, etc.

Colour wheels/circles represent the relationships between colours. Wheels include a number of saturated hues, and sometimes show a variety of tints, tones, and shades. They constitute the most common and convenient method for visually representing colour theory, and help us to understand and compare the relationships between different hues.

In the early 1900s, Albert Munsell created a three-dimensional model based on human perception, which he presented in his book *A Color Notation*. Munsell's system suggested, for the first time, that colour could be described using numerical values of three independent properties - hue, value, and saturation - and was the first to systematically illustrate colour in three-dimensional space (Feisner, 2006, p. 13-22; see Fig. 1). In 1961, Johannes Itten developed a contrast-based system with which to study and use colour. He organised colours according to contrasts, identifying them through harmonious colour strategies (Itten, 2003; see Fig. 2). Josef Albers' (2006) *Interaction of Colour*, which was published in 1963, proposed an approach for studying and teaching colour based on learning by direct perception, rather than through theories or colour systems (see Fig. 3). The same year saw the invention of the Pantone Matching System (PMS) by Lawrence Herbert, in which a numbering system is utilised to identify colours. Still in use today, the PMS employs a variety of colour sample books and chips which help designers to compare colours on different types of textiles and papers, as well as provide a computer colour-matching system (Gordon & Gordon, 2002, p. 193; see Fig. 4). In 1979, Anders Hård introduced the Natural Colour System (NCS), which adopted a similar model and theory as Munsell's and the PMS (Hård & Sivik, 1981); it defines the actual colour more precisely than previous systems as it is based on the visual appearance of colours, has a broad colour range, and provides an easy way of matching hues (see Fig.5).

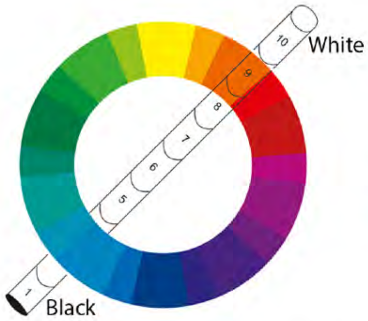

Fig 1. shows Munsell colour system

Fig 2. shows Itten colour system

Fig 3. shows Aibers colour system

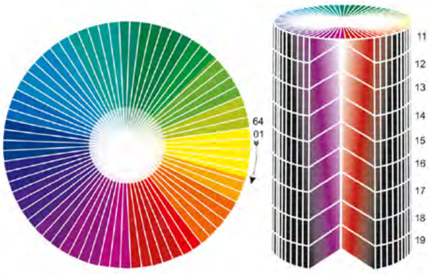

Fig 4. shows Pantona colour system

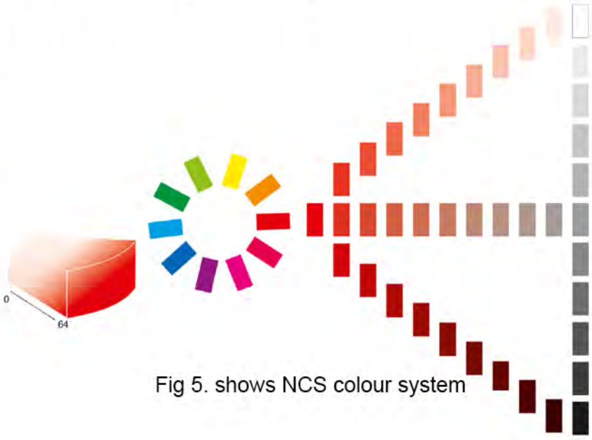

Fig 5. shows NCS colour system

The existing colour systems mentioned above allow textile designers, who are interested in textile printing techniques, to learn how to mix primary colours in various proportions, expand the palette of colours for use with textiles, and ascertain how colours change in varying circumstances - they can be made to appear lighter, darker, or transparent, and to be more or less prominent relative to other colours. These systems are unable, however, to support a textile designer in a design process which involves the use of thermochromic inks. These colour systems were created for and intended to accommodate only static textile pigments and, thus, were not designed to deal with smart and dynamic colours or their properties. For this reason, textile designers are unable to define a temperature-sensitive colour mixture and its various stages of colour transition using any of the colour systems discussed above.

This paper attempts to highlight the need for a new colour system; one which can describe the behaviour of thermochromic inks in relation to other static pigments and varying temperatures (cf. Manzini 1989, p. 34). The significance of this for textile design is related to the development of a methodology for designing dynamic surface patterns. To design such a pattern, a textile designer requires basic knowledge regarding how to use thermochromic inks on textiles, as well as an understanding of how to apply thermochromic ink principles to textile design practice through the use of different methods, and approaches. At present, in the absence of a thermochromic colour system, it is difficult to construct detailed descriptions of the methods and approaches, and how they could assist a textile designer in creating a wider range of colour-changing effects on textiles. As a consequence, the ability of a textile designer to make informed decisions and to predict colour-changing effects when designing dynamic surface patterns currently suffers from severe limitations. This is exemplified by the four design experiments described below, in which thermochromic inks were used; Experiment IV provides a further basis for discussion regarding the problems related to the lack of a thermochromic colour system in textile design practice.

Experiments

Experiment I

When a material is new to us, one way of learning how to use it is to follow another person's advice regarding technical procedures, as a certain amount of basic knowledge is needed in order to begin the exploration. The aim of the first series of experiments was to determine the ratio of thermochromic ink to textile pigment paste for the recipe. The first attempt was a 3:97 ratio of blue thermochromic ink (with an activation temperature of 27°C) to acrylic-based extender (for more information on mixing colouring agents see Worbin, 2010). The mixture was silkscreen-printed by hand on a plain white cotton weave fabric. The effect produced was a lighter blue than that of the pure blue thermochromic ink, which gave rise to the idea of mixing the thermochromic ink and extender in other proportions. Thus, in the next step, two thermochromic inks of the same colour (blue) but with different activation temperatures (27°C and 15°C) were mixed with extender in different proportions, producing different shades of blue at ambient temperature (20°C). It was observed that ratios of 99:1, 75:25, and 50:50 of thermochromic ink to extender were problematic as, after removing the silkscreen, most of the ink remained stuck to the screen; this was most likely due to the thermochromic ink and extender having been mixed in a faulty proportion, resulting in it not properly adhering to the fabric. Further experimentation showed that a 25:75 ratio of thermochromic ink to extender provided a desirable textile printing effect, with maximum colour intensity at ambient temperature (20°C). The effects produced by both inks at ambient temperature led to the idea to explore colour-changing effects at different temperatures. The blue shades were then tested at equal to or below 15°C and at or above 27°C. An ice bag was used to cool the printed fabrics, and an iron was used to warm them. It was observed that a 1:99 ratio of ink (with an activation temperature of 15°C) to extender resulted in a colourless (or transparent) at ambient temperature (20°C) and light blue at equal to or less than 15°C, which suggested that this effect may be used to hide or reveal surface patterns. After an understanding of how thermochromic ink printed on textiles behave at different temperatures had been reached, a yellow textile pigment paste was mixed with the inks used to produce the blue shades of the previous experimental stage in order to explore additional effects. The same methods of cooling and heating were used to explore the design potential of the mixture at different temperatures (see Fig. 6).

The outcome of this experiment was the formulation of printing paste recipes, presented as printed colour scales. The scales showed and facilitated comparisons of the effect of cooling and heating the blue or green shades, providing valuable information on how thermochromic inks can be used and how they behave when printed on textiles.

In all of the experiments, surface patterns were designed in order to assist the exploration of the design properties and potentials of thermochromic inks through their artistic expression. The primary inspirations when designing with the thermochromic inks were Persian designs; this was due to the personal interest and cultural background of the author.

Fig. 6. Surface pattern created using thermochromic inks with activation temperatures of 27°C (at a ratio of 25:75) and 15°C (at a ratio of 1:99). The original pattern comes from the Jameh Mosque of Qazvin, Iran 1623.

Experiment II

The results of the initial experiments formed a basis for the development of more complex colour-changing effects, where the colour transition was not from Colour A to Colour B and back again to Colour A, but rather from Colour A to Colours B, C, D, E, F, etc., and then back again to Colour A.

Due to the molecular structure of leuco dye-based thermochromic inks (Kooroshnia, 2013), it is not possible to make a single ink that is able to change from one colour to many different colours. This fact directed the second experiment towards the creation of colour mixtures which would have a similar hue at temperatures below the activation temperature but which, at temperatures above it, would show multiple colours. The experiment used two different colours, blue and magenta, in an attempt to achieve this.

Just as both one plus two and two plus one equal three, mixing blue (1) and magenta (2) in a particular proportion result in the same violet (3) hue as mixing magenta (2) and blue (1). Thus, with both the above theorem and the previous experiment, in which it was found that each colour mixture should consist of at least one pigment colour and one thermochromic ink, in mind, blue thermochromic ink with an activation temperature of 27°C and magenta textile pigment paste were mixed, which resulted in violet below 27°C and magenta at or above 27°C. Next, magenta thermochromic ink with an activation temperature of 27°C and blue textile pigment paste were mixed, which resulted in violet below 27°C and blue at or above 27°C. A screen-printed pattern was produced, which involved printing each violet shade next to the other. As the temperature was raised, the violet colour mixtures activated and started to change, from violet to blue and magenta.

The above result directed the exploration towards working with multiple colour-changing effects rather that just one or two, at once. To propose another theorem, 1+2+3+4 equals 10, and the same is true for 2+1+3+4, 3+1+2+4, and 4+1+2+3. In this experiment, colours were given a number - blue (1), magenta (2), yellow (3), and green (4) - and combined so that, in each mixture, the first colour was a normal pigment and the rest were thermochromic inks. For example, the mixture of blue (1), magenta (2), and yellow (3) thermochromic inks with an activation temperature of 27°C and a green (4) textile pigment paste resulted in violet-greyish (5) below 27°C and green (4) at or above 27°C. The mixture of blue (1), yellow (3), and green (4) thermochromic inks with magenta (2) textile pigment paste resulted violet-greyish below 27°C and magenta at or above 27°C. The same principle was then used to prepare four colour mixtures. Another screen-printed pattern was produced, which involved printing each colour mixture next to the other ones. As the temperature was raised, the colour mixtures activated and started to change, from brown-greyish to four different colours (see Fig. 7).

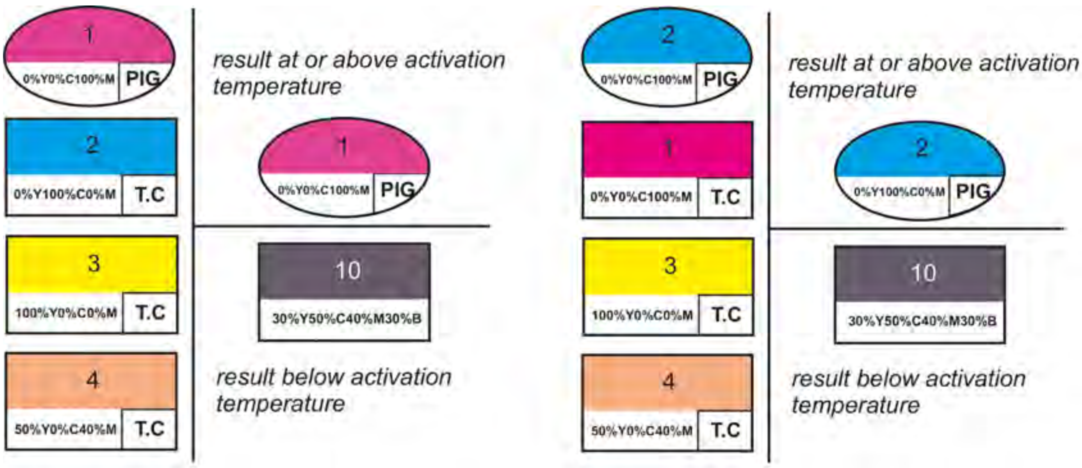

Fig. 7. Two of the four possible temperature-sensitive colour mixtures that displayed the same colour at ambient temperature, but different colours when heated.

This approach resulted in a method of mixing colours for formulating a temperature-sensitive colour mixture consisting of multiple colours. It expanded the available range of possibilities for designing dynamic surface patterns in terms of revealing latent colours and designs.

The method suggested greater colour-changing possibilities than seen in earlier interactive textiles, in which thermochromic inks were used to create multi-coloured patterns that simply became transparent when heated. The approach discussed above offers the opposite transition, i.e. from a single-coloured (plain) background to one with several colours (see Fig. 8).

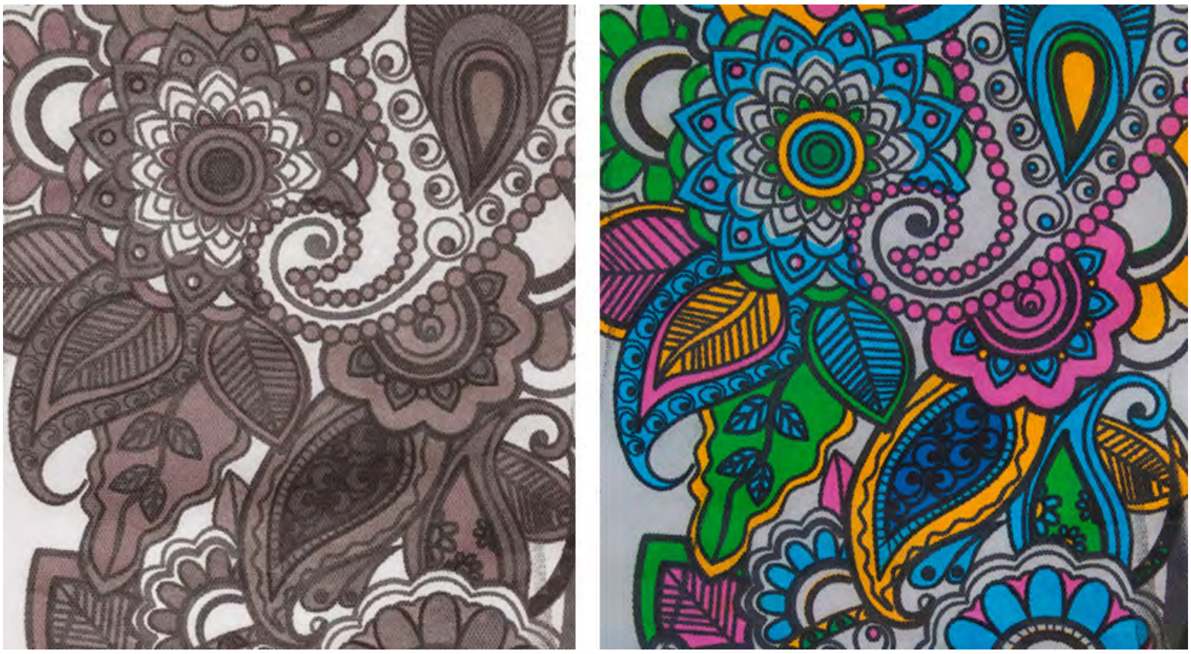

Fig. 8. A printed fabric produced using four temperature-sensitive colour mixtures with activation temperatures of 27°C (at a ratio of 25:75), shown at ambient temperature (left) and heated to above 27°C (right).

With reference to Experiment I, temperature-sensitive colour mixtures can be made using thermochromic inks with activation temperatures lower than ambient temperature, e.g. 15°C. They thus become visible when exposed to a change in temperature; i.e. the temperature-sensitive colour mixtures are slightly coloured in a heated state, and *more* coloured when cooled.

Experiment III

The results of Experiment II suggested the potential of layering colour mixtures. In the paper printing industry, the offset lithography printing method is one of the most common techniques used to print full-colour images or photographs. It is performed in a series of steps beginning with colour separation, during which the image is decomposed into the four process colours (CMYK), followed by translation into halftones. This technique inspired the printing of a pattern with the colour mixtures developed in Experiment II, and involved the digital design of a full-colour surface pattern and its preparation for four-colour printing in Photoshop, using the Channels function. This included creating four halftones by selecting each channel in turn and exporting the result as a bitmap image. Based on the principles of CMYK separation, four ink mixtures were prepared, all of which were a greyish-brown colour below 31°C, but which changed to cyan, magenta, yellow, and black, respectively, at or above 31°C. The layers were printed in succession, with halftone screen angles (cyan 60°, magenta 110°, yellow 120°, and black 30°). The colour mixture made with black pigment was thus printed last, i.e. over all of the others. When the temperature was increased, the temperature-sensitive colour mixtures were activated, and started to change, from dark greyish-violet to vibrant colours (see Fig. 9).

Fig. 9. A printed fabric produced with four temperature-sensitive colour mixtures with activation temperatures of 27°C (at a ratio of 25:75). The original pattern comes from one of Lotfali Shirazi's paintings, Iran 1846.

This approach resulted in a textile printing method which combined the offset method of printing and the method of forming a temperature-sensitive colour mixture comprising multiple colours.

This method demonstrated that it was possible to create a wider range of colour-changing effects through layering different temperature-sensitive colour mixtures, which allows for more complex dynamic surface patterns on textiles, in which the pattern changes from one colour, possibly in different shades, to continuous tones. Although leuco dye-based thermochromic inks cannot currently be used in the digital printing process, this technique offers a new method for obtaining an effect similar to that of digital printing.

Experiment IV

Studying and teaching how to use thermochromic inks involves an understanding of colour transition. We often teach in the way that we ourselves were taught; it is, however, almost impossible to teach the behaviour of thermochromic inks by employing existing theories and practical exercises intended for static colours. In the absence of a proper colour theory and system for thermochromic inks, one way of teaching this subject is to demonstrate the colour transitions of thermochromic inks at various temperatures. When the author of this article was asked to hold an experimental workshop, it was decided that this should take place in the form of a hands-on experience where, first of all, the basic colour transitions of thermochromic inks were demonstrated at various temperatures via colour swatches, in order to help students better understand this phenomenon. Additionally, in order to further encourage the learning process, some exercises were designed so as to more fully engage students in practice-based processes.

For this purpose, the experiment began with two collections of colour-samples; one with only the thermochromic inks in different colours, with activation temperatures of either 27°C or 15°C, and the other a mixture of thermochromic inks and yellow textile pigment paste. The colour samples were then measured with a spectrophotometer at three different temperatures: at ambient temperature (20°C), after heating (above 27°C), and after cooling (below 15°C). The measurements were then translated to colour swatches, made using the textile pigment printing pastes; these swatches made it possible to effectively demonstrate the colour transitions of the thermochromic inks at different temperatures.

A printed thermometer was placed on the table of the printing lab in order to illustrate three different temperatures. The colour swatches were placed on the table so as to display and compare the effects produced by either the inks with activation temperatures of 27°C or 15°C, or the mixture of the inks and yellow textile pigment paste at ambient temperature, after heating, or after cooling (see Fig. 10). As it was important to provide the students with a thorough understanding, the strategy followed was to give them exercises which allowed them to experience the phenomenon for themselves.

Fig. 10. Colour-swatches made with textile pigment, demonstrating the varying colours of thermochromic inks at different temperatures.

A pedagogical tool for teaching the behaviour of leuco dye-based thermochromic inks to students in textile design was the result of this experiment.

The exercises involving colour swatches helped the students to learn the principles of colour transition in an easy way and step-by-step. While this teaching approach increased their ability to design dynamic patterns for textiles and created inspiration for continued investigation through design, it was, however, limited to basic colour transitions - from Colour A to Colour B and back again to Colour A. Thus, the more complex transitions of Experiments II and III, i.e. from Colour A to Colours B, C, D, E, F, etc., and back again to Colour A, were not demonstrated.

Discussion and conclusion

In order to obtain knowledge and improve our understanding of materials, verbal instruction is not sufficient; rather, what is required is a more engaged form of study so as to truly experience and demonstrate material properties (Albers, 2006). Experimental research through design is one way of gaining new knowledge which develops new knowledge which assists in developing the field of [textile] design with suggestions for a change of practice by introducing design programmes, methods, and techniques (Hallnäs, 2010; Durling, Friedman, & Gutherson, 2002; Frayling, 1993).

Although the experiments have created insight and understanding, they have also emphasised the fact that exploring thermochromic inks is not just about finding new design possibilities; rather, the need for a new terminology, so as to be able to discuss these possibilities, has been demonstrated (cf. Manzini, 1998). This paper has shown that a new language is required in order to discuss colour-changing effects at varying temperatures. For example, in Experiment I it was observed that a pattern printed on a white textile using a 1:99 ratio of thermochromic ink (with an activation temperature of 15°C) to extender became transparent at ambient temperature (20°C) and light blue at equal to or less than 15°C. With reference to existing colour systems, light blue is made by adding a large quantity of white to blue; in Experiment I, however, there was no white added to the blue thermochromic ink, which indicates that, at present, the lack of linguistic terminology makes it very difficult to describe a colour-changing effect without giving the audience the wrong impression when, for example, attempting to describe the behaviours of thermochromic inks at varying temperatures.

Experiments II and III resulted in examples of how to combine a static pigment and thermochromic inks into temperature-sensitive colour mixtures which are able to change from single to multiple colours. Almost all existing colour systems explain the alternating relationships between primary, secondary, and tertiary colours, as well as the relationship of each of them to black and white. The fact that they are unable to describe how temperature-sensitive mixtures can change from one colour to various others at different temperatures and then back again, however, indicates the need to incorporate the dimensions of temperature and time into existing colour systems.

Lastly, Experiment IV clearly indicated the need for a colour theory which visualises the behaviour of thermochromic inks at different temperatures and proposes terminology for discussing the behaviours of thermochromic inks. The pedagogical tool presented in this article increases the ability of students to integrate their new knowledge of the behaviour of thermochromic inks with what they already know about static pigments in relation to the design of a dynamic surface pattern. However, the workshops were limited to basic colour transitions – i.e. from Colour A to Colour B and back again to Colour A - and the colour swatches alone were not able to demonstrate the more complex colour transitions that were demonstrated in Experiments II and III - i.e. from Colour A to Colours B, C, D, E, F, etc., and back again to Colour A. Therefore, the difficulties in effectively communicating during the study, application, and instruction of the thermochromic inks showed that there is a need for a more complete pedagogical tool.

Designing with thermochromic inks is largely concerned with colour transition. A thermochromic colour system would be able to demonstrate and describe a variety of colour transitions, e.g. from Colour A to colourless and back again to Colour A; from Colour A to Colour B and back again to Colour A; from Colour A to Colours B, C, D, E, F, etc., and back again to Colour A. Thus, such a system would provide a greater insight into and understanding of the behaviour of thermochromic inks when printed on textiles. As a consequence, the ability of textile designers to articulate ideas, make better-informed design decisions, and push the boundaries of their understanding of the role of thermochromic inks in a textile design context would increase, leading to previously unimaginable outcomes (cf. Manzini, 1989).

In addition, the thermochromic colour system would promote knowledge transformation and collaborative work between disciplines such as textile design, interaction design, computer science, and many more fields.

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Alabaster Chambers – Sacred Folds

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Abstract

My paper is a discussion of how I have been developing a visual language to evoke the experience of the sacred expressed in the poetry of Emily Dickinson, particularly her poem *Safe in their Alabaster Chambers.* Experiential knowledge, through experimentation with materials has generated the project leading to at times unexpected and serendipitous outcomes.

Using print processes of layering, words, images and folded textures, the poetry of Dickinson provides me with the "tacit" knowledge to make material the sacred "unknown" in her poetry. Printmaking, with its traditional links to religious texts and imagery, is a particularly appropriate medium to explore the sacred through the poem. I employ it to suggest a space, which hovers between the material and the sacred through enfolding multi-layered textures and spaces. Gilles Deleuze provides an allegory for this in his concept of the Baroque fold. The materiality of the fold allows it to be used as a visual tool denoting the fluidity of matter, and the ephemeral state of the 'soul'. (Deleuze, 1995)

Inspired by Dickinson, who found within her domestic interior the sacred space where she could retreat to write. I seek to recreate the experience of her poem *The Alabaster Chamber* through the tangible means of the art – making. Dickinson's *chamber* can reference a space where earthly and sacred fold or co-exist in a state of suspension.

Keywords

Gilles Deleuze, Emily Dickinson, Alabaster chambers, serendipity, printmaking, sacred, folds

Introduction

My understanding of material knowledge is two-fold. First, it entails knowledge, gained through experiential understanding of the process, and reflection to create material manifestations of my concerns and ideas. Secondly, knowledge, in a spiritual or sacred sense, means using the experiential approach to ground the sacred through tangible means. Emily Dickinson's poetry is the tool, which I use to unfold experiential knowledge through materials that act as a conduit between matter and the sacred. The poem, which informs this exploration, is *Safe in their Alabaster Chambers,* while printmaking with its traditional links to religious texts and imagery is the means by which I seek to express Dickinson's experience of the sacred.

Donald Schön in the *Reflective Practitioner* argues "Often we cannot say what it is that we know". This statement is particularly pertinent to an inquiry - based practice, like the creative arts where unforeseen outcomes, which I refer to as serendipity, are on reflection a result of "tacit" knowledge. Schön goes on to say that it is in the "feel of the stuff" that our actions are ingrained with knowing. He argues that "tacit" knowledge is embedded in and inseparable from inquiry based practice (Schön, 1983, p. 49). In this paper I will show how inquiry and reflection through my practice provides me with the fundamental tools to develop tangible means and methods, to invoke the sacred in the poetry of Emily Dickinson.

In her introduction to *Material Inventions*: *Applying Creative Arts Research* Estelle Barrett comments on the subjective nature of artistic research and how this is integral to the acquisition of knowledge. Lived and learned experiences are imperative in practice research where personal interest is an advantage to be “exploited”. She also argues that knowledge is *“action* or knowing” (Barrett & Bolt, 2007, p. 5). Both Barrett and Schön stress the importance of the practitioner’s active role in validating the experiential experience. As I navigate my way through the interconnecting folds of *experiential knowledge through materials* I am aware of underpinning concerns that steer my journey.

Religion and Mortality

Underpinning this project are my concerns with religion and mortality. The paradox of humanity is the belief or myth that it can transcend its physical qualities through the religious experience therefore allaying a fear of death through the immortal soul. Julia Kristeva (2009, p. 3 -12) states “This incredible need to believe” is a necessary paradox that responds to an anthropological need, which continues to be a source of anxiety and analysis. The need for reassurance through an afterlife is an overarching factor of most religious belief. The need to believe brings families, communities, and countries together, and pulls them apart. Perhaps this is why Dickinson chose to turn away from the outside world and enclose herself within her domestic realm, finding solace in her cloistered existence, seeking the unknown through her quest for the sacred.

Dickinson embedded her fears within the labyrinthine layers of her poetry. She questioned her existence, her fear of the unknown and the possibility of an afterlife. J. McIntosh (2000) proposes, “the unknown is not so much a subject she takes up as a condition of her poetic existence she perpetually comes up against it” (as cited in L. Freedman, 2011, p.1).

Dickinson’s search for the unknown was embedded in her life it took the form of the non-being, and the sacred in her poetry. Iris Van der Tuin explains that the unknown creates new knowledge and opens up new vistas and influences our relationship with the world and ourselves (Van der Tuin, 2014, p. 256 - 258).

Dickinson’s iconic poem *Safe in their Alabaster Chambers* infers the material spaces of her domestic chambers and the ‘unknown’ spaces of time and eternity.

Safe in their Alabaster Chambers –

Untouched by Morning –

And untouched by Noon -

Sleep the Meek Members of the Resurrection -

Rafter of Satin – and Roof of stone!

Grand go the years – in the Crescent – above them,

Worlds scoop their Arcs –

And firmaments – row –

Diadems – drop – and Doges – surrender –

Soundless as dots – on a Disc of Snow

(Johnson, 1970, poem no 216)

Dickinson’s material space is her domestic realm and like the *Alabaster Chambers* cold is a tomb. She is cloistered, wrapped in the satin, but contained within the stone roof. The dash between the satin and stone is ambiguous as Dickinson’s Alabaster Chambers is both protective and suffocating. Dickinson is like the restless soul caught between the folds of the material space, the chamber, which is her containment and her sacred space. Dickinson's chamber can infer the intimacy of a womb–like, more erotic presence through the folds of satin. Gilles Deleuze proposes that the pleats of matter and the folds of the soul co-exist in a state of suspension, "a fold between two folds" (Deleuze, 1993, p. 4)?

The fold can also suggest a dis-continuation or a disruption that Karen Barad refers to as a refracturing of events through "imaginary time / mythic time / experimental time / now / before / to come … time (van der Tuin, 2014, p. 224). Barad proposes a "non linear enfolding" of time, as Deleuze (1993 p. 4) proposes the fold suggests an enfolding of matter and ideas soul. The disruption of time is what Dickinson proposes through the second stanza of her poem.

"Grand go the Years – In the Crescent - above them"

The beginning line of the second stanza marks a disruption, a disjunction from the enclosed chamber. The Crescent stretching to infinity is suggestive of the restlessness of time and infers the ghostly presence of the soul stretching into oblivion while the body remains in its Alabaster chambers. Dickinson is also suggesting the sacred space of infinity and time through the "firmaments row". There is juxtaposition between the worldly narrative inferred by the riches of humanity through the reference to the "Doges" and the timelessness of space. Kings and clergy must surrender their earthly bodies to the passage of time (Freedman, 2011, p. 164 – 166).

Dickinson's worlds, both earthly and imaginative are incomplete, like the incomplete folds. The earthly chamber, is her retreat, her cloistered space and the "firmaments" refer to the sacred space of her imagination.

The dash emulates the Arcs of the worlds, the curvature of the folds. The dash punctuates the text – to disrupt the rhythm. The dash is the silence - she threads through the folds of her poetry - like folds that envelop other folds. She is untouched – safe in the folds of satin – contained by stone. I propose the dashes are between – matter and the soul – they are the blanks of sacred space.

Dickinson, claims Camille Paglia, (1990, p. 629, 668 - 69) invoked the devotional mysteries of the catholic imagination rather than the more austere protestant ethos. Paglia's subversive understanding of Dickinson and her poetry - removes her from the overtly sentimental nineteenth century romantic heroine - into a formidable warrior of words.

Dickinson used the tools that were readily available to her to make material her imaginative musings and sacred concerns. Her tools were books, scraps of paper, envelopes, ink, pens, pencils, scissors, paper knives and pressed flowers. Dickinson knew her space intimately from the cracks between the cold walls, to the endless skies above. She wove these through her poetry, her letters, which, she wrote for friends and lovers, real and imagined. She toyed with personal experience, emotions, imagination and her sexuality through her poems. In-between she interwove whispered messages and sacred meanings.

The second stanza of the poem alludes to the light of the worlds; where the silence of infinity is inferred by the dash. The earthly chamber, is her retreat, her cloistered space and the endless worlds exist in her imagination. The dash emulates the Arcs of the worlds, the curvature of the folds. The dash punctuates the text – to disrupt the rhythm. The dash is the silence - she threads through the folds of her poetry - like folds that envelop other folds. She is untouched – veiled in satin – contained by stone. The dashes are between – matter and the soul. Kings and clergy all surrender their earthly bodies, but time and infinity are unknown (Freedman, 2011, p. 164) as their souls are "Soundless as Dots – on a Disc of Snow*".*

Oblivion! We are left restless and wondering as to what happens to material world - the soul!

Dickinson's poetry disrupts, splicing and enfolding visceral shards of the sacred "unknowing" between and through her words. The art maker shifts between exploring the material process and seeking that which is unknown or sacred. I am reminded of Jane Bennett's concept of *Vibrant Matter* drawn from Deleuze amongst others. She highlights the importance of giving "material agency to non–human or not quite non–human things" and proposes that there is a "hovering" she refers to as "vibrant matter" (Bennett, 2010 p. ix, p. 66). Van der Tuin (2014, p. 261) proposes the artist's studio is a sacred space where there is an intra–action between maker and the materials.

Sacred Spaces – material knowledge

Printmaking for me has always been a cathartic process; it requires the body and soul engaged in making. Souriau refers to this as the '"creative act'". The convergence is complete when material and spiritual reality coincide, mirroring each other. (Van der Tuin, 2014, p. 261)   Bennett in her chapter on "the force of things" proposes a shift from the attachment of an exclusive relationship between God to a more fluid relationship between matter and humans. I often use lithographic stones as a device for image making. The stones are heavy, inert and require considerable effort to move. There is a ritual of washing and erasure or absolution of the previous image. This requires the use of physical and chemical solvents as well as human intervention through the continuous grinding and milling. Bennett takes Henri de Vries definition of '"absolution"', detaching it from its association with God extending its meaning to the loosening of ties from existing contexts (Bennett, 2010, p. 3, 49). Bennett explains the etymology of *absolute; "*ab *(off)* + solver *(loosen)*. Once the stone is cleansed it leaves little or no trace of any previous image. The porous stone is then activated and is ready to be transformed. Bennett takes de Vries refers to the symbiosis between maker and material as the creative act. Karen Barad explains the inter-action as a "phenomenon". I find that Shön's reference to the exploration of materials as the "probing, playful activity by which we get a feel for things" he then says that the success of the process is when it leads to discovery (Schön, 1983, p.145).

Figure 1. Fra Angelico, Madonna of the Shadows (1450-52). Fresco and tempera. 273 x 193 cm. San Marco Convent, East Corridor, Florence. Http://www.artres.com/c/htm/Home.aspx; http://www.scalarchives.com

San Marco Convent (lived and learned experiences)

Folding back to the fifteenth century four panels at the San Marco Convent in Florence are a reminder of Barad's reference to "phenomenon". The four panels sit under a large fresco *Madonna of the Shadows* (Fra Angelico, 1450 - 52). The fresco is simply rendered, with the formal arrangement of the figures typical of fifteenth century religious art. Art historian

Georges Didi-Huberman found the little acknowledged '"fictive' ground"' of the four painted panels, perplexing. He posed that the seemingly careless blotches on the surface of the panels were more than decorative manifestations of "fictive-marble" used as a substitute for marble. Instead Fra Angelico's panels reactivated the narrative of the Madonna by enfolding multi-coloured zones of paint, intercepted by stretched arcs, to resemble unrefined beeswax more than the refined veins of marble. Didi-Huberman argues that the arcs disrupted the pictorial ground confusing the foreground and the background. In an analogous manner Dickinson's dashes disrupt the flow of meaning in her poetry. Fra Angelico's experiential knowledge was the sacred narrative, which he knowingly infused into the pictorial space of the panels through swirling arcs and formless blotches (Didi–Huberman, 1995, p. 31 - 34). It was as if he sought to remind the Monks that the phenomenon of the sacred mystery is imbued within their daily lives.

Beeswax, bees, golden shards, smothering green fields and splatters of light, are folded through swirling arcs in the panels as Dickinson's words "worlds scoop their Arcs" infers the swirling of life, death and the sacred through the arc of infinity (Freedman, 2011, p. 165).

Figure 2. Fra Angelico, Four panels under Madonna of the Shadows C1450-52. Fresco and Tempera. Photo: Jane Slade 2014.

Trick of light – serendipity

Late last year (November, 2014) I visited Florence where on a dank and rainy day I made the pilgrimage to Convent of San Marco. I was totally unprepared for the elegant simplicity of Fra Angelico's frescos that adorned the walls of the otherwise sparse convent. The frescos, carefully crafted, were the only adornment in the cells of the Monks. Few frescos were painted on the walls outside the monk's cells with the exception of, *Madonna of the Shadows* and *The Annunciation* (1438- 45). It struck me that this most intimate part of the religious narrative, was on display for the Monks to contemplate. What was Fra Angelico speaking about in these stunningly gentle images of the well-known story?

The panels under *Madonna of the Shadows* held the clues I was seeking. The gaudy were colours unsettling, the planes of ground created a folding, a slippage of surfaces that was disturbing. The colours referenced the painting above, but were more intense, more dramatic. The fictive surfaces reminded me of Deleuze's folds.

> Sometimes the veins are the pleats of matter that surround living beings held in the mass, marble resembling the rippling lake that teems with fish. Sometimes the veins are innate ideas in the soul, like twisted figures or powerful statues caught in a block of marble.
>
> (G. Deleuze, 1995, p. 4)

The "ideas in the soul" bring to mind the sacred that Fra Angelico revealed between the splattering of paint (Didi–Huberman, 1995, p.35). Fra Angelico had attempted to solve the problem of the sacred through his panels through the dissemblance of the painted surface.

Vibrant Matter – serendipity

When I returned home I found an uncanny trick of light had captured myself, a fleeting figure, within the far left panel. I had inadvertently diffracted the space in the panel causing a fleeting moment of disruption to the visual space. Barad refers to “diffracted spatialities” and “diffracted temporalities” entangled '“across”' space-time; past and present threading through one another (van der Tuin, 2010, p. 224). I was a tourist, passing through taking photos of the past to remember a fleeting moment. Yet an uncanny trick of light tells another story. The light reflected from the window within the cloister alludes to the ‘unknown’ – the sacred, while outside the light reflects the ‘known’ - harshness of the material world. I find a comparison with Dickinson’s Alabaster Chambers, where the coldness of the chambers is juxtaposed with the arcs of infinity.

Figure 3. San Marco Convent panel, 700 x 430 cm. Photo: Jane Slade, 2014.

The folding surfaces have been “refractured” through the figure disrupting time and meaning. There is a tension between materials and the sacred inferences of the painted surfaces as the arcs enfold the figure. The folding surfaces, now emulate the pores of skin where inner thoughts seep, from inside to outside, hovering between, revealing and concealing. The serendipitous moment reminds me of van der Tuin’s interview with Barad who proposes that “intra–action” is where “subject and object emerge, “as a new understanding of causality itself” (van der Tuin, 2010, p. 55).

The figure hovers through the space while simultaneously being outside the space, it is ambiguous as Dickinson’s “meek members” “sleep” suspended between their earthly bodies and the timeless arcs of eternity.

The photo of the panel generated a shift in my approach to the practice lead research. I began to realize that I was searching for a more ambiguous reading of the emerging images. Barrett and Bolt (2014, p. 109) state that ambiguity “can facilitate new understandings” through the artwork. The photo has been printed so that the fictive frame encloses the panel, as a reminder of its place in the corridor of the convent. While a Serendipitous moment caused the shift in my approach to the project future possibilities were yet to unravel.

Sacred Chambers

The crouched figure juxtaposed between the arcs in the panel I propose references Dickinson's body wrapped in satin and suspended in the Alabaster chambers. The body in the chambers waits for redemption as the figure in the photo shifts between the harsh reality of the outside world and the sacred space within the panel. The timeless arcs of eternity enfold the figure between the surfaces of the panels as the "Crescent – above them – " move through time and space above the impenetrable chamber.

I began to reflect on Schön's (1983, p. 49) statement about knowing; that often saying what it is that we know can be fraught with difficulty. This is true when it comes to image–making in that often we can visualize an idea without being able to explain the thought process. The figure in the panel, while invoking a moment of serendipity was missing from the printed image yet validating the figure as part of the project, meant providing the context. G. Sullivan (2010, p. 147) discussed *Research and Exhibiting Visual language* in reference to the work of artist Jayne Dyer said the work "possesses the possibility of transporting one's understanding towards previously inaccessible territory". Breaking through the seemingly impenetrable barrier of how to image the figure began with my own reflection. Pressing my body against a large lithographic plate (120 x 80 cm) I was able to reactivate the reflection of the figure in the panel through the reflection in the mirror. Through my exploration and experiential understanding of the materials I was able to reframe the figure as an external form on the lithographic plate. The image was chemically etched, inked and printed onto rag paper. Each time the plate was etched something of the figure was lost leaving an increasingly vague impression on the paper. The almost impossible task of registering the large sheet of paper for printing (120 x 80) resulted in a distortion or shimmer around the figure. Printed mulberry paper torn and glued either side of the figure. This was removed through washing in a large water trough leaving two white spaces. The spaces are a reflection of the light that disrupted the panel at San Marco trapping the figure between the folds of the paint they can also reference angel wings or lungs.

Figure 4. Work in progress, 120 x 80 cm. Litography (plate) 2015.

Reflecting on the image I began to understand how Deleuze folds of matter and folds of the soul interconnect through the project through unrelated events like the panels. Barad's "cutting – together – apart" also references the physical and experiential inter-action with materials. I am reminded too of Barad's notion of "knowing" being messy.

Tacit knowing – serendipity

Early in 2014 my studio at the College of Art became waterlogged, and I had to pull everything off the damp walls including the strings of words from the poem that had been suspended between two industrial pipes. As I pulled the string, the text became jumbled and fell to the ground. Looking at what was now a mess it occurred to me that meaning, implicit and explicit also becomes tangled, shifts and changes between generations, cultures and over time. It was also messy. Now the ambiguous folding forms alluded to something else, something unknown. It was a tacit reminder of the panels under the *Madonna of the Shadows.* The letters, dissembled from their original intent, became unknown possibilities.

Figure 5. Artists proof. Work in progress, 380 x 110 cm. Text rolled onto lithographic stone. Jane Slade.

I took the tangled mess to the print studio and rolled the organic forms around a large inked roller. The mangled form became embossed in the ink. I started to roll the embossed impression directly onto the lithographic stone. The form left a smear of ambiguous stains and reflective spaces. While there was an element of Schön's (1983, p. 49) "tacit" knowing through actions, on reflection Barad's (van der Tuin, 2010, p. 224) reference to the "refracturing" of events had caused a serendipitous upheaval in understanding the role of the poetry. My "personal reactions" had brought about a shift in the process challenging the role of materials in the project (Barrett & Bolt 2007, p. 5).

Reflecting on the experience I began to wonder what was the function of the poetry, as a material means. I wanted to shift from using the text from the poem in a conventional manner, to grounding it directly into the process. I was reminded of Fra Angelico's painted panels. The paint appeared to be wildly splattered, but on closer scrutiny, it had its own rhythm, its own meaning as Dickinson's poem has its own rhythm, although at times "spasmodic" (T. H. Johnson, 1975, p. vi) within each stanza. Is this the "tacit" knowledge that Schön refers too? Is this Barad's notion of knowing? And what of the sacred?

The text was not just part of the image it was ground into the stone. The folding form hovered between inky grounds formed through the rhythmic rolling. The inked roller had created its own rhythm; the letters were no longer readable instead radiated shards of light. The process reminded me of Barad's idea of knowing where the entanglement of the subject (the maker) and the object (the lithographic stone and strings of letters) are immersed in the "phenomenon" of art making. Barad suggests that it is through a form of "violence" like the pulling down of the string of letters, that new possibilities can eventuate. The strings of letters and the lithographic stone are my "agential conditions of possibility" (Barad 2010, p. 52) that when explored have brought about new understandings and forged new relationships between the materials. The process while being activated by the art-maker was precipitated by events that Barrett (2014, p. 201) refers to as "alchemy", which I call serendipity.

The next step was to print what I had initially expressed as a mess. The stone made ready for printing through processes of etching, resting, rolling up with bitumen, then water and ink. The stone is then rolled with lithography ink and sponged with water. Between the water and the ink an image begins to appear. Paper is then placed onto the stone and passed through a press. The text no longer visible has taken on the form of shimmering light. The space around the form imitates creases and folds. The image shudders through the folds of the roller. It is incomplete but on reflection it takes on an ambiguous form rather than draining meaning from the words.

The experimentation has become an integral part of the image. E Barrett (2007, p. 5) says that art reconfigures our understanding of knowledge as action or knowing in that it comes from both thought and sensory interaction. She bases her understanding on the work of Michael Polanyi (1958) and Ian Sutherland and Sophia Krys-Acord (2007). Deleuze's (1993) ethereal approach to knowledge is through the folds of matter and "ideas of the soul" as fluid, enfolding and folding creating new understanding.

Laser-cutter

I began to look around for other tools that were available and how previously printed images could be reconfigured to reflect the new information. Establishing that cutting the text was partially successful I realized this could be refined, using the technology of the laser-cutter. I began experimenting with cutting out repetitive lines of the poem on large paper prints. (120 x 80). The laser cutter left behind burnt spaces of text reminding me of a pianola roll with its rhythmic pricks. As Dickinson's dashes suggest a disruption, a temporal suspension between the words the spaces made by the laser cutter marked a physical absence of text. The text fallen through the cracks of the laser – cutter has now become the evidence of the material holes in the paper, mimicking the tangled letters that were strung across the room.

Figure 6. Litography stone – inked with scattered text.

Sweeping the text into piles can represent Deleuze folds of marble where ideas flow between the folds of matter (Deleuze, 1993, p 4). The text is messy. As van der Tuin (2014) (referring to Barad's discussion of onto - epistemology) acknowledges it is through the possibility of being messy that known assumptions are discarded and new possibilities of knowing are created. The piles of text meant nothing, yet they meant everything. They no longer carried the message, they are the residue of my ideas, scattered, waiting to be reformed, reimaged. Experiential knowledge is not static but is ongoing, though not in a linear way as it folds and enfolds like the veins in marble, interweaving ideas with physical manifestations through the artwork.

The piles of text, released from their intent embody the ideas of the soul, like the folds of veins in marble. (Deleuze, 1993, p. 5) The pattered holes in the prints infer an absence; they can also infer a rupture - a cutting apart of the past.

The introduction of the laser-cutter as a tool caused a serendipitous eruption. It is as if one eruption precipitates another. Barrett states "This *durée* occasionally allows the fleeting moments of alchemical magic to occur, where the art object takes shape as an entity" (Barrett, 2014, p. 201).

Material Folds

As well as experimenting with the text itself I began to imitate Dickinson's modus operandi where she wrote on scraps of paper, backs of paper and envelopes. In my case this took the form of tearing the prints into shards of ambiguous images. They were to reference the torn pages, the folds of a book. However, the act of tearing (cutting) caused a disfigurement in the shape of the prints.

Figure 7. Works in progress. Flower and text, 30 x 27 cm. Jane Slade, 2014.

The shards of prints began to mimic of the scraps of writing that Dickinson left behind, the poetry and her pressed flowers. The fragments are not quite a square, not quite rectangular (27 x 30 cm). Pinned to the wall they can reference undulating folds. The heavy darker prints block the viewer, like a barrier, other prints are lighter, the spaces between, brighter more translucent. They remind me of the textual qualities of Dickinson's – *Soundless as dots – on a disc of snow*. Tearing prints the spaces of the text has left a physical disfiguration. Dickinson famously sewed one thousand of her poems together, in no particular order, as facsimiles. I have printed one hundred small prints some are pinned to the wall others are stacked in a pile. The stacked prints will be pinned, sewn or grouped together over time.

The shards on the wall remind me of a corridor, a between space. The corridor is a space for loitering, for moving through, for fleeting moments a space of imagination, contemplation and anxiety. Between the prints are scraps of writing that reveals the process of the artwork, the poetry and the ideas. The corridor is also the space Fra Angelico chose for his most important works, The *Annunciation and Madonna of the Shadows.*

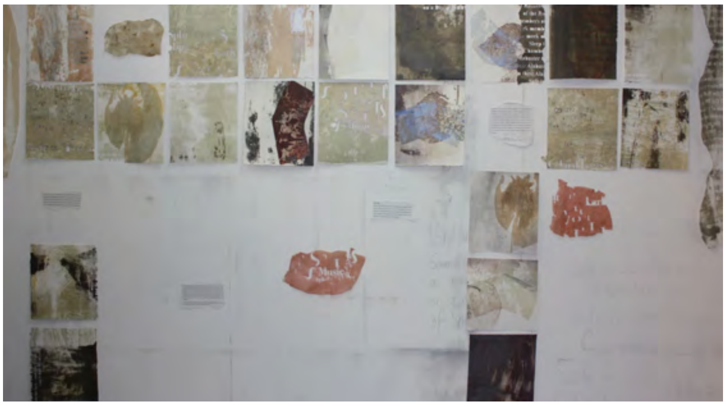

Figure 8. Work in progress. Torn prints, text and torn mulberry paper.

Dead flower

The small prints have brought into focus Dickinson's herbarium. Her herbarium is manifestation of her ideas through matter; dried flowers have been pressed between the pages of books. Matter and text enfolded through the ideas of the words in the books, as the prints are flattened manifestations of ideas, of matter.

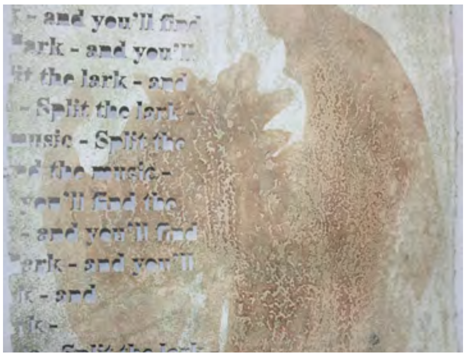

Figure 9. Untitled Work in progress. Torn print, 30 x 27 cm. 2014-2015.

The leaves of the flowers brought to mind the flattened folds of satin, in the *Alabaster Chambers*. I found myself searching to find the essence, the vitality of matter in the shape of the flower. Flowers caught between two leaves resemble an arc. The resemblance has resulted in a refolding of ideas, a return to the Dickinson's quest for the unknown. Shapes referenced from the pressed flowers are cut from pieces of etched linoleum. Warmed over a hot plate the linoleum becomes malleable, it is then inked and pressed onto the paper. The materials are aged and pressed as Dickinson's flowers are pressed to stall the passing of time. Elvin Karana (2014, p. 204 -205) says that the desire for the evidence of the passaging of time through deterioration is in part a longing for the past and the need for confirmation of one's identity.

The palette comes from the Fra Angelico's panels but the colours are faded, dusty and dirty. They are the colours of unrefined beeswax taken from a hive. Some of the wax has dead bees caught between porous bubbles. They are reminiscent of Dickinson's dead flowers pressed, flattened between the pages of a book.

Figure 10. Unrefined beeswax.

Conclusion

Donald Schön, refers to the actions of the practitioner: “Often we cannot say what it is that we know. When we try to describe it we find ourselves at a loss, or we produce descriptions that are obviously inappropriate. Our knowledge is ordinarily tacit... our knowing is in our action”. (Schön, 1983, p. 49) Schön’s reflection on the actions of the practitioner points to my difficulty in describing how the process of knowing affects the manifestation of the poetry, the unknown sacred space.

I agree with Barad (van der Tuin, 2014, p. 259) when she says the notion of knowing comes from being messy, where known assumptions are erupted leading to new understandings. Knowing then is often fleeting often evasive, as the unknown, the sacred is evasive.

I am reminded of Deleuze folds, of the veins in marble. Sometimes they come to the surface causing a rupture in the project, like pulling down the strings of letters, while at other times they lead to more ambiguous outcomes, like the figure in the panels at San Marco. These moments are pure serendipity yet they also reflect what Schön refers to as “tacit” knowledge.

Early investigations relied on what Schön describes as “tacit knowledge, which caused me to pause and reflect on my intention”. However, as happens in most explorations of materials not all goes to plan. It is the unplanned or serendipity, alchemy, and at times seemingly random events that stimulated and facilitated new understanding (knowing) in the project.

I refer to ‘Serendipitous’ events; Barrett refers to them as ‘alchemy’. Perhaps they could also be referred to as ‘sacred’ insofar as they make it possible to slip in-between the cracks of matter, to an intangible space, of imagining. This is the space that Dickinson slipped into when she wrote her poetry, her sacred space: her alabaster chamber. The corridor can refer to the space between the chambers, as the shards of torn prints have become a reference point for the past and the future images. The materials of stone, aluminum plates, linoleum and paper are the evidence of the disruption of the past and present. The inter-action with materials is an integral part to the narrative in gaining new knowledge and understandings. “Experiential knowledge” through ongoing exploration with new and known materials, has lead to surprising outcomes, as with the piercing of the laser through the prints.

As I reflect on the process of the work I find there is a continual tension between process and outcomes. Through reflecting and questioning my motives, I have found I have become more intuitive and more willing to let go of the materials and the visual outcome allowing them to become embedded with the process.

Emily Dickinson’s poetry, her cloistered life, her quest for the unknown – the sacred – is the “knowing”, which keeps me fully engaged with the project. Her poetic ‘stanza’ comes from the folds of the soul contained within her “stanze”, (Italian for room) – the sacred space within her alabaster chamber.

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Jane Slade

Jane Slade is currently a Candidate in Masters by Research (MRes) at the Tasmanian College of the Arts, Hobart, UTAS. Her research project is an investigation of art, text and the sacred through the visual language of printmaking. She is exploring the poetry of Emily Dickinson through her practice-based research, which involves understanding experiential

knowledge through materials. The Fold, as proposed by G. Deleuze provides the material and experiential means for the investigation.

Jane Slade received a Bachelor of Education in 1992 and taught with the education system for 22 years during which time she developed her interest in Visual Arts. In 2011 she achieved a Bachelor of Fine Arts with Honours in Printmaking and was listed on the Deans Roll of Honour in 2009. She has exhibited in local exhibitions including the annual Images Tasmania at the Salamanca Long Gallery. Her practise seeks to re-contextualise the traditional links between the Sacred, text and art.

Kindness as a Collective Wish to Co-Design with Communities using Physical Installation

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Abstract

This paper reports a co-design intervention experimented with ‘kindness’ as a community value for social innovation during Dutch Design Week 2014. We discuss the insights gathered from the practice-based research aimed to envision and enact community’s creative imagery as a shared space for co-creation. The co-design intervention visualized, enacted, connected and structured community’s ideas by projecting “kindness” as an idealistic social value to inspire the community’s collective wishes. The activity was instrumented by Collective Imagery framework supported by two co-design tools: Collective Imagery Weave as a physical installation using tags and threads to envision creative complexity; and Mind Weave Theatre as drama sketches to enact design solutions through narrative reasoning. Collective Imagery Weave was presented in a public space and continued to engage the community to co-design for social innovation. The physical installation’s aesthetic quality evolves in its static form, the interactive process of being constructed, as well as stories resulted from this intervention, which demonstrated a structuring process possible to innovate from the abstract concept of “kindness” as the community’s ideal collective wish into concrete design solutions.

Keywords

co-design; social Innovation; public Installation; collective imagery;

Envisioning Community’s Collective Wishes

Design to encourage positive change for society such as community wellbeing is commonly done through large-scale activities, such as policy-making and urban planning, which design researchers often faces challenges to collaborate directly with communities (Fuad-Luke, 2013; Manzini, 2013). Difficulties lies in devising design tools to collaboratively tackling cross-disciplinary and cross-cultural social problems as often these design problems are not immediately evident and often undefined in the social contexts. In order to consolidate individual mindsets as a social collective, the participatory method designed requires a visualization of diversed cultures, values or economics of the communities.

Conventionally, design starts with a design context or problem, based on which designers can define specific user groups, stakeholders, challenges and other factors in seeking design solutions. In the context of design for social problem, designers often find themselves in a typical wicked problem’s paradox of “we cannot think about solutions until we understand the problem” and “we cannot understand a problem until we think about solutions” (Wendt, 2015). While Kees Dorst (2001) identified this as the co-evolution of problem and solution, recent design strategy involves service design thinking to tackle complexity and implicitness of design context or problem brought by these difficulties (Meroni & Sangiorgi, 2011). For some, intuitive tools are employed to help communities to achieve societal transformation by connecting abstract issues to concrete solutions (Fulton Suri, 2008).

“Kindness” as a Collective Wish

Aligning with the concept of collective dream in the field of co-design (E. B.-N. Sanders & Stappers, 2008; L. Sanders & Stappers, 2014), we describe a co-design engagement to enact and envision community’s collective wishes to allow a common space to facilitate collective needs without focusing on individual differences in mindsets. In particular, we proposed that collective wishes as a projection of abstract design goals, such as human feelings or common values shared by communities. In this exploration, we shy away from the debate of epistemological tradition of designing as problem solving (Dorst, 1997), instead we experimented with the notion of “kindness” as a projected concept which abstracts ethical design value, to facilitate emotional and empathetic responses within the community that can be multi-interpretive. To do so, we carried out a co-design intervention to envision and enact community’s “collective kindness”. We asked to what extend the co-design framework and tangible tools can envision the abstract concept of ‘kindness’ and devise communities’ collective wishes, for social innovation.

Co-Design with Collective Imagery

In order to visualize the abstract concept with communities, we adopted first author’s work on the “Collective Imagery framework” to guide the creative activity of co-design, mediating through a physical installation as a co-design tool which envisions and enacts social innovation with the community who is not trained to be creative. (P. Chueng-Nainby & M. Gong, 2013) The Collective Imagery is a framework for co-design originated from an aim to overcome individuality in a creative process that potentially hinders design collaboration. It has evolved from practice-based research which extends creative cognitive approach to a collaborative settings, in particularly design space is collectively mediate with the concept of preinventive structure of creative imagery, which act as divergent insights that drive creativity (Finke, 1995). And the collaborative activity employed in the framework works through the externalization of individual creative imagery in sharing with others, to achieve collective creativity.

‘Collective imagery’ is a conceptual structure of design elements that mediated communities’ shared imagination space, in which connections of ideas are made possible through spatial activities of deconstruction, construction and reconstruction (Chueng-Nainby, 2014a). Collective Imagery as co-design framework has been experimented at various cross-disciplinary products, systems, and service designs for healthcare, tourism, rural development, for both private and public sectors in the world (Chueng-Nainby, 2014a, 2014b, 2015; Chueng-Nainby, Fassi, & Xiao, 2014; P. Chueng-Nainby & M. Gong, 2013; P. Chueng-Nainby & M. S. Gong, 2013; Mulder-Nijkamp & Chueng-Nainby, 2015; Preez, Cilliers, Chueng-Nainby, & Miettinen, 2015).

The framework of Collective imagery was experimented by carry out co-design interventions as a collective activity of conceptual construction using mostly tangible and physical materials as props to engage communities to ideate collectively and to connect their ideas. The flow of the engagement has no fixed process, instead a situationist approach centred around allowing the structural connectedness of ideas to give rise to the emergence of creative concept through an activity of ‘deconstruction’, ‘construction’ or ‘reconstruction’, in a hermeneutical circle. The connections are forged either through association or narrative reasoning. Participants collaboratively generate design elements in keywords or drawings, and connecting them into narratives, using threads or strings, and sticks. Participants then construct these narratives into a physical structure that forms a common creative space for conceptual understanding of their collective wishes. Various tools have been created and experimented with to facilitate community's to co-design through the construction of collective imagery. For example, wool thread as connections; paper tags, printed photos as element; bamboo sticks to link narratives; cardboard boxes as three-dimensional narrative space (Chueng-Nainby, 2015). Each tools are combined and used according to needs arise for the work.

A Mind Weave Theatre Installation for Collective Kindness

This paper reports a co-design engagement in workshop format, which we experimented with "kindness" as a concept to facilitate collective wishes, the framework works to engage local communities to collectively envision and enact the transformative possibilities in their daily lives. The workshop was commissioned for the Dutch Design Week 2014 (DDW 2014), titled "Collective Kindness: A Mind Weave Theatre Workshop Installation". Mind Weave Theatre is the co-design tool based on the Collective Imagery framework using tags and threads to envision creative complexity, and improvised theatre as narrative-forming activity (Chueng-Nainby, 2014b, 2015; Chueng-Nainby et al., 2014; P. Chueng-Nainby & M. S. Gong, 2013; Mulder-Nijkamp & Chueng-Nainby, 2015; Preez et al., 2015).

The process of intervention was designed by the first author and implemented in collaboration with the second and third authors. The intervention was held in an open space at the lobby of the main building of Eindhoven University of Technology, which welcomed DDW 2014 participants who signed up for the workshop through a social media page. The diverse background of participants, such as industrial design, information management and nursery, made the activity into an interdisciplinary cooperation. The four hours intervention was divided loosely into two creative sessions followed by a feedback discussion session. Each session consisted of iterative and occasionally parallel activities of deconstruction, construction and reconstruction (Fig. 1), instrumented by a physical installation, which externalized individual creative imagery to share with others.

(a) Deconstruction Write down keywords | **(b) Construction** Build narrative sticks | **(c) Reconstruction** Connect stories into structures

Fig 1. Process of deconstruction, construction and reconstruction

First session started with a generative activity to explore the concept of "kindness" in relation to contexts (deconstruction): 1) general concept of kindness; 2) kindness in the world; 3) kindness in the city; and 4) kindness in yourself (Fig. 2 and Fig. 3). Participant populated their tables with as many keywords as they could, using texts and doodles on colourful tags. When their tables were saturated or when participants stopped generating, we intervened by rotating participants to other tables. Working on others' tables inspired participants to generate more design elements, which resulted a larger collection of design elements in words and visuals than the first round, ready for construction in next session.

During construction participants began to work in groups of three or four to construct the populated tags into narratives which represented their concept of “kindness”. They were free to select tags from any of the tables. Each narrative was made of four or five tags, connected and displayed on a bamboo stick - namely narrative stick (Fig. 4a). Each participant was asked to construct at least two narrative sticks, and when done, to share their stories to each other firstly within their group. They were later to move around spreading their stories to as many participants as possible to discover any similarities and connections in their narratives to combine them into stories. Stories were constructed by linking related narrative sticks with rubber bands into a collective structure (Fig. 4b). Each group selected these stories in the form of an interconnected structure to perform as a two minutes long drama sketch by acting out the stories in front of an audience of other participants and passers-by (Fig. 4c).

Fig 2. Materials for the intervention   Fig 3. Colourful tags for “Kindness”

Fig 4. Co-construction of narrative structures and performative storytelling

Drama sketch is a performative form of story co-constructed by acting out stories on the connected narrative sticks, often done intuitively and embodiedly while interacting with the physical installation. The process of interpreting and acting allowed participants to empathetically synthesize social design solutions through narrative reasoning in the form of drama sketches, in which their roles were users within a context or scenario. By describing their interactions with the potential products and services, conceptual solutions were holistically presented in plausible stories easily understood by the audience. The stories inspired by the generated keywords and drawings, can be considered as a collective imagery of “kindness”, gradually enriched with focus and details over two performances of drama sketches.

Second session resembled a similar process of activities as the first session. We zoomed out and in on the concept so the stories would become more realistic than the conceptual ones resulted from the first session, though we didn’t insist on continuity from previous stories. An interesting phenomenon observed during this session was that the participants tried to improve the connected structures by visually redesigning or restyling the structures to be related to their design solutions. Props were added to the structures in order to change the shapes (Fig 5). Some groups even used these structures as props to help convey their stories during the drama performance.

The feedback session was mainly a discussion on participants’ understandings and considerations on the usage of the methods and the future possibilities in improvement and application. At the end of the intervention, all stories, solutions and feedbacks were grouped and connected into small structures, which finally made up a collective installation as a physical and opened-up representative of the co-design process (Fig 6 and Fig 7).

Fig 5. Structures mixed with props

Fig 6. Physical style of the collective installation

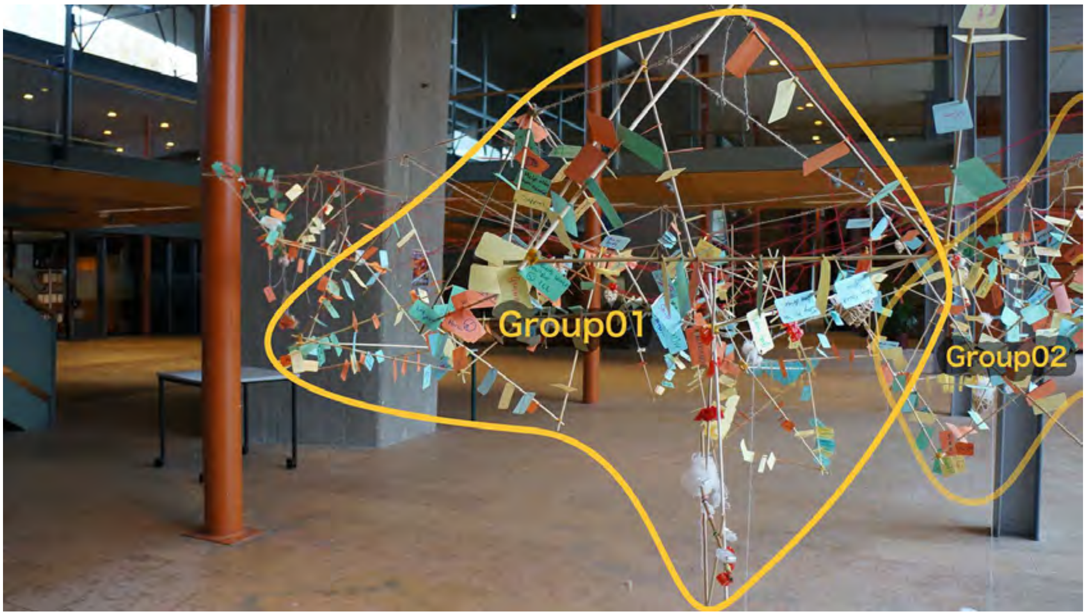

Fig 7. Grouped structures of narrative sticks

The collective installation, constructed with connected bamboo sticks and colourful keyword tags, not only showed the final results of the co-design intervention, but also put the design process in display. Colours suggested the 4 contexts of “kindness” (Fig 3) where the keywords came from, the sticks showed how they were connected into narratives, and the grouped structures (Fig 7) presented which and how stories were related to each other. The installation indicated aesthetic qualities both in its hierarchical structure and in its dynamic process of being constructed.

The inviting form (Fig 6) of the physical installation shaped through the co-construction process allowed visitors a space to walk in and out, reading the narratives, even adding new tags or sticks. It became a social research instrument and continued to gather input from other people after the event for two months. The collective installation, as a result of this co-design process, became a visual externalization of the community’s collective understanding on “kindness”. The presence and the constructing process of the installation together formed the basis of design for social innovation in this intervention.

Intuitive co-construction with imagery in embodiment

Concept exploration was guided step-by-step for participants to get used to the intuitive approach. They were given very limited time to perform each step to prevent thinking too much on the their thoughts which come into their minds. The process is resemblance of brainstorming as such that the participants would not be able to think too much on the large amount of elements coming into their minds. They had to write down all the things coming out as imagery as quickly as possible, which means that most of the elements were created intuitively based on participants’ life experiences and knowledge.

The embodied cooperation for construction supported the participants to dig deeply for potentials. The interactive process of ideation, involved the participants not only in thinking, but also in doing, is especially valuable for interaction design: “interaction, is ungraspable in more than one way. It only ‘exists’ when it happens.” (Overbeeke, 2007). Designing for interaction shall happen in the process of interacting with the forming concept, and the aesthetics in interaction shall be experienced and possibly, ‘graspable’. This embodied cooperation process together with its tangible instruments, provides a platform for discovering, experiencing and shaping the aesthetics in interaction.

When connecting narrative sticks into grouped structures, participants’ thinking reached a shift by linking the structures physically. The complex shapes and the mass of contents led to a lack of time for people to make a so-called perfect choice after browsing all the elements. Thus, the participants had to think of as many alternative options as possible, which made it into a creative space for more possibilities. The narrative sticks not only displayed the keywords and different understandings of people on “kindness”, but also mediated physical affordances (Overbeeke, 2007) to facilitate the participants to find new relationships between elements when they browsed the content and built the structure. When people walked in and out through the structures, the features that could be seen kept changing with their perspectives and moves, and the affordance thus changed. They thought and connected things rationally as well as intuitively, using forms and shapes to express their considerations on the relationship between narratives, which finally led to co-constructed structures both literally meaningful and physically harmonious, representing as an interconnected embodiment of ideation.

Empower creativity through co-construction

The co-constructed installation represented a shared understanding and a collective narrative about “kindness”. As the construction work could not be completed individually, collaboration happened throughout the whole design intervention, including the process of deconstruction, construction and reconstruction. By co-constructing the installation, the general and abstract concept was deconstructed into detailed elements, between which people could find or create concrete connections easily. When generating keywords as design elements, the participants switched between different tables to get inspired from others' ideas, which finally helped them to continuously come up with new keywords and visuals. Individually created key elements and stories were joined into conceptual structures.

Narratives based on the structures were made into stories and dramas through the cooperation. The collaborative nature of this co-constructing process drove participants to explore the contexts and possibilities more creatively through discussing with and learning from each other, instead of isolated thinking in their own minds. When they walked around to browse and search for more appropriate keywords, the participants kept finding new relationships between tags and narratives through others' comments. The performative story co-construction also allowed participants who generated the keywords to experience the stories developed by the others, and get inspired by the new understanding and the enriched contexts interpreted in the performance.

Embody solutions from life experience through story co-construction

"Collaborative storytelling is a research approach, which facilitates communicating, interpreting and giving meaning to people's lived experiences" (Bishop, 1999). Commonly, people gained their subjective and objective thoughts and findings from deeply looking into their lived experience (Bengtsson, 2013). Collaborative stories allow people to select, recollect and reflect on stories according to their own understandings from life and culture, instead of being defined by researchers after study (Bishop, 1999).

During the intervention, this method was employed to lower the threshold of design and help deal with the complexity and abstractness of the theme. Since not all the participants knew service design methods or held the design background, making stories became an acceptable and adoptable approach to help them define design factors for their solutions before they were aware of it. The participants considered important factors when telling their stories to others, including who were the hero(ine)s, what happened and how it was developed, which props were used and how they were used, who could be considered as target users and in which contexts and scenarios, with which products and related interaction. The performative way to act out the stories helped them embody the imagined situation and refine the concept intuitively in this structuring process. During the telling and acting process, the general concepts gradually became concrete, so was design focuses and solutions.

Engaging with physical affordance

The collective installation was one of the most important deliverables of this co-design intervention, providing us a new perspective to explore the impact of this design framework and its tangible instruments. An installation is usually considered as a static or interactive structure, completely designed and prototyped before it is placed or implemented into a public space, for public show, or for engaging the public in social interaction (Hu, Frens, Funk, Wang, & Zhang, 2014; Hu, Funk, Zhang, & Wang, 2014). However, the installation introduced in this paper, presented as a result of the intervention, was more than a last pose of the co-design practice. It was co-constructed utilizing Collective Imagery framework which facilitated the process of design activity and provided possibilities to involve new elements after the events.

The presented structure of the installation was a physical record of its design process and a collective understanding of "kindness", visualizing what local people were concerned about. The constructing process of the installation could be treated as an embodied approach for people to explore concepts, as well as a physical affordance for people to create new connections beyond rational thinking when they walked through the installation to browse the keywords. Based on relativity of the content, the participants were also inspired by its layouts and structures, and created ideas intuitively for an expectation of beauty or harmony in shape and structure.

The approach of using bamboo sticks to link paper tags contributed to the preservation of details in each step, so that people could to some extent read and understand the narratives, as well as analyze how they were connected together. The installation told people the design thinking process from the beginning, instead of only showing the final answers found by the participants. In addition, the opened-up structure of the installation resulted from the way it was constructed, as well as the colourful appearance and natural feelings gained from its materials – resemblance of traditional architectures or installations such as those wishing tree with people's wishes on display for blessing. It was inviting for passers-by to get closer, reading and touching it. It was possible for them to go through the installation, browse the keywords and drawings on the tags, and even change some parts of the structures. The openness of the installation showed its potential of attracting extra attention and participation as a developing project to evolve even after the intervention.

Discussion on future work

This paper introduced a co-design method with tangible tools for people to deal with the abstractness in design concepts for social innovation. The embodiment of collective understanding through the design intervention provided a new perspective of viewing the installation as a physical medium to facilitate co-creation during and after the design process. The intuitive interaction and experiential knowledge of the participants played important roles throughout the co-constructing process. Future work is needed to improve the process and the instruments employed in this design intervention, in order to help facilitate intuitive interaction more easily and provide better outputs for data analysis.

Improve the intervention tools and process for smooth construction

The main suggestions received from the feedback session focused on the improvement of the tangible design tools and the relation between two intervention sessions.

Currently the colourful paper tags were linked by the bamboo sticks which were connected with each other by rubber bands. Although these materials were flexible for making joints and helpful to trigger intuitive creation, it was still not easy to change certain part of the content (a tag or a stick) when the narrative sticks were already connected to others. There is a need to improve the way of making these joints so that participants' thinking pace would not be interrupted too often by the limitation of the physical tools.

The two sessions of the intervention focused on concept creation and solution design respectively. However, as the two sessions used the same materials and a similar iterating process, some of the participants felt confused when distinguishing them and figuring out the goal of the second session, which suggests a space for improvement in the intervention guidance and process, in order to clarify the progressive relation between the two sessions.

Explore data analysis and evaluation methods

The Collective Imagery framework is based on the use of tangible instruments to engage the community and empower the intuitive creation, which at the same time is relatively difficult for data collection and analysis. Currently data is recorded and kept as photos, videos and text by the organizers, while there is a need for a more efficient and suitable way to digitalize the content for making further use of the concepts and enhancing the continuous impact of the collective creation.

Furthermore, while there exists subjective measures of the aesthetic quality of the installation as a final product (Hu, Le, Funk, Wang, & Rauterberg, 2013), it would be challenging to evaluate the experience and the aesthetic quality of the dynamic and interactive process of the Collective Imagery framework with retrospective subjective measures. Digitalization could help provide objective measures and insights into this process. It would provide a possibility for designers to combine virtual and physical content together with real-time interaction, so that people may create content physically while having a transformed online version at the same time, or making changes to the installation and receiving real-time feedback. This will also be helpful for the analysis and evaluation of a dynamic process.

Refine the visual guidance and support

The collective installation created through design intervention provides the researchers with new perspectives in the use of the framework, considering the physical presence as a dynamic process. According to the observation on the installation after the intervention, there were people showing interests in the installation. They walked into it, read the tags, tried to understand it and even helped to repair some broken joints, while it was difficult for them to take more actions due to the lack of proper guidance and support.

There is a need to enhance the visual guidance and add necessary instruction to the installation, since the organizers and participants couldn't be always there to interpret the concepts. A clearer physical hierarchy of different sessions in the installation would be needed to help catch up with the design process, which can be implemented through the difference in the structure, material, and colour. Simple but clear instructions are also needed to provide basic background information for visitors, not for constraining their imagination, but for understanding the theme and finding a starting point.

Current method to create narrative sticks is suitable for intervention events, while the passing-by situation may require an easier and faster way, which requires the design iteration to lower the threshold of adding contents on to the installation, the appropriate choice of location and the space design on surroundings, considering the protection of the installation, and the spatial influence on people's behaviour.

In this practical study, the Collective Imagery framework is suitable for defining design focuses for complex and abstract social problems, while the co-design process employed in the intervention is more helpful when creating and refining conceptual solutions, rather than tackling the final feasibility in implementation. The improvement of design instruments and process is also needed to enhance the content quality of the output.

Conclusion

This paper presents a design intervention deployed during Dutch Design Week 2014, considering the general and abstract concept of "kindness" as a community's collective wish. Through this practical study, we explored the impacts of Collective Imagery framework as a co-design method for complex social innovation contexts, analyzed the potentials of using tangible tools and physical spaces as mediation to facilitate co-creation, and highlighted some future directions to improve the design instruments and process.

The design intervention focused on exploring concepts exploration and solutions for the social value of "kindness", in which Collective Imagery Weave and performative story co-construction showed their potential in facilitating co-creation within communities with different knowledge backgrounds. Tangible tools and performative approach contributed to dealing with the complexity and abstractness of the social innovation context by helping the participants think and design intuitively through their life experience. Through the intervention process of generating keywords, co-constructing stories and physically architecting narrative structures, the participants were inspired by embodied co-creation and reached a shift in conceptual design beyond individual thinking.

Furthermore, the co-constructed installation showed externalized the participants' collective understanding and presented the dynamic design process through its physical structure. The inviting form shaped through the co-creation work and the natural aesthetic in the material triggered passers-by to walk into or through it, browsing and exploring the contents. The interaction between people and the installation during and after the design intervention suggests the potential of using physical materials as co-design mediation. The approach also needs further experiments and explorations in its design, data analysis and evaluation.

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The role of doing and making models with materials: Outlining "designerly and human-centred entrepreneurship"

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Abstract

This paper seeks to demonstrate the central role of making and creating models in what we call "designerly and human-centred entrepreneurship". We refer to empirics from studies of Danish entrepreneurs working on how to develop their businesses.

In Drucker´s (2001) "Management Challenges for the 21st Century" he predicts the new paradigms of management will change and continue to change our basic assumptions about the practices and principles of management. One of the key influences is that of design. 10 years later Johansson & Woodilla argue there is a need for a paradigmatic widening within Design Management, since, if it stays within the current Functionalist paradigm, it is difficult or even impossible to embrace the ambiguous aspects of praxis-based design knowledge (Johansson & Woodilla, 2011).

We believe this paper contributes to the more humanist and interpretive paradigm, by bringing forward examples from design research with entrepreneurs, clearly indicating the power of design processes in business. Our paper focuses specifically on how design processes, here defined as 'reflective-conversation-with-materials' (Bamberger & Schön, 1983), can act as strong 'inner dialogues' (Sørensen, 2011) about personal values in life and in business. Thus, our outline of 'designerly and human-centred entrepreneursip' builds on designerly ways of knowing (Cross,1982), Drucker's idea about value clarification and self-management (2000), as well as Sheldon's idea about 'motivation' (2012). We frame this within Goleman & Senge´s recent concept "The Triple Focus" - in this paper emphasizing the 'inner focus' (2013, 2014).

We briefly refer to experiential and aesthetic learning experiences that leads not only to value clarification, but also to changes in the entrepreneurs' self-awareness, values and identity. Thus we highlight, and suggest the current design management discourse to promote, the strong role design processes with materials can play in business modelling and entrepreneurship.

Keywords

values, entrepreneurship; 'reflective conversation with materials'; The Triple Focus; experiential learning

Introduction

We are all born with deep natural capacities for creativity (Robinson, 2009, Gelb, 2014). It is increasingly urgent to cultivate these capacities and use creativity and imagination for rethinking the dominant approaches to life, Maxine Greene argues; *"…taking it for granted, we do not realize that the reality, like all others, is an interpreted one. It presents itself to us as it does because we have learned to understand it in standard ways"* (Greene, 1995:44). To Greene imagination is the cognitive ability that permits us to give credence to alternative realities, "*…it allows us to break with the taken for granted, to set aside familiar distinctions and definitions"* (Greene, 1995:3). But to do so, we argue that it is necessary to become aware of our individual and dominant values or mental models, which steer our habitual ways of thinking and acting (Senge,1990, Fredens & Prehn, 2009). Not until this is done, can we understand them nor break with them.

Changing dominant values and mental models are central in a Danish design PhD (Sørensen, 2011) in which participants were offered creative design processes in order to make them reflect deeply about concepts such as 'money', 'banks' etc. These designerly methods - designerly ways of knowing thinking and acting (Cross, 1982, 1999) included activities like 'thinking-with-the-hands', working with materials, reflecting, imagining, visualising and making models were experienced by various participants as a strong 'language for self-dialogue' (Sørensen, 2011, 2012, 2013).

In the workshops the participants reflected deeply and came to 'see' their dominant values, which often lead to an intrinsic motivation for a change of values as well as behaviour. The theoretical explanation for this lies within Neck & Manz´s concept about *Thought-Self-Leadership* (Neck & Manz, 1992, Neck et all., 1999).

Subsequent research amongst entrepreneurs showed how similar processes lead to changes in values and behaviour (Evers & Sørensen, 2014).

In this paper we:

1) Briefly present the PhD research on customers becoming aware of and changing dominant values and behaviour
2) Present current research on entrepreneurs and how their reflective conversations with materials made them change their understanding of themselves and/or their businesses, as well as behaviour
3) Add a theoretical perspective by presenting design processes as aesthetic experience and aesthetic learning processes
4) Briefly discuss these findings within a business perspective

'Seeing' our dominant values through creative processes

The objective of a Ph.D. thesis completed in 2011 (Sørensen) was a deep concern about our dominant values and mental barriers to change. The concrete research object was people´s perception and behaviour in relation to money. Our experiments showed, like Greene stated, that people seldom reflect on their dominant values, neither their core values, (Goleman, 2013; Covey, 2005; Fredens & Prehn, 2009) - nor the values that guide their behaviour in relation to money (Sørensen, 2011).

The hypothesis was then to design a Money Workshop including creative processes aimed at individual value clarification and offer these to students and banking customers who wanted to change their 'money behaviour'.

We concluded that participants practiced design activities like 'reflective thinking' and 'conversation with materials' (Bamberger & Schön, 1983) and thereby created visual, hand-made strategies, here making primarily collages and 3D models. All in all, the workshops proved to be strongly self-persuasive, stimulating mental imagery and leading to new cognitive strategies (Neck & Manz, 1992, Neck et all. 1999): six weeks later the majority of the participants had changed their behaviour in accordance with their new visualized strategies. Additionally participants felt increasingly empowered and were taking action and showed leadership – only a few did not change behaviour (Sørensen, 2011).

Overall this kind of working with materials acted as visual ‘making’ language for the purpose of seeing, reflecting and changing mental and narrow perspectives – here in relation to money (Sørensen, 2011).

Fig.1: A young man’s collage of the future. Here he illustrates himself as “The Money Man Jazz” which to him means “being in control and in charge of his money”- an example of a generative metaphor (Schön, 1993).

From ‘money’ to ‘values’ in entrepreneurship

These experiences of reflective conversations with materials as exemplified in the Money Workshop, is further explored by presenting cases illustrating how it can be applied in entrepreneurship.

Here we are in line with Sarasvathy (2001) who describes that all entrepreneurs begin with three categories of means including: Who they are, what they know and whom they know. However, Sarasvathy´s theory is focusing on ‘effectuation’ as an entrepreneurial way of thinking and not so much on a deeper investigation of the personal values and mental models of the entrepreneur. Nor does she take the significance of empathy, designerly knowing, emotional and aesthetic experiences into account as we do when outlining ‘designerly and human-centred entrepreneurship’.

The literature on clarification of personal values (e.g. Drucker, 2001) has recently been followed by related research like Goleman & Senge (2014) who argue that you need to start with ‘an inner focus’. Their idea about ‘The Triple Focus’ (Goleman, 2013) represents three different foci that act as our framework for outlining ‘designerly and human-centred entrepreneurship’;

1. Inner focus: referring to ‘self-awareness’ and ‘self-management’, attunes us to our strengths and limitations, guiding values, feelings and intuition
2. Other focus: attunes our relationship with the people that are in our life
3. Outer/Systemic focus: helps us understand and navigate in the larger world

In this paper we explore the ‘inner focus’, by working with doing and making models for the individual entrepreneur to connect with, and understand better his or her's underlying values and beliefs, and how they (could) become enacted in their business. Working with inner focus “gives us a realistic sense of self-confidence, [makes us capable of handling] our distressing emotions so they don't interfere with getting things done, marshal our positive emotions to stay motivated in working toward out goals, and bounce back from setbacks" (Goleman, 2013 in Forbes).

Another paper (Evers & Sørensen, 2014) concentrates on the 'Other focus' i.e. the relationships, where an entrepreneur co-create meaning and understanding of her underlying values and beliefs in strategic business modelling workshops with business-to-business partners (suppliers, customers and advisors).

The inner focus in 'designerly and human-centred entrepreneurship'

In an interview about entrepreneurship the Danish business professor Hildebrandt argues: "…forget everything about the perfect business model…dare to embark on an inner journey to find meaning" (Hildebrandt, in Matzen, 2013). Similarly the creativity professor Robinson (2009) stresses the importance of finding 'The Element', Stephen Covey uses the term 'voices' (Covey, 2005) and professor in psychology Kennon Sheldon´s uses the term intrinsic motivation and 'self-determination theory' (Sheldon, 2012). These terms we relate to Goleman & Senge´s 'inner focus' below.

Hildebrandt doubts that working towards "finding your unique talents" and "embarking on an inner journey to find meaning" is included in any entrepreneurial course. But it is. At the entrepreneurial initiative, 'Iværk' at Designandelen, Vejle we, as part of the teaching team, take our point of departure in a workshop about inner focus and personal value clarification, developed based on the above-mentioned research results and experiences (Sorensen, 2011, 2013).

Drawing on Revans (1982, 1998), Carr & Kemmis (1986) and Zuber-Skerrit (2001) this particular kind of action research - or action learning - aims at technical and practical improvements for the participants, informed or based on the participants' *transformed consciousness about themselves and their business*, which motivates and empowers them to change themselves and/or their firm's existing boundaries and conditions.

Thus we start our entrepreneurial courses with a personal value clarification about talents, passions and barriers. It includes a deeper investigation of dominant values, motives and questions like: Why do you want to start up your own business? What kind of emotions do you feel when drawing or illustrating your business? Sheldon distinguishes between different types of intrinsic and extrinsic motivation (Sheldon, 2012) whereas Goleman et all. (2002) refer to how you move from understanding 'My Ideal Self' and 'My Real Self', to identification of supportive relationships that makes change possible. Later the entrepreneurs start working with user studies, researching the needs in the world and how they cope with their own ideas. Likewise they work with Business Model Canvas (Osterwalder & Pigneur, 2010), service design, customer modelling etc. In that sense they learn a designerly approach to entrepreneurship and business, constantly *remodelling* their businesses - but *also* focusing on themselves, the business context and the world.

As action researchers we aim at giving an honest account of how the participants in the project view themselves and their experiences, as argued by Zuber-Skerrit (2001), and we will therefore in the following present excerpts from some of the workshops. The two examples are chosen since they both represent significant changes in understanding of values and mental model, as well as changed behaviour. But whereas the first example clearly embraces and acknowledges the influence that working with materials at the workshop had on her and her business afterwards, the second does not. On the contrary he refuses, although the way he refers to the action following the workshop, shows a strong connection to the model he made and the meaning that he put into it.

Insights into value clarification among entrepreneurs

In some of the introductory workshops participants were urged to:

- Create two collages: one illustrating themselves as entrepreneurs today and the other one illustrating themselves as entrepreneurs in the future
- Develop and visualise a personal statement about how to move from a to b
- Build or create a 3D model or object of their personal statement using various types of materials
- Make a presentation of these objects and reflections

Fig. 2: The artist presenting her model

The artist

Entrepreneur:

> *This one is called "I am Rockefeller"... One of my nasty thoughts concerns my father, who during my childhood used to say: "do you think this is Rockefeller?" It takes up a lot of space in my business acumen. Today's work has been a lot about business acumen, both with words, but also in relation to sales – for I am an artist and "you should not sell your things; they should sell themselves" [she changes her voice when she says this] – that has to change.*
>
> *That's why I made this platform. The roses symbolise Rockefeller, fun and celebrations….and roses for me integrate greatness and wealth. And they are also a symbol of yes, trees actually grow into the sky [she points at the object behind the TV and they are even turned a little upside down because we are talking about art."*

In this case the artist reveals two dominant values/mental models that both refer to the central business activity: "selling", which often is a key barrier amongst creative entrepreneurs. One value and mental model relates to an artist community saying: "you should not sell your art, it should sell itself", the other refers to her father saying, "this is not Rockefeller" indicating money is not something we have. In her 3D-model she reframes this perception and the understanding of herself as an artist not selling her art. Subsequently, after the workshop sessions she starts acting in a new way and develops various different types of approaches to concrete businesses.

The cabinet maker

Workshop facilitator:

How do you see yourself as an entrepreneur in the future?

Entrepreneur:

I don't see a big difference. It's the customers who decide what I should make.

He explains that he has three different products or offerings in his business, number one (and his favourite) was to create new tables, number two was to renovate classic furniture, and number three was doing all kinds of odd jobs, like painting a garage. He also explains that he is only doing odd jobs and that this won't change, since "the customers are the ones who decide."

He elaborates:

If a customer comes and asks me if I can make this ceiling and I am in the middle of doing something else I prefer from this, I will still say yes. I have to get food on the table. I cannot say no to work…

That leads to a long discussion about running a business, what one wants to change, how to read one's customers and one's personal impact on the business.

Finally, the participant realises that his perception of his business is rigid and leaves him no room or influence. At this entrepreneurship course, the participants were introduced to Business Model Canvas and its nine building blocks (Osterwalder & Pigneur, 2010). We use the image to turn' on the various elements and building blocks in the business plan. It is as if he suddenly discovered some possibilities he simply had not imagined. He was fixated on a certain way of seeing himself and his business – a locked situation, where he did not make the decisions, but rather the customers decided what he should do.

Subsequently the cabinet-maker starts building his vision and 3D-model of his future business.

General findings

In our workshops (experiences from more than 100 creative entrepreneurs at Iværk, Spinderihallerne, interviews with around 20 entrepreneurs) we had several interesting findings. Some of them – relevant for this paper – are centred on the value of these creative workshops and the central role of making with materials, as listed below.

1) The majority of the participants argued they had a strong experience and considered this creative way of working with materials, tangible models and visuals to be a way of obtaining deeper knowledge about themselves, also revealing deeper dominant values.

2) Some participants identified hidden talents or passions that later contributed to a more unique business. Others revealed various, often unconscious, mental barriers to business (money, sales, accounting, taxes, customers etc.) like the above-mentioned examples of the artist and the cabinet maker. A few entrepreneurs realised they did not want to become entrepreneurs after all.

3) Generally people had a strong experience of how this creative way of working with materials, tangible models and visuals opened up for their deeper values and empowered them to take action, show leadership and create new opportunities. The course accentuates "embarking on an inner journey" (Hildebrandt, in Matzen, 2013) to find talents, passions and dominant values that result in strengths and barriers in a business context. As Louise, one of the participants, stated*:*

…It was extremely liberating, it was enormously liberating...For a long time I have tried to figure out what kind of competencies I have, what kind of services I am capable of delivering…but this creative process kicks into gear. This making and doing process, creating these collages, really kicks into high gear… This way of working is an absolute 'possibility generator', there seems to be no limits as opposed to for example Business Model Canvas, which is much more rigid – there is not so much of myself in that model.

The statement "there is not so much of myself in that model" – indicates that 'the traditional entrepreneurship courses do not explicitly include an inner focus (Goleman & Senge, 2014) which has also been noted by Hildebrandt (in Matzen, 2013).

Theoretical perspectives

As the theme for this conference is focusing on designerly methods and materials as well as experiential knowledge, the following will be centred around this perspective.

Materials stimulate the creative processes

In these examples of design processes, design is represented as a distinct mode of knowing and reflecting (Cross, 2004, 2006; Lawson & Dorst, 2009). Lawson and Dorst consider design processes to represent a higher order skill (Lawson & Dorst, 2009) and another way of reflecting ('reflection-in-action', Schön, 1987) - a reflection that includes thinking with the hands, also described as follows:

"*The process of design is a complex, multifaceted activity that requires sophisticated professional thinking and competence, described as reflection in action an embodied process where hand, eye, and mind collaborate"* (Seitamaa-Hakkarainen et al., 2014).

This distinct mode of knowing and reflecting is reached through the use of generative tools. In the field of design, generative tools are used as thinking tools or 'making tools' and they have a strong appeal to our visual ways of sensing and expressing ourselves. Generative design processes appeal to our tacit and unconscious knowledge, our feelings and dreams (Visser et al., 2005, Brown, 2014), as illustrated in figure 3 (Visser et al., 2005). Pioneers within the field of generative tools, E. B. Sanders´s definition of generative tools is as a language for co-creation aimed at the collective creativity and co-designing (Sanders, 2000, 2008). In contrast to Sanders, this research demonstrated the potential in seeing generative tools as "a language for self-dialogue aimed at the creativity of the individual" (Sørensen, 2011).

Generative tools are used as 'a making language' and represent what Sanders calls 'a say-do-make approach' (Sanders, E.B.-N., 2002). Sanders accounts for how different methods appeal to different types of knowledge claiming that generative sessions can reveal 'latent needs' and provide 'tacit knowledge' (fig. 3) – *knowledge that can't readily be expressed in words* (Polanyi, 1983).

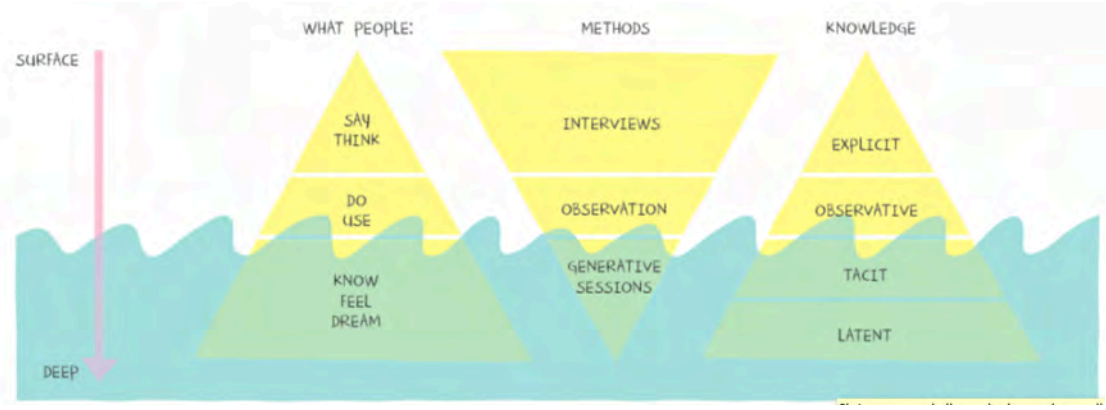

Fig. 3: Different levels of knowledge can be accessed through different methods (Visser et al. 2005).

Two central activities included in the workshops using generative tools are ‘doing’ and ‘making’ representations, which are essential activities in design practise. Representations of problems, solutions or situations are important because they allow designers to develop their ideas in conversation with these representations - in *a reflective conversation with materials* (Bamberger & Schön, 1983). Designers externalise their thoughts in all types of drawings, doodles, models, sketches etc.; they ‘talk’ to their sketches and have conversations with representations, activities, which in our workshops are performed by the entrepreneur. These sketches act not only as outputs, but as important inputs to the thought process and stimulate the act of framing and reframing a design problem or situation (Bamberger & Schön,1983). As exemplified in our cases, *the participants are becoming designers*, by making models for meaning, while guided by a facilitator.

Designing as ‘framing’ and ‘reframing’

Design practice is also seen as the art of seeing the design situations in multiple ways or ‘seeing as’ (Schön & Wiggins, 1992; Lawson & Dorst, 2009). As Lawson and Dorst argue, “Designers are used to performing this little dance around a problem, taking stabs at it from different sides” (Lawson & Dorst, 2009, 26). This is represented in the pivotal design activities ‘framing’ and ‘reframing’ what the ‘real’ problem is.

Using generative tools to frame and reframe in our workshops includes working with numerous pictures and various materials such as wood, fabric, cardboard, pipe cleaners, beads, gizmos i.e. ‘stuff’. Making and doing collages and 3D objects include reflective conversations. The ambiguity in the visuals and various materials is pivotal as it encourages the central element of problem ‘framing’ and ‘reframing’. Yet, in these workshops we did not explicitly urge participants *consciously* to reflect on the very characteristic of materials. Thus we cannot say if or how they reflected in detail as proposed in Karana´s Meaning Driven Materials Selection (MDMS) (Karana, 2009).

In Paton & Dorst´s understanding of framing, ‘reframing’ refers to “building a new frame for oneself, based on changing one’s view…” (2010:318). In other words, reframing is changing your perception, which can include deeper self-reflection about unreflective, or maybe underlying and subconscious mental mappings and/or dominant values, and seeing the situation anew (Senge, 1990, Schön, 1993, Schön & Wiggins, 1993).

An example from the workshops with entrepreneurs: When participants become aware of their current dominant values they more or less come to ‘see’ their dominant values in what they model. At that moment they need to choose; They can continue living as they used to, now being (more) aware of their dominant values, or they can interpret their values, perhaps even identity new values, to work on getting them ‘implemented’ in their thinking and behaviour. Thus by ‘seeing’ their dominant values, they are urged to *reframe* their perception of themselves *by doing design* – like the artist who used to see herself as a passive artist, who did not need to sell her art (as it should sell itself) who changed into a proactive entrepreneur, showing leadership and developing new types of proactive selling activities as part of her business strategy.

The cognitive workings of the value workshops

As elaborated in the doctoral study (Sørensen, 2011) these value changing processes echoe in Neck & Manz’ idea about Thought Self-Leadership (1992, 1999). Self-Leadership was originally applied to organisations, developed with the purpose of improving employees’ performance. Self-leadership seeks to appeal to an individual´s inner motivation, as Neck & Houghton explain: “Self-leadership is a self-influence process through which people achieve the self-direction and self-motivation necessary to perform” (Neck & Houghton, 2006, 271).

In the perspective of the theory about Thought Self-Leadership (1992, 1999) this visual making-language seems to stimulate the development of new cognitive strategies and thus make entrepreneurs capable of changing their habitual ways of thinking and acting (Sørensen, 2011, Fredens & Prehn, 2009 Schön, 1993).

Limitations and future perspectives

Since our research is based on experiences from many entrepreneurs, but only a few in depth cases, we acknowledge that our findings are preliminary and limited, but also promising for future research. We will exemplify and elaborate on this in the following.

Presenting his model, the cabinet-maker had made an object and a model consisting of a wooden centre with five different wooden handles. He seemed enthusiastic in his description of his model and future business strategy. In an interview two years later he explains that he did change his business after the course, now having many new types of customers. Yet, he cannot remember the model, the collages or what he said back then. On one hand he argues the workshops made him reflect, but only price and that Google Ads are the reason for his current success. On the other hand he explains that he ‘turned down completely’ the odd handyman jobs and ‘turned up’ the creation and design of his own tables, and restoring of classical furniture; “I have been capable of changing my business from offering odd handyman jobs into offering a product and a service, which I am very enthusiastic about”. So even though he does not acknowledge the influence of the creative workshop sessions, the changes in his firm indicate a clear connection between them and what happened afterwards.

In comparison the architect attributed both importance and value to the creative processes in her process of creating her business: “*…this creative process kicks into gear…I am familiar with business modelling, but I think this process includes ‘me’ in a whole different way.”*

Acknowleding emotions, aesthetics and experiential knowledge

Aesthetic knowledge includes relying on our emotions. Aesthetic knowledge is often tacit and experiential, instead of explicit and exact (Barett, 2007). Thus it is challenging our rational way of thinking, - as it has been indicated in all our workshops, including the examples given in this paper. In the following we will elaborate on different aspects of the significance of this in our outline of ‘designerly and human-centered entrepreneurship’:

First of all Goleman & Senge (2014) argue In their book *The Triple Focus* that we tend to have a single focus on goals, ignoring our emotions, human relations and human concerns.

Goleman (2013) argues that it is embedded in the norms of the workplaces in the West, where we see:

> *…work as a moral obligation that demands suppressing attention to our relationships and what we feel. In this all-too-common view, paying attention to these human dimensions undermines business effectiveness…the failure is not in reaching the goal, but in connecting with people. The just-get-it-done mode runs roughshod over human concerns* (Goleman, 2013).

This perspective is reflected in the Functionalistic paradigm of design management (Johansson & Woodila, 2011) with its more traditional focus on business and goals. Within this field design is often presented as a new way of (only) *thinking*. Although most designers and design managers know that design thinking *includes doing*, we propose to accentuate and present design thinking *as* design doing. By doing so, we would be able to increase the focus on doing and making and on experiential 'knowledge' and 'knowing' (Johnsson in Niedderer, 2007, Fajardo, Rehm, Joffres, 2012, as well as the aesthetic processes that involve the emotional side of human experience.

> *An aesthetic learning process is a creative process where impressions are processed creating an aesthetic expression and hence the development of a new understanding* (Sørensen, M, in Asterisk, 2015:7).

As such, aesthetic experience is considered to be a potent catalyst for a deeper inquiry, accessing deeper levels of knowledge (as in fig. 3). Looking into the domain of 'transformative learning', aesthetic experience is considered to be key (Greene, 1995). Transformative learning processes lead to changes in identity (Illeris, 2013, Mezirow 1991) - like in the example of customers and entrepreneurs who changed their identity e.g. from being 'a big spender with no control' to being 'in charge' and 'in control' of spendings, or from being 'a passive artist" into being 'a proactive artist', organising new sales campaigns. Moreover recent research with similar making and modelling workshop methods (Buur & Mitchell, 2011; Buur et al, 2013; Evers & Sørensen, 2014) indicate a promising future direction of research acknowledging emotions, aesthetics and experiential knowledge.

Conclusion

In 2000 Drucker predicted a new paradigm of management. Today, 15 years later design is having an increasing importance in our world. In Design Council´s Design Economy Primer (2015) they argue: "Design is revolutionising health, business, cities and government". Despite this role, there is a need for a paradigmatic expansion within Design Management in order to embrace the ambiguous aspects of praxis-based design knowledge (Johansson & Woodilla (2011).

In this paper we build on Drucker, Goleman & Senge's term 'inner focus' and similar motivational-related research (Covey, 2005; Robinson, 2009, Sheldon, 2012) but also research from the field of entrepreneurship, specifically Goss et al (2011) who argue that entrepreneurship has the possibility to unleash a valuable and creative potential which lies within every human being. In line with us, they focus on both emotional issues and 'a practice based' understanding of entrepreneurship (and power). Still we presume there is a need for more designerly ways of thinking, doing and knowing in the domain of entrepreneurship, with 'The Triple Focus' as a relevant framework.

In our workshops we have identified the power of designerly thinking and doing, and the importantance of making and doing with materials. The underlying premise in these workshops is our preliminary findings that experiential and aesthetic ‘knowledge’ and ‘knowing’ are powerful not only for human beings – but also for growing businesses. Hence we argue that our workshops demonstrate the power of stimulating value clarification in entrepreneurship, as it can lead to changes in values and behaviour in a way that grows more successful businesses as well as more successful personal lives; in other words it is ‘designerly and human-centred entrepreneurship’.

In the field of design there has been a shift from ‘technology-centred design’ to ‘human-centred design’, where focus is more on the people we are designing for rather than the product or service in itself. As argued by Brown, this includes “…a thorough understanding of what people want and need in their lives…” (2008:86).

Central to this perspective is the focus on designing for (and with) fellow human beings, whereas the central idea in our proposal is to *empower* the entrepreneurs to take charge of their development, by becoming designers that are making models of their future (business) selves, using materials. By doing so, the deeper values and beliefs of the individual surfaces (Drucker, 2000, Goleman & Senge 2014, Hildebrandt 2013) including why they are entrepreneurs. This is a key realisation to achieve as motivation to act on the entrepreneurs self-made projections (models) of the future.

As such what we outline as ‘designerly and human-centred entrepreneurship’ is more an inside-out approach than ‘human-centred design’. In our designerly & human-centred entrepreneurship outline the individual entrepreneur takes a point of departure in an ‘inner focus’, contrary to human-centred design that focus on involving stakeholders throughout the design process (Krippendorff (2006). Moreover we focus on designerly ways of knowing and doing.

In the fields of design and design management we therefore propose to:

- acknowledge the importance of experiential and aesthetic ‘knowing’ and ‘knowledge’ (Johnson in Niedderer, 2007)
- emphasize Johansson & Woodilla´s (2013) distinction between ‘design thinking’ and ‘designerly thinking’ in our and other design researchers work,

Moreover we encourage more examples of the strong role designerly ways of knowing (Cross, 1983), design processes and 'reflective-conversation-with-materials' can play in business modelling and entrepreneurship in future research. Finally, we highlight the importance of value clarification and inner focus in entrepreneurship praxis, as part one of what we term ‘designerly and human-centred entrepreneurship’.

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Kirsten holds a design degree from Kolding School of Design, a MA in rhetoric from Aarhus University and a PhD in strategic design from Kolding School of Design. Currently assistant professor, researcher, workshop facilitator, and working on leadership development.

Driven by a deep concern about our mental barriers to change, both in organizations and individuals, Kirsten researches on creative processes aimed at 'self-dialogue' and 'value clarification' for the purpose of seeing and changing our mental and narrow perspectives. This theme was central in her PhD (2008-2011), in which she developed a new type of financial service that stimulated people to take leadership and change their behavior - in accordance with their 'inner values'. Since 2011 she has used these processes in different domains - in particular in the field of entrepreneurship, working with more than 100 entrepreneurs (2011-14).

Winie Evers

Since 2012, Winie Evers is a PhD student, teacher, supervisor, and design related business-to-business researcher at University of Southern Denmark, at the department of Entrepreneurship & Relationship Management.

In 2010 Winie graduated as international MSc in Economics & Business Administration: Business Relationship Management at SDU, with an Action Research Thesis focusing on the value of involving industrial Project Managers in process improvements, framed within an organizational learning perspective. This was followed by a position as Research Project Manager at the Technical Design Research Centre SPIRE, Mads Clausen Institute, University of Southern Denmark. In this highly interdisciplinary environment crossing co-design, innovation, anthropology and engineering she decided to get into research. Currently Winie is therefore writing up her action research PhD monograph about design tools and designerly thinking in strategy workshops, having facilitated, interviewed and followed a co-creation process of business modeling ideas, scenarios and new meanings with a firm and its business-to-business partners. Winie positions her action research within the interpretive / radical humanist paradigm, with a strong interest in studying and facilitating processes of meaningful change, including co-creation in business relationships as well as designerly thinking and doing.

Toy Trucks in Video Analysis

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Abstract

Video fieldstudies of people who could be potential users is widespread in design projects. How to analyse such video is, however, often challenging, as it is time consuming and requires a trained eye to unlock experiential knowledge in people's practices. In our work with industrialists, we have discovered that using scale-models like toy trucks has a strongly encouraging effect on developers/designers to collaboratively make sense of field videos. In our analysis of such scale-model sessions, we found some quite fundamental patterns of how participants utilise objects; the participants build shared narratives by moving the objects around, they name them to handle the complexity, they experience what happens in the video through their hands, and they use the video together with objects to create alternative narratives, and thus alternative solutions to the problems they observe. In this paper we claim that when analysing for instance truck drivers' practices, the use of toy trucks to replicate actions in scale helps participants engage experiential knowledge as they use their body to make sense of the on-going action.

Keywords

Tangible Tools; Driver Experience; Sense Making; Design Collaboration

In design, the use of video recorded 'user studies' is now widely accepted as a precondition for creating user-centric solutions. Video is engaged primarily because designers have little time to spend in the field, and because the human practices one can observe are complex and difficult to understand. But even with short time in the field, such video studies tend to produce hours and hours of recordings that are of little value, unless analysed. In this paper we argue that analysis can be organised as a playful collaborative activity among designers and engineers, using scale-models to replicate the practices observed on video. This turns

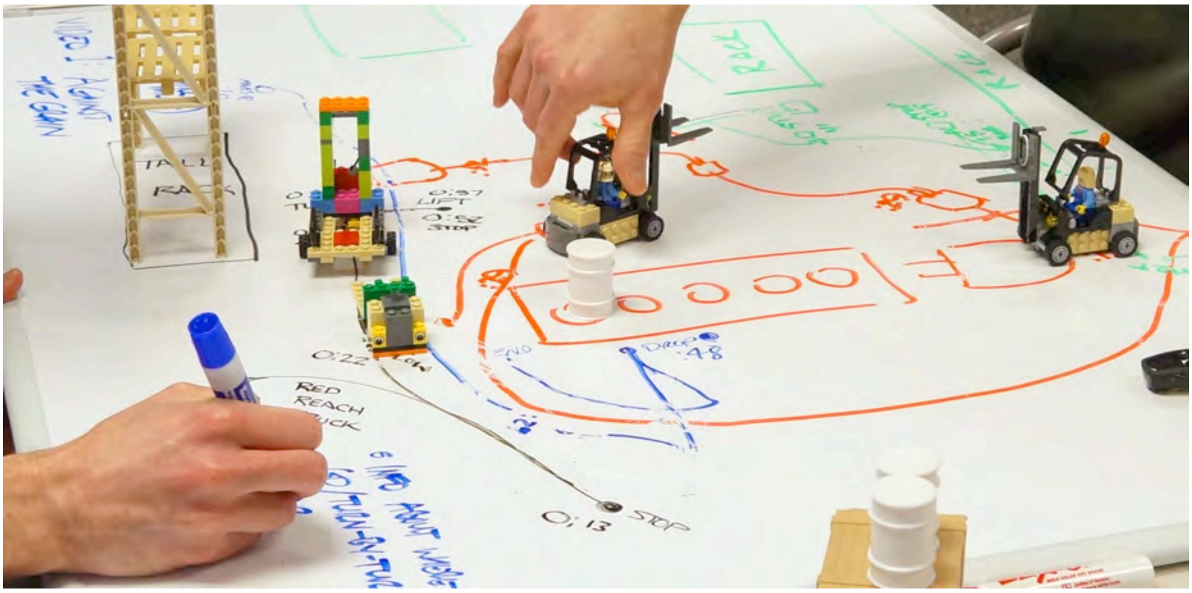


Figure 1. Designers analyse video recordings of forklift truck driving by re-enacting the actions with toy truck models in scale.

video analysis from an abstract, thinking activity into bodily action, in which the scale models – toy trucks in this case – help elicit and build experiential knowledge.

For video work in design, Interaction Analysis draws increasing attention as a powerful research method for understanding activities and social processes. Originating from Ethnomethodology and Conversation Analysis, this method aims to make sense of data 'from within' – that is, it looks at naturally occurring everyday and workplace interactions and focuses on how people themselves make understandings visible, thus avoiding interpretation of the data based on preconceived theories (Sacks et al. 1974, Heritage & Clayman 2010). Interaction analysts rely heavily on video data for their analysis, making the data "workable" through use of transcripts that allow them to track speech, body movements, gestures or other relevant features of the interaction (Goodwin, 2000). However, one of the challenges that often arise when integrating such detailed analysis into the design process is related to how to share these transcripts, descriptions and findings among members of the design team, some of whose might be looking for "implications" (Dourish 2006), or might be less experienced with analysis and uncomfortable with the complexity of transcripts. Instead of a traditional model of 'analysts communicating findings to designers', it has been argued that video can be regarded as a 'design material' with which designers collaboratively 'build meaning', rather than as 'hard data' that support design decisions through appropriate analysis (Buur et al. 2000).

Foci for interaction analysis

Our work is particularly influenced by Jordan and Henderson (1995), who proposed to make interaction analysis collaborative through the concept of *Interaction Analysis Labs*, in which researchers (with cross-disciplinary backgrounds) look at the video recordings together. This practice, widely used also in Conversation Analysis in the form of data-sessions (Have 2007), encourages multiple points of view to meet, and possibly allows for a broader and less distorted look at what is happening in the data. The Interaction Analysis Lab concept has gained wide acknowledgement in design circles, likely because of the mixed backgrounds of the authors in anthropology and computer science and their affiliation with the Xerox PARC environment. As a guideline to initially approaching video material, Jordan and Henderson provide a list of possible *foci for analysis* – such as how people participate and take turns, how people occupy space, etc. These foci act as 'entry points' to the data by guiding a first look, in order to identify elements to be further investigated with deeper and more detailed analysis. Inspired by this idea of 'entry points', we experiment here with using objects, acting as tangible tools to make video analysis engaging and support specific foci. In this case, we work with a focus on the *spatial organisation of activities*, where attention is drawn to '*the physical copresence of persons is always managed by socially recognized (although often*

Figure 2. Video footage of 'social' forklift truck operation in a truck driving school.

unstated) expectations regarding occupancy of space, interaction with others, use of objects and resources, display of physical presence, and voice' (Jordan & Henderson 1995, p. 72). One aspect of spatial organisation that seems particularly important for our case of analysing truck driver practices, is the *ownership of territory* that '*affects the mobility of participants – whether they can move around at will or have to ask for permission*' (p. 74).

Skilled forklift truck driving

The method presented here is the result of a series of design experiments over two years with various materials, deployed with different groups of industrialists, researchers, and graduate students, who make sense of a variety of video recordings. In this paper, we build on a case of studying skilled forklift driving in collaboration with Crown Equipment Corp.

Crown Equipment Corp is a manufacturer of material handling equipment used in warehouses, manufacturing facilities, and outdoors. The most common type of material handling equipment is the counterbalance forklift truck. Operating a forklift truck requires a high degree of precision and skill to be productive and efficient, while remaining safe. Past research suggests that operators value visibility, control precision, comfort and performance.

The corporation has a powerful design department that has contributed significantly to truck innovations. Within the past two years, the design research group has conducted an extensive ethnographic study of sit-down counterbalance forklift truck practices around the world, in order to identify potentially unmet needs and opportunities for innovation by understanding better how drivers perform their everyday activities. However, one challenge the design research group encountered was how to make sense of the ethnographic data for or with other departments.

In this context we set ourselves the challenge to develop a tool that can support sense-making of how the work of truck drivers is spatially organised, and do so in a collaborative manner for designers untrained in video analysis. We also conducted an ethnographic study by ourselves of skilled truck drivers performing their everyday tasks, and of unskilled drivers while learning in a truck driving school in Denmark (Figure 2).

Understanding truck driving with scale models

We address the sense-making challenge with simple, tangible tools that support hands-on collaboration. This relies on a tradition of research, which sees objects as central to participation, reflection and exploration of alternative views (Brandt, Messeter & Binder 2008, Schön 1992, Cross 1982).

One aspect that we found particularly intriguing in the field recordings is the 'social truck skills' – professional truck operators seem to sense each other's positions and movement patterns at an incredible pace without explicit rules about right of way. How do operators learn to navigate their trucks in shared workspaces; how do they drive in and out between one another without accidents? Is it possible to track this development, and use it as a source for truck innovation?

Scale-Model Sense-Making in all its simplicity relies on participants re-enacting the activity observed in the video with objects – in this case with toy trucks. The participants build a scale model of the workspace in front of the video screen and drive the truck models around in sync with the video running (Figure 3).

Prior to the sense-making (Weick, Sutcliffe & Obstfeld 2005) session, facilitators choose two or more sequences of videos to analyse, preferably containing similar activities. Video sequences of 1 to 5 minutes' length can be analysed effortlessly with the tool, depending on the level of granularity that participants want to achieve. In our case, the bulk of video footage was first analysed using the Video Card Game method (Buur & Soendergaard 2000), which helped us define the theme of 'social trucks' and enabled us to assemble a collection of suitable video clips.

For every video sequence, the sense-making session runs in four phases of 10 to 15 minutes each (or more if needed).

1. Recreating the scene. In the first phase, the participants focus exclusively on the physical environment that sets the limitations of the workspace, as seen in the video. Using various materials, they establish the workspace layout in scale on the board.

2. Tracing movements. Next each of them chooses a driver in the video and draws lines on the board to indicate truck routes. The video may be slowed down, stopped or reviewed whenever participants feel the need.

3. Re-enacting actions. In the third phase, participants place toy trucks corresponding to each truck in the video on the board, and try to run them through the stipulated routes (Figure 3). In the process, the participants will typically notice things that otherwise would have stayed unnoticed.

4. Reflecting observations. In the fourth phase, participants reflect on the experience and relate their observations for general discussion. After several videos this will naturally include comparisons between the different practices observed. These steps tend to lead to discussions of innovation: which redesigns may alter the situation to a 'better' one?

Through the four phases the participants constantly use the video data as a point of reference; they orientate their bodies to gain shared access to the monitor, they pause the video and watch specific moments over and over, and their talk is often linked or even synchronized to the video. We were surprised to find some quite fundamental patterns of how participants utilise objects in their efforts to make sense of experiences, when we analysed five such sessions documented on video. The sessions include two with industrialists, two with researchers, and one mixed group, of which we here mainly rely on the first two. We use two variants of interaction analysis for our research: conversation analysis to make sense of *how* participants take turns with the objects and a content-oriented analysis of *what* participants do and say.

Using toy trucks to build narratives

One pattern that stands out is that participants build shared narratives with the trucks about what might have happened in the video under scrutiny. Figure 3 shows a team of four participants re-enacting a 1 min. video clip from a collection of 'traffic jams', i.e. situations in the warehouse, in which several trucks suddenly come to a stop and cannot move past each other. Warehouses are busy workplaces where efficiency in handling goods has high priorities; traffic jams are expensive and can be dangerous. The participants are two industrial designers, an engineer and an interaction designer from the forklift truck company. We have asked the group to investigate 'Why did the Traffic Jam occur? And how does it resolve?' The participants took 40 min to analyse two video clips.

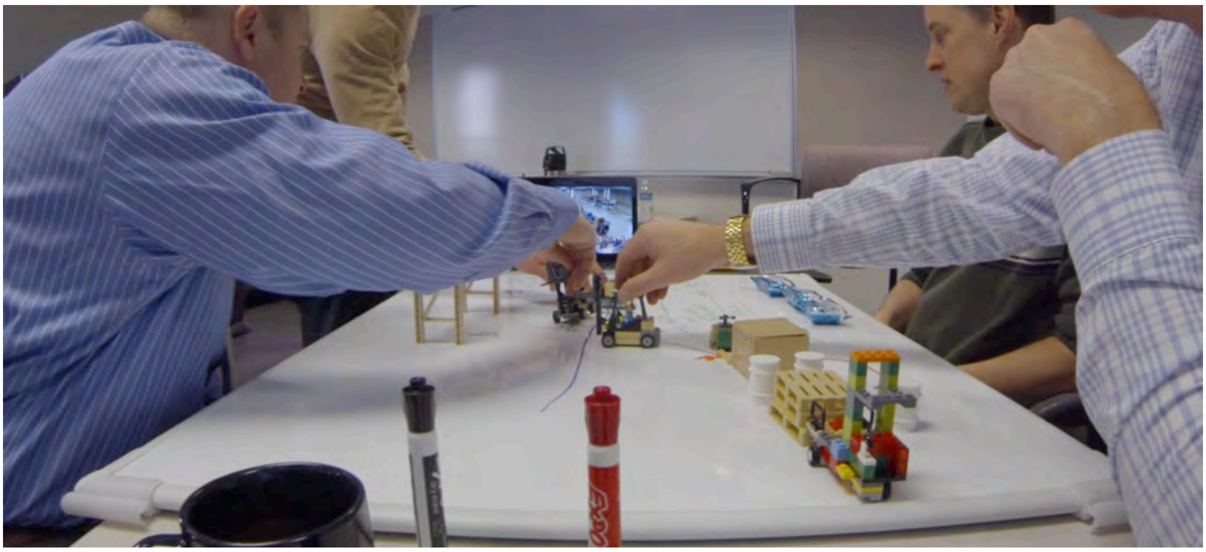
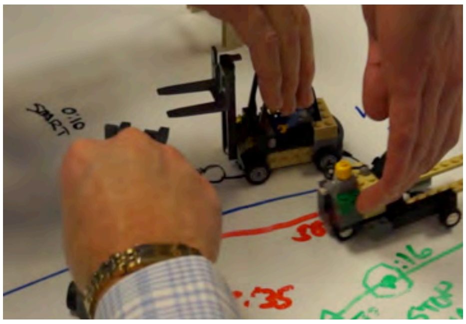


Figure 3. A video sense-making session in action. Four participants A, B, C and D (from left to right) each operate a toy truck to re-enact patterns of forklift truck drivers on the screen.

The Fork-to-Fork Pirouette

Transcript 1 is taken 14 min into the analysis of the first video sequence. The participants have each made notes on the whiteboard about how 'their' truck moves, and now they try run the trucks through the motions in sync with the video.



The Fork-to-Fork Pirouette (14:06)

B "This guy is still stuck right there."
C: "And then this one comes as there is a stopping point."
B: "So they are all sort of… And you guys are lifting over there."
(A and D move their trucks)
C: "And this one is doing his turn. Turn…"
C: "So they are trying to do this Fork to Fork Pirouette.
(makes a counter-clockwise gesture)
This one goes around."
C: "So they kinda get into a swirl here."

Transcript 1. Participants re-enacting a traffic jam in a warehouse.

The participants are clearly very focused on the sequence of how the trucks move *("And then…" "So…" "And this one…")*. They start noticing what the other trucks/colleagues are doing – *"And you guys are lifting over there"*. And one of the analysts tries to find expressions to explain what is going on between the trucks: "…Fork to Fork Pirouette", "a swirl". We will claim that the participants construct a shared narrative with the toy trucks, and engage experiential knowledge in the process:

'Experiential knowledge is often expressed in the form of narratives. People almost always make sense of the experience by constructing narratives about it.' (Baumeister and Newman 1995 in Storkerson 2009).

While this statement relates to people's *own* experiences, in our case the participants create narratives to make sense of *others'* experiences. However, as we shall see later, this also helps them link the assumed experiences of truck drivers on screen to their own recollections of situations experienced.

With the elegant expression *Fork to Fork Pirouette* – with the other participants also adopt afterwards – we observe that the participants strive to boil down the essence of a narrative to a few descriptive words. They name the shared narrative. This encapsulation of a high-complexity observation into a simple representation serves as an agreement of the shared narrative (Heape 2005:49). Naming the narrative or even categorizing the activity at hand through a narrative process, aligns well with Schön's definition of problem setting, and thus is an important precondition for design:

"Problem setting is a process in which, interactively, we name the things to which we will attend and frame the context in which we will attend to them." (Schön 1983:40)

A 'pirouette' has very little relevance in the truck practice that the participants observe, but the term corresponds to an experience of one of the participants. They make a link between what they see on video, of what the trucks do, and their own experiences. 'Lanes' is another term that comes up in the conversation, even if it belongs to a private traffic experience, as warehouses do not have lanes to control traffic. The participants pull in their own experiential knowledge to 're-experience' what they see in the video data.

The 4-Way Traffic Crossing

Transcript 2 includes a series of screenshots of when the team tries to re-enact their second video clip. The re-enactment happens after about 15 min of discussing which trucks are most important, deciding who takes which truck, and tracing which route they each drive. While tracing, the participants concentrate primarily on their own trucks – we hear only few comments on others' trucks in this part. It seems that they each manage to construct a partial understanding of the video.

Then B says: *“OK. Are we ready to act it out?”* and starts the video. The participants start moving ‘their’ trucks along the traces on the board in sync with the video.

After a short while of driving – with some of the participants humming along making truck noises – things come to a halt. C starts talking through what his left-hand truck is doing. Realising that they are short of one truck, he adds a sweet as stand-in for another truck he can control with his right hand. His one truck is *“waiting”* while the other one *“backs up to here because he can’t go anywhere”*. Then, when D is pushing through his truck *“This guy is coming here”*, suddenly all trucks are able to move again: A, B and C, who all report that their trucks are moving.

In the ensuing reflection, the participants form explanations of how one truck operator apparently *“created a conflict”* because *“he was trying to take the shortest route”.* They form their shared narrative of the complex patterns they observe around the term *‘flow’*.

*C: "But probably **the flow** should be **this way** (gestures counter-clockwise) so he should come out and come right down around here, then it would have been no issue. (35:45) "*

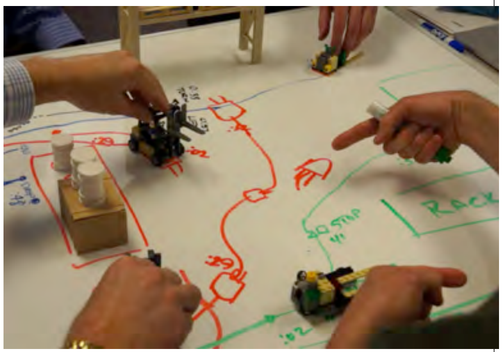
Up to the re-enactment the explanation given by the participants is fragmented. All they can do, when limited to verbal communication, is to report what the trucks do one by one, even though many of the movements happen simultaneously and affect one another. However, during the re-enactment, the participants manage to explain the complex movements simultaneously by moving the toy trucks. Apparently moving the trucks together provides an overview that allow them to weave together the fragmented explanations and make sense of what is going on in the video.

The next re-enactment seems to mainly confirm that the word *flow* reasonably explains what is going one in the video.

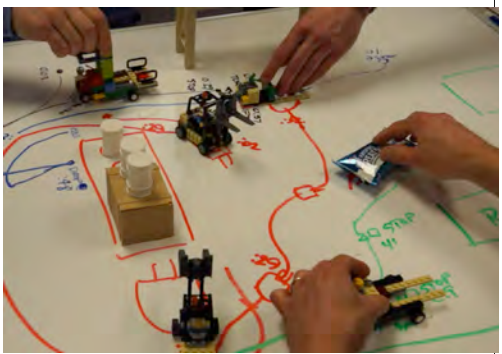
Towards the end of the session, the participants are called upon to present their outcomes to the other teams, and this they do mainly by words and by coarsely demonstrating the movements of single trucks. In the presentation, one participant from the Traffic Jam team finds a simple way of describing the pattern they have identified:

C: “…he was part of that initial traffic jam where you’ve got (…) four trucks staring at each other. And once this guy pulled in, and this guy pulled in, these two were able to go where they needed to go.”

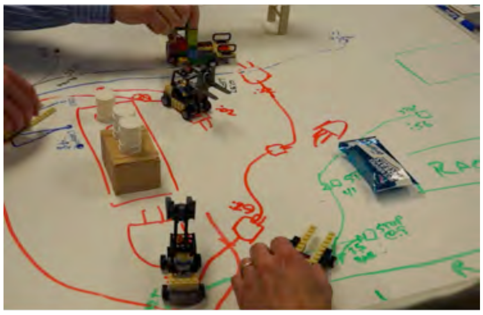
Waiting (34:36)



C: “OK. So you got the trucks here … (points with both hands left and right)”



C (placing a sweet as stand-in for a truck): “Here’s our Rice Krispies truck. So he is waiting, he can’t go anywhere.”



C (moving his toy truck): “This guy then backs up to here because he can’t go anywhere.”

D (pushing his toy truck through): “This guy is coming here”

C: “This goes around” (points to D’s truck) “And then he starts to move through, because this guy stopped.”

A: “This guy is here.”

B: “And this guy over here”.

Transcript 2. Participants re-enact a second truck traffic jam.

From his hand gestures we can understand that this explanation is inspired by the 4-way traffic crossing rule in some US states: whoever arrives first at the crossing has the right of way. And if you all arrive simultaneously, you are 'staring at each other' to negotiate who goes first. The coupling of the sense they make of the video with concepts from their own memory seems important:

'Experiential knowledge is highly dependent on memory and recognition, thus on semantic and sensory patterns and features' (Rubin, 1995 *in* Storkerson 2009).

By following the truck movements and what the participants say, we observe how the participants collaboratively build narratives to make sense of what is going on in the video. We see how they struggle to name the narratives with clear terms that resonate with their prior experiences. One question, then, is to investigate if the participant's experiences when constructing the truck driver narratives in any way relate to what the truck drivers themselves experience in real life, when driving in a warehouse?

Experiencing the truck driver experience through hands

The participants in the sense-making sessions employ a variety of situated resources: they talk, gesture, trace lines and manipulate the objects all while orienting and paying close attention to the video data. The other industry team with two participants, E and F (and a research colleague G) were challenged with two video sequences themed 'Near Misses', i.e. situations in the warehouse, in which trucks seem to just about run into one another. Forklift trucks are heavy, powerful vehicles, so near misses are potentially dangerous. Like with the other team, we have asked the participants to investigate '*Why did the Near Miss occur? And how was it resolved?'*

To understand if the participants actually 'experience' anything relevant to the sense-making, we go into deeper detail with the interaction analysis. The incident shown in Figure 4 takes place in the beginning of the sense-making process. The participants have watched the video once and roughly recreated the scene. Rather than start tracing truck routes, they spontaneously try to run the two toy trucks through the motions they see in the video data, one each across the table. As the trucks need to pass around each other in close space, so do the hands of the participants, and they inevitably touch. Transcript 3 starts with this potential trouble of hands becoming entangled. In line 33, E reacts to the trouble with the interjection '**wo:::ps**'. It marks the situation as problematic and initiates a sequence of ensuing sense-making actions:

First, F resets the here-and-now trouble source by letting go of the toy truck in line 35. Next, and coordinated with letting go of the truck, F turns his head and E shifts gaze to look at the

Figure 4. Two participants, E (left) and F (right), when re-enacting a 'Near Miss' video, get into a tight trying to move their toy trucks past one another. The detail on the right shows the temporal conjunction between the here-and-now and the video data on the screen (top left).

monitor to watch the situation unfold in the data. By not turning his upper torso, but just his head, F demonstrates a "…*capacity to display engagements with multiple courses of action and interactional involvements, and differential ranking of those courses of actions and involvements*…" (Schegloff 1998:536). The turn of his head marks a temporary shift of attention directed at the monitor, while he maintains a bodily orientation towards the joint focus of attention: the manipulation of the toy trucks.

The Woops Moment

```
33  E:   →  wo:::ps
34          (1.4)
35          ((F lets go of second truck -> gazes at monitor
36                                      E gazes at monitor))
37  E:   →  wait a minute (.) we'll make some room for you↗
38          ((F shifts gaze from monitor -> trucks -> monitor))
39          (1.7) ((F shifts gaze from monitor -> trucks))
40  F:      ÷hhhnnhh÷
41  E:      can I give you a try
42          ((F shifts gaze from trucks -> monitor))
43          ((E gazes down at trucks and commences moving them))
44          (3.5)
45          ((E moves fist truck ->
46              F reaches for second truck ->
47              E moves second truck
48              F shifts gaze from monitor -> trucks -> nodding))
```

Transcript 3. The two participants, who get their hands entangled, when guiding their trucks through a Near Miss incident, repair the potential trouble.

Next, in line 37, E makes a direct verbal link between the here-and-now kinaesthetically experienced trouble and the actual situation they are analysing: He repeats in direct speech the actual words uttered by the truck driver in the first truck: "*wait a minute (.) we'll make some room for you*". In the data, this marks the end of the potential trouble as the trucks make room for each other. F's shifting eye gaze from the monitor back to the toy trucks on the table combined with his laughter in line 40, as well as E's second iteration commenced in line 41, indicates that for E and F the situation is no longer perceived as troublesome enough to stop the re-enactment. The entire sequence prompted by their physical experience of the entanglement is rounded off by F nodding in line 48 in agreement to E's second iteration and continuation of the re-enactment in lines 41-47.

The sequence demonstrates how participant's interaction and sense-making is accomplished by (1) manipulating the toy trucks, (2) by orienting their bodies to have shared access to the monitor and toy trucks and (3) by linking their gestures and talk to the data they are analysing. This elaborates Goodwin's point of the multimodal triad, where talk, gesture and objects "… *mutually elaborate each other to create a whole that is not only greater than, but different from, any of its component parts*" (2010:115). The rapid shifts in gaze from the video to the physical setting in front of them (lines 35-36, 38-39, 42 and 48) demonstrates how the video data serves as a constant point of reference throughout the re-enactment.

There is a fine synchronisation, temporally as well as physically, between E and F's here-and-now entanglement, and the experience of the potential near miss in the situation they are trying to re-enact, Figure 4 detail. Manipulating the toy trucks and getting into trouble here-and-now sensitises the participants to the situation in the warehouse: they so to speak experience the interactional trouble physically as a kinaesthetic experience. As they physically experience it on their own hands, they pause the re-enactment and link the experience of the truck driver to their own, before continuing the re-enactment.

What has this sense-making process to do with design, then? Other than a playful, but academic exercise, does what the participants find out have any relevance to design?

Using toy trucks to create alternatives

The participants in the two industry sessions are designers and engineers employed to contribute with design ideas to new, better forklift truck constructions. Considering this, naturally in the sense-making sessions they will focus on the usefulness of what they learn about truck driving towards that end. As the concept of *'what-if?'* questions is considered core to the design activity, we will analyse the video documentation for when the participants speculate in alternative scenarios: e.g. if operators would drive differently, if the conditions for driving would be different etc.

In the toy truck sense-making sessions, the participants do not analyse the data scientifically or accurately, but they create a believable narrative as an analysis of the trucks' movements. To make the narrative believable, it needs a reasonable storyline, a development, a problem to overcome. In a sense, the 'problems' were already given in the outset, as the videos were introduced with the names "Near Misses" and "Traffic Jams". Though the 'problems' that the videos show are complex because many events happen simultaneously or affect each other, it is clear to the participants that these videos include 'problems'. When reflecting their observations, they try to build explanations of why the 'problems' occurred.

As noted by Cross and other authors, 'problems' and 'solutions' are intrinsically intertwined in design (Cross 2000:14). What designers choose to interpret as a 'problem' depends on which 'solutions' they can imagine. Hence it is not so surprising that the participants in the sense-making sessions couple the two in their discussions. For instance, B shoots off the first reflection phase in his Traffic Jam team by repeating the question (16:25): *"Why did the traffic jam occur? How are they solving it?"* The double question seeks to identify problems and suggest solutions at the same time.

When we hear the participants repeatedly suggest what the truck operators 'should have' done to avoid the near misses or traffic jams, it is not just an attempt to put the 'blame' on the humans and their skills, but we see it as an opening to identify problems that the company may solve in the future.

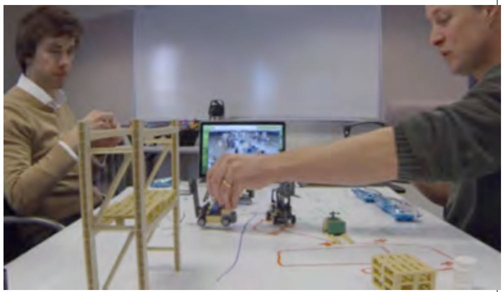
Transcript 4 shows a part of the reflection phase, where one of the participants summarises the discussion by suggesting an alternative narrative based on the 'solution' of traffic lanes. He brings in his own experience from car driving to suggest that if the operators follow lane markings, then the traffic jam that they studied would not occur.

If there were traffic lanes (23:33)

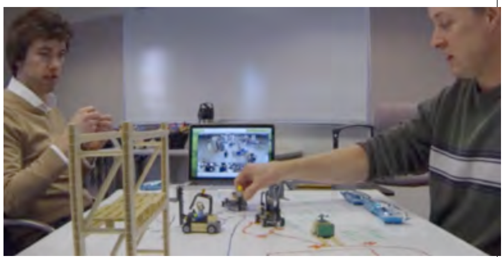
C: "Had there been more of a pattern…"

B: "Yeah, they would have kept driving then."

C: "Then they wouldn't have done this."

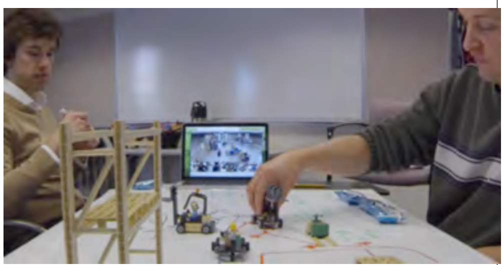


C (moving one truck): "This guy would have stopped and said 'I see a guy coming here."



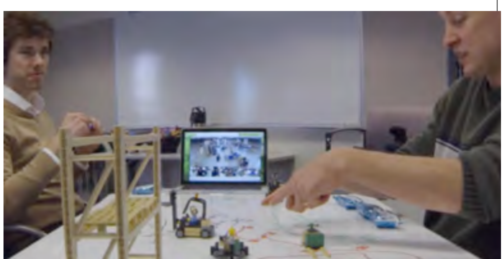
C (moving a second truck): "He should be able to come straight down and get out of the way."

C (touching the first truck): "Now I'm allowed to back up."



C (touching a third truck): "This guy should have come out."

C (moving a fourth truck): "He should have allowed this one to go first and then behind and then followed the lane down."



C (pointing to the centre): "…everybody went to the centre and they should have followed lanes."

Transcript 4. Participant C (right) builds an alternative narrative of what the drivers 'should have' done by moving all the trucks in turn.

The participants use the toy trucks to describe the coupling of problems and solutions. They move the trucks to show how alternative narratives may have another outcome. It seems the toy trucks enabled them to discuss narratives in a simple manner while maintaining the complexity of the problem. If just listening to how the participants explain their points, without seeing their truck movements, one stands a very small chance of understanding what they are talking about.

While the participants succeed in making sense of the video, they also *give sense* to other participants – in particular in the presentation round:

"'Sensegiving' is concerned with the process of attempting to influence the sensemaking and meaning construction of others toward a preferred redefinition of organizational reality." (Gioia and Chittipeddi 1991:442)

The participant above, for instance, insists that warehouses should introduce traffic rules to ensure 'flow'. He tries to persuade a salesman from another team, who disagrees with this idea because, from his experience, no operator would follow such a rule.

Gioia and Chittipeddi claim that sense-making and sense-giving are the best concepts to understand strategic change (1991:433), to enable them means provoking innovation. Our observation that the participants, in addition to make sense, give sense – try to persuade other participants with their alternatives and provoke discussion – implies that this toy truck analysis seminar can create an opportunity for innovation in the truck company.

Conclusions

Thorough our interaction analysis, we observed three patterns of how participants utilise objects in their effort to make sense of experiences: the participants use the toy trucks to build and name narratives, they re-experience the truck driver experience through their hands and body movements, and they use the toy trucks to create alternative 'what-if' narratives that may serve as bridges to design. They do this while never really losing touch with the original video data.

The material facilitates what the participants act. All three patterns indicate that physical interactions between participants and the toy trucks help the participants to not only make sense of what happens in the video and identify problems but also to give sense – to negotiate the interpretation of the video with each other and to create a shared understanding of problems and solution to be able to proceed. This combination of make-sense and give-sense can lead to innovation as we see from the way participants work out suggestions for how to change situations.

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BACK

Counterculture, Ju-jitsu and Emancipation of Wood

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Abstract

This paper sets out to formulate the notion of material-oriented design in wood. In this respect I propose an alternative ontology, where the material is seen as an equal rights partner to the designer. Further, I contrast the constructivist and evolutionary types of management, where in the latter systems are produced with minimal waste and energy expense. I discuss the implications of the approach on an example of five experimental projects, including my own in more detail. I advance that material-oriented design challenges the established form-matter relationship, design process, our understanding of authorship and bears an environmentally friendly potential.

Keywords

wood; material-oriented design; experimental design; New Materialism; material agency

Our approach to wood in architecture has been affected by the spirits of the Scientific Revolution, Enlightenment, and Industrial Revolution. Considering the material's high strength, low weight, low cost and abundance, "timber remains the world's most successful fibre composite" (Dinwoodie, 2000, p. 2), nevertheless it has lost market shares as raw material. It is not an optimal material for mass-production processes, due to its variability, inconsistent makeup and difficult to predict behaviour. The methods of wood remanufacture, focused on homogenising and standardising the material, are not without impact on the environment, effect of energy- and chemicals-intensive processes.

Is the raw material really used to its full potential following this model? In the context of arising ecological concerns, are there new efficiencies and effectiveness yet to be discovered? Could the *disadvantageous* traits be used to benefit? If so, what kind of reference frame that would entail?

The countercultural project

Striving to address these questions I propose to formulate a notion of material-oriented design. The material perspective, however not non-existent, is rare in the design disciplines[1]. As a result of the long established hierarchy that has prioritised form over material and idea over its manifestation "material is rarely examined beyond its aesthetic or technological capacities to act as a servant to form" (Lloyd Thomas, 2007). In this context material-oriented design appears as a countercultural project -- it opposes the well-established hierarchies and the accepted order.

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[1] In architectural theory the perspective started to shift in the mid-2000s. While traditionally materials were concerned either in technical or aesthetical terms, some other perspectives began to come forth: emancipating material as the outright counterpart to form (Weston, 2003), *biographies* of materials, such as iron (Rinke, 2010), concrete (Forty, 2012), or steel (Fry & Willis, 2015), or contextualising materials vis-à-vis modern technologies (Addington & Schodek, 2005; Fernandez, 2006; Kolarevic & Klinger, 2008; Schröpfer, Carpenter, & Viray, 2011).

I propose to base the project on the metaphysical foundation of New Materialism. The New Materialism discourse acknowledges both human and non-human agency in the production of form and strives to reconfigure and to think past the well-established dichotomies: nature-culture, body-thought, concrete-abstract, subject-object, human-nonhuman, matter-mind, real-ideal, digital-manual, formal-material etc. (Dolphijn & van der Tuin, 2012). The New Materialism proponents, such as Canadian philosopher Brian Massumi (b. 1956) or Mexican-American philosopher and artist Manuel DeLanda (b. 1952), argue in favour of recognition of the potential of matter to self-organise, and see it as a potential path of development for design (DeLanda, 2001; Massumi, 1992).

This, however, cannot be achieved by the existing design methods, not capable of embracing that perspective, e.g. material behaviour as a design potential eludes the means of design, from drawings to building information models (BIM). In order to address the challenge, a change of the frame of reference is necessary. To this end, I try to establish theoretical and methodological frameworks for material-oriented design.

The emancipation of wood

Architectural design is a complex entanglement highly affected by a variety of factors belonging to a wide range of disciplines. The tectonic quality of architecture emerges from the interplay between material, economical, technological, environmental or cultural factors. I propose to look at material agency in this complex interplay.

Material agency

British philosopher and sociologist Andrew Pickering (b. 1948) had formulated a shift in science studies from epistemology to ontology. More specifically, he indicates a shift from representational understanding – being an accumulation of data and knowledge -- towards performative condition characterised by “dance of agency” (Pickering, 1995, p. 21). This *dance* occurs between both human and nonhuman actors. Pickering sees material agency as undefined, constantly changing in time:

The contours of material agency are never decisively known in advance, scientists continually have to explore them in their work, problems always arise and have to be solved in the development of, say, new machines (Pickering, 1995, p. 14).

Architecture, not unlike science or engineering, encounters resistance and unpredictability of matter. From the designer’s perspective these are seen as inconvenient problems to overcome. In this light heterogeneous material and its behaviour cannot become design potentials. In my view this situation is a result of the long established hierarchy, where material manifestation is below the form and idea, additionally amplified by the19th century industrial standards where material is passive in the production processes.

An alternative ontology is offered by the actor-network theory (ANT)[2]. In the view of ANT *actants* are both human and nonhuman actors with equal ability to act. In ANT the concepts of agency and intentionality do not have to be bound together. At the same time, this is neither an anthropocentric nor a hierarchical concept. Central to the theory is a web of relations, being both material -- between things, and immaterial -- between concepts. In order to see architecture through this lens, emancipation of material is prerequisite. Latour describes a *nature-culture hybrid* that in the context of materiality and architecture may be understood as a synthesis of materials and cultural ideas. I argue that this concept is central to the material-oriented design.

[2] ANT was developed in 1980s in France by science and technology scholars: Bruno Latour (b. 1947), Michael Callon (b. 1945), John Law (b. 1946) et al.

In 1990s French philosopher Michel Serres (b. 1930) proposed that objects -- inanimate matter and nature -- become legal subjects. For Serres, this subjectivity of objects is a necessary condition for bringing back the equilibrium to the world facing ecological disaster. As a remedy, Serres proposes *natural contract* – between human and nonhuman actors, not unlike our *social contract* – between humans (Serres, 1995). Serres thus linked material agency and ecology.

ANT established science, technology and society as a field of human and nonhuman agency in a symmetrical rather than hierarchical fashion. This approach has the capacity to embrace the unknown arising from the material side by the process of cooperation. Pickering says that "disciplined human agency and captured material agency are (…) constitutively intertwined; they are interactively stabilized" [3] (Pickering, 1995, p. 17).

That approach provided a theoretical framework for material performativity. Michael Hensel extended that formulation into the realm of architecture. In this view architecture is identified as a domain of active agency (Hensel, 2010), where the "spatial and material organisation complex" is defined as a "synthesis of the various scales and their complex interactions" (Hensel, 2011, p. 4). While in the industrial tradition architects and engineers prefer materials that can be considered homogeneous and predictable -- as exemplified by the case of steel and iron -- Hensel postulates dynamic condition required by the spatial and material organisation characterised by active agency. E.g. wood structure must be understood in relation to environmental conditions affecting its growth. Higher in the hierarchical organisation system, material behaviour is determined by the material properties and environmental conditions. This in turn has to be harnessed by architectural design, what is the basis of the "instrumentalisation of material behaviour as performative capacity" (Hensel, 2011, p. 8).

Beyond hylomorphism

Hylomorphism, a concept introduced by Aristotle (ca. 385-322 BC) in his *Metaphysics*, distinguished between form and matter. Matter -- *hyle* -- became the substrate out of which all physical things were made, while form was the structure – *morphe* – that gave them their characteristics and attributes. In the view of Aristotelian hylomorphism a thing is a unity of form and matter. This stance, however not seeing material as active in the form-giving process, laid a foundation for materialist approaches and was prerequisite for the recognition of material agency. The often attributed to Michelangelo (1475–1564) proverb: *every block of stone has a statue inside it and it is the task of the sculptor to discover it* – actually originated in *Metaphysics* where Aristotle remarks that we can speak of seeing Hermes in the uncarved stone. The mid-20th century philosophy started to question the concept of hylomorphism as being insufficient. In 1950s Martin Heidegger (1889–1976) posited that the fusion of form and matter is additionally controlled by the purposes served by the thing: "[the] serviceability is never assigned and added on afterwards to beings" (Heidegger, 2002, p. 10). The material choice in design is informed by this serviceability. French philosopher Gilbert Simondon (1924–1989) criticised hylomorphism as being based on a hierarchical relation where form is superior to matter and is not concerned with the transformative processes. Reflecting on a make-up of an adze, he points to "the progressive heterogeneity of tempering at certain points". The gradual change of material properties -- being instrumental in the functioning of the tool – eludes the dichotomies of form-matter or form-structure, and further:

The tool is not made of matter and form only. It is made up of technical elements arranged for a certain system of usage and assembled into a stable structure by the manufacturing process. The tool retains within it the result of the functioning of a technical ensemble. The

[3] Pickering credits this observation to Engels' *coproduction*, later recalled by Callon and Latour, and dubbed by Law *heterogeneous engineering* (Pickering, 1995, p. 17).

production of a good adze requires a technical ensemble of foundry, forge, and tempering (Simondon, 1958, p. 84).

The thread of the heterogeneity of materials was picked up by Gilles Deleuze (1925-1995) and Felix Guattari (1930-1992) in their seminal *A Thousand Plateaus: Capitalism and Schizophrenia* in 1980. When discussing Simondon, Deleuze and Guattari reflect on “the variable undulations and torsions of the fibers guiding the operation of splitting” wood:

(…) it is a question of surrendering to the wood, then following where it leads by connecting operations to a materiality instead of imposing a form upon a matter (Deleuze & Guattari, 2005, p. 408).

In such formulation matter can only be *followed*, what obviously transgresses the hylomorphic conception. Deleuze and Guattari credit Simondon in this respect:

Simondon demonstrates that the hylomorphic model leaves many things, active and affective, by the wayside (Deleuze & Guattari, 2005, p. 408).

In this light, there is a spectre of potential in *following the material*, available after transcending the hylomorphic model. These *many things, active and affective* could be accessed, to our advantage, by entering into the Serres’ *natural contract* and making the Latour’s *nature-culture hybrids*.

Tectonics and time

The material focus engenders the problem of time in architecture. Materials change and perform in time. Shifting perspective to the material agency also requires refocusing from static to dynamic aspects of materials. This in turn triggers both change of the method of design and the way in which materials are used.

To this end I look into the discussion of architectural tectonics. The notion of tectonics brings about two important implications. Firstly, the term tectonics is inseparable from materiality, e.g. Antoine Picon sees it as “based on prescriptions regarding the proper use of materials” (Picon, 2010, p. 161). Secondly, the tectonic discussion -- in contrast to earlier theories that focused on the imitation of objects -- concerned the processes behind making a building[4]. The tectonic discourse, besides redirecting the interest towards the rational principles, introduced the idea of dynamic relations as informing design.

In the case of wood, the undesired by the current industry phenomena -- when seen through the lens of tectonics, agency and performativity -- could become generators for new tectonic systems. I argue that these systems would have a capacity to reduce the environmental footprint of construction: e.g. in my previous work it has been demonstrated that wood shrinkage from green to dry can replace metal connectors or adhesives in wood construction (Wójcik & Strumiłło, 2014a, 2014b).

I propose to see the discourse of tectonics as a move towards rational principles in architecture. Central to tectonics is the division made between the ornamental, artistic and symbolic versus structural, constructive and rational attitudes. A parallel could be drawn between these notions and the opposition of *representational* and *ontological* aspects of architecture, as presented by architectural historian Kenneth Frampton (1995)[5]. Following on

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[4] In 1840s Karl Bötticher (1806–1889) defined architectural tectonics as the activity of forming a building.

[5] Frampton partly attributed this idea to Semper, however he also points to (1995, pp. 71, 82) some earlier analogies in Bötticher, who in a similar vein to the ontological and representational aspects of architecture, opposed *Kernform* (core form) against *Kunstform* (art form), and designated the representational to the Greek and the ontological to the Gothic already in the first half of the 19th century (Frampton, 1995, pp. 71, 82). In Bötticher, Kernform achieves an intrinsic, or ontological

the notion of representational and ontological material-form relationship I propose to extend its meaning onto the understanding of the use of material. Under this framework I use the notions of *representational* and *ontological use of material*. In today's parlance the term *materiality* usually refers to the former, while *material logic* to the latter, corresponding respectively to the *soft* and *hard* narratives of the use of material in construction.

Ju-jitsu of matter and energy

The discussion about form – matter relationship in architecture could be enriched by some observations of biological systems. Julian Vincent, British pioneer of biomimetics, argues, that our technology *kills the information* of raw materials, with a substantial expense of energy to make the material ordered with imposed shape and structure for the final product. Quite the opposite, the biological systems use information and structure rather than energy to solve technical problems. In live organisms information, stored in DNA, is used to drive specific reaction at the cellular level and self-assemble structures (Vincent, Bogatyreva, Bogatyrev, Bowyer, & Pahl, 2006, pp. 474-478). Vincent argues that conversely to nature, where “”shape is cheap but material is expensive””, in engineering “material is cheap and shape, resulting from energy-intensive processing, is expensive”. Vincent points to our ability to tap abundant and cheap fossil fuels during the Industrial Revolution as a key turning point in our relationship with nature. The scarcity of material in nature leads to several rational solutions, such as blurring the distinction between structure and material, multifunctional use of material, hierarchical structural organisation or oblivion of waste. There is definitely something momentous we could learn about resources management from nature.[6]

To relate the discussion back to architecture I advance to use the concept of periodization of wood construction introduced by Christoph Schindler (2009). The model integrates fabrication with manual, industrial and information technology and is based, in a cybernetic fashion, on the relation between three categories: matter, energy, and information in each respective period. Schindler identifies three waves of technology in the history of wood construction: (1) *hand-tool*, (2) *machine-tool* and (3) *information-tool* technology. (1) In the first wave, dominant in the preindustrial era, the main operator of energy-matter-information was the man's hand, and the main intellectual achievement was the design of the tool. The tool operated by hand followed the growth direction of the tree and the fibre direction of the wood. Natural shapes of wood were incorporated in the design. Parts playing the same role in the building structure, even when sharing the same dimensions were not interchangeable. (2) The *machine-tool* technology is connected with the Industrial Revolution of the 19th century when machines substituted repetitive physical operations, while a human operator processed information. The design of the interconnection of power machine and machine tool was the crucial intellectual achievement. The working process was adjusted not to the potential of the hand, but to the potential of the machine what resulted in homogenisation of

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status, while Kunstform extrinsic, corresponding to representation, what prepared the ground for radical technological innovation: introduction of iron as a material representing dynamic character of the industrial society. Also Schwarzer (1993, p. 273) attributes the introduction of this concept to architectural thinking to Bötticher.

[6] This is especially important in the context of arising environmental concerns. Various efforts are geared towards providing a reference frame for material use in this regard. The concept of Life Cycle Assessment seeks to quantify the environmental impact of products over their entire lifecycle. Accordingly to the 2006 EU Eco-Innovation Panel material innovation should satisfy human needs and bring quality to life “with a life-cycle-wide minimal use of natural resources (material including energy, and surface area) per unit output, and a minimal release of toxic substances”. This notion is largely based on the concept of the *ecological rucksack* of materials and its measure – MIPS (material intensity, or material input, computed as mass per unit service), as introduced in early 1990s. The goal of MIPS is to maximise the amount of units of service with minimised use of material and material-intensive energy (Hinterberger & Schmidt-Bleek, 1999, p. 53).

wood and mass production of wood-based products and standardised building components. (3) The third wave in the Schindler's model began when machines started to replace both physical and intellectual operations. The highest achievement was the interconnection of power machine, machine tool and information machine.

I pose that this formulation can be expanded vis-à-vis the problem of material agency in design. From this perspective, the *hand-tool* technology (1) has the capacity to integrate material agency into the design, while the *machine-tool* technology (2) has not. The evidence of that are: (1) for the *hand-tool* technology – use of hand tools in connection with material traits (e.g. grain direction) and incorporation of naturally grown shapes in designs, and (2) for the *machine-tool* technology the efforts towards standardisation and homogenisation of material (e.g. wood-based panels).

While some characteristics of the *information-tool* technology (3) take after the *hand-tool* technology (1), e.g. non-standardised and non-interchangeable components, I pose that the role of material agency could also bear resemblance in the two respective periods. In other words, while the *machine-tool* technology (2) supressed material agency, a new potential has been opened for it by the *information-tool* technology (3). Such potential though requires a management strategy.

One possible management strategy is the concept of networked thinking, as originated by a German biochemist and ecologist Frederic Vester (1925-2003). Based on systemic and cybernetic approaches, in unison with the Vincent's theory, Vester opposes constructivist against evolutionary types of management. In the former the system is produced at great expense of material and energy, in the latter it emerges spontaneously at little expense. The 4th rule of his eight basic rules of bio-cybernetics outlines the strategy: "exploiting existing forces in accordance with the ju-jitsu principle rather than fighting against them with the boxing method" (Vester, 2007, p. 160). This formulation transcends the framework of resilience. While resilience is the ability to absorb and release stresses, no gains are sought after in being exposed to the stress. The main goal is to *bounce back* and remain unaffected. Quite the contrary, Vester's 4th rule, reflecting the bio-cybernetic stance, takes inspiration from the martial arts strategy of exploiting the opponent's force. This insight opens a new perspective when applied to our understanding of material in construction.

The New Materialism of wood

While the possibility of application of the concepts of New Materialism and bio-cybernetics in architecture may sound vague, recently a series of researches attempted to take heterogeneous material properties into the production of form. I would like to discuss the ones dealing with wood (Figure 1, left to right): (i) Helen & Hard *Ratatosk Pavilion* at the V&A Museum in London, (ii) Hironori Yoshida *Digitized Grain* (iii) Christoph Schindler at al. *Serial Branches*, (iv) Ryan Luke Johns and Nicholas Foley *Bandsawn Bands*.

Figure 1.

The projects are of limited scale, ranging from a pavilion (i), through an art installation (ii) to furniture (iii, iv). Nevertheless, their innovative approach to the design process and technology points into a very promising direction for the material-oriented design in wood. They emancipate the material in the production of form, minimise the energy use in favour of the information use, and strive to challenge the commonplace design practice.

(i) Helen & Hard's project breaks away with the conventional design sequence: finding, scanning and digital modelling of the ash trees became the initial rather than the final design phase. As a result, the sketch phase was omitted as an inadequate work method for heterogeneous material: "[the] forms were dictated largely by the shapes of discarded branches, and therefore could never have been predicted in a preliminary sketch". Material idiosycrasies -- organic shapes, knots, holes and fibres -- led the design and construction (Stangeland & Kropf, 2012, pp. 172-179).

(ii) Yoshida's project seeks to translate the craftsman's interaction with natural materials into a fully automated *Scan-To-Production* process. The wood grain is digitally scanned, image-processed and transferred into motion paths for a CNC machine. As a result, the grain pattern of wood is replaced by polyester resin, based on colour analysis. "The Scan-To-Production (STP) process, through the use of digital scanning and robotic fabrication, proposes to take material irregularities as design input, to distinguish and create meaningful order from material *noise*" (Yoshida & In, 2013).

(iii) Schindler's project took inspiration from the Viking boatbuilders and vernacular joinery, where superior strength was achieved by using naturally forked hardwood pieces. As a result of a trial and error process a method was deviced to minimise the amount of information neccesary to compute the shpes for design: all branches were planed on both sides resulting in two parallel evenly distanced surfaces. The project demonstrates how "although we claim to explore the benefits of digital tools, our thinking is bound to the heritage of industrializaion: we are used to work with measurable geometry, minimal tolerance and reliable mateiral constraints" (Schindler, Tamke, Tabatabai, & Bereuter, 2013).

(iv) Johns and Foley in their project reverse the commonplace logic of digital manufacture: "rather than transferring material, (…) from a curved tree into dimensional lumber which is then re-machined into curvilinear digitally designed geometry" the authors "take the tree as the starting point for design and move directly to digital fabrication. This leap in the production sequence enables more sustainable material efficiency while simultaneously conferring the natural aesthetic advantage of *beauty's found geometries.*" The devised technique uses a robotically operated bandsaw to cut series of strips following the curvatures "which, when rotated and laminated can approximate doubly-curved and digitally defined geometry". As a result of the "close relationship between available material and designed geometry" the process yields "practically zero-waste". Interestingly, some tool operations are closely connected to material features, e.g. the robot cut speed is programmed as a value proportionate to the curvature of the cut, resultant from the grain pattern (Johns & Foley, 2014).

In all these examples the material properties are equal rights partners to the designer. Helen & Hard (i) or Yoshida (ii) partly cede responsibility regarding the design to the material. Should the material had different features, it would have resulted in different shapes or patterns. In this case one cannot fully claim the authorship. A hypothesis can be formulated as to whether is this a necessary trade-off, the *natural contract*, where -- by *surrendering to the material* – we can access new territories of unknown architecture, effects, affects and effectiveness? The projects seem to tentatively confirm this hypothesis. As Johns and Foley (iv) say their method is "one of few woodworking techniques which are explicitly not subtractive, but transformative" (Johns & Foley, 2014, p. 25) indicating the potential for the approach regarding minimising waste in digital manufacture. Strikingly, this applies to other presented projects: Helen & Hard (i) or Schindler (iii) also dodge waste and pollution. Intricate forms are result of naturally grown shapes and mindful handling of information, rather than sculptural milling. In this regard all four projects rely on 3-dimensional and 2-dimensional scans and digital image or model processing to form a *nature-culture hybrid,* used as a starting point for the design. It is telling that none of the projects could stick to the conventional design method, where a conceptual sketch through iterations becomes a working drawing. Not only drawings representing final forms were difficult or impossible to produce, but also obsolete. For the final product more important were process sequences and strategies regarding digitising and operating material information.

The Swelling Vault – a self-bending shape

I argue that -- however the presented projects are legitimate examples of New Materialism of wood – there still is undiscovered potential under the framework of material-oriented design. One yet little explored area remains the utilisation of dynamic, or kinetic, relations informing design. I pose that such approach opens design towards harnessing emergent phenomena. By emergence in this context I understand a process where form is produced through interaction between small components, while the meaningful properties of the form are not exhibited by the components themselves.

In order to illustrate the approach, as well as investigate its implications, I[7] carried out an experiment together with the students of design at the Hochschule Luzern. The main goal was to device a method for harvesting phenomena resultant from kinetics of material behaviour, and thus to extend the notion of material-oriented design in wood.

Parquet buckling, that became an inspiration for the project, is a well-known and undesired phenomenon caused by increased moisture content in wood. The aim of the experiment was to replicate it and to test how the buckled shape has been affected by various block patterns, and also how the emergent shapes could be predicted by digital simulations.

The aforementioned DeLanda sees digital simulations as prerequisite for harnessing emergent phenomena:

[Digital] simulations are partly responsible for the restoration of the legitimacy of the concept of emergence because they can stage interactions between virtual entities from which properties, tendencies, and capacities actually emerge (…). [S]imulations can play the role of laboratory experiments in the study of emergence complementing the role of mathematics in deciphering the structure of possibility spaces. And philosophy can be the mechanism through which these insights can be synthesized into an emergent materialist worldview that finally does justice to the creative powers of matter and energy. (DeLanda, 2011, p. 6)

It was decided to lay two different patterns: checkered, using square blocks laid with alternating grain orientation; and herringbone, using elongated rectangular blocks (Figure 2). As a connection between the blocks The Lamello Joining System (biscuit joint) was chosen and no adhesives were applied.

[7] The project was made possible thanks to the invitation and support from the Hochschule Luzern, Design & Kunst, and especially Christoph Schindler and Sebastian Kraft.

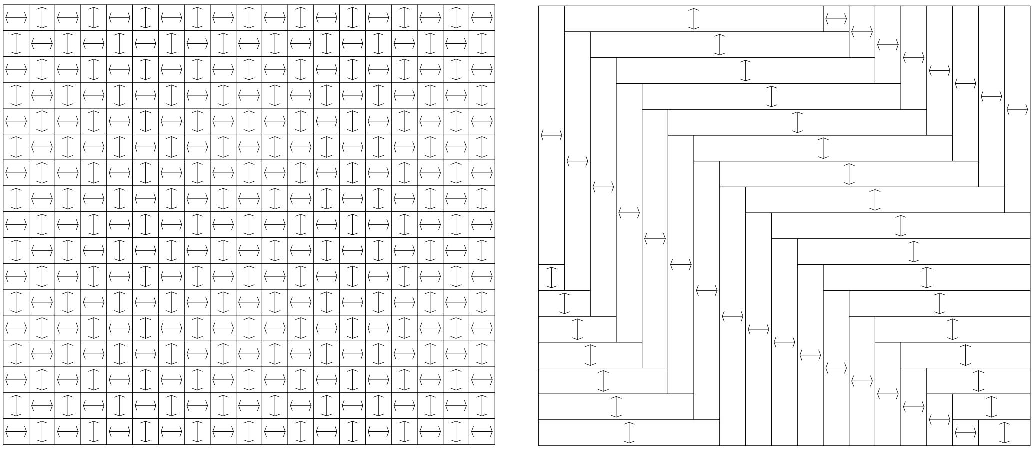

Figure 2.

After laying out the patterns warm water was poured on (Figure 3), and the pieces were left to soak in for the wood to swell. A few days later the surfaces have bulged up, the checkered patterned shape was rather regular and domed (Figure 4), while the herringbone formed a conical, almost ruled surface (Figure 4). Both resultant shapes were very strong. Four people weighting ca. 280 kg could step on a 3.2 m^2 piece not causing any damage (Figure 3).

Figure 3.

It remains to be tested to what degree the deformation is reversible when the moisture content drops. Should it reverse too much, the surface could be sealed to fix it in the warped shape.

Figure 4.

In parallel, a digital simulation model was devised to compare the results with the empirical tests. Swelling of wood was estimated using a formula based on the equation from Covington and Fewell (1975). Comparison of the estimated elongation of the surface (1730.6 mm) to the empirical (1726.7 mm) yields only 0.2% discrepancy, and results in ca. 6% discrepancy between the measured 132 mm and calculated 140 mm for the sagitta (Figure 5, where solid line indicates measured and dashed line estimated shape). As for now, the digital simulation is only operational to predict the bulging for checkered patterns. Had the model been fully working, it would have been possible to predict resultant 3-dimensional forms from flat patterns.

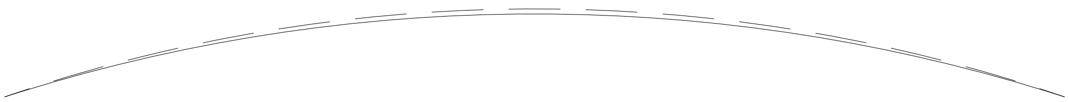

Figure 5.

Material takes command. Discussion

New ontology

The Swelling Vault project explores the symmetrical and reciprocal relation of the *natural contract*. In the process of forming neither the designer's nor the material agency could be seen as superior. In this view, the concepts of agency and intentionality are decoupled. The form is emergent, where its main property – the curvature -- is not reducible to the properties of its constituent parts. The system behaviour is anticipated by means of computer simulation.

The reciprocal relation between the designer and the material can be describes as a *dance of agency*, where none of those two could be omitted nor prioritised. Any imbalance would invalidate the process. However the designer and the material are equally valid, there obviously are important differences between them. At different stages of the process one or the other comes to the fore: the designer in the preparatory stage specifying the layout of the blocks in order to achieve – within tolerances -- desired result, and the material in the final stage, where the totality of material and environmental factors give the vault its final shape.

A prerequisite for the balance to be operational is that the material is seen and used in the *ontological* terms. Not only pieces of other material looking like wood, but even some other species of wood, would not perform the task. For the *natural contract* to be valid, a total understanding and acceptance of the material behaviour is necessary. In a way, that may be seen as yet another come back of the clichéd 18th century concept of *truth to materials*[8], this time in a purely *ontological* understanding of material without any references to moral values.

Bio-cybernetic process

The project harnesses an emergent, moisture induced phenomenon, rather than uses external energy for forming. Therefore it conforms to the bio-cybernetic and biomimetic models. The shape, achieved with negligible use of energy and waste, becomes *cheap.* The *ju-jitsu principle* is applied in the process as the ability not only to accept setbacks but also to turn them into advantages. In the project the material characteristic usually seen as disadvantageous -- moisture related dimensional instability -- is exploited. The change of perspective, allowed by the countercultural design approach, allowed not only to *even up* or *compensate* for it, but also to turn it into design strategy. And even more, this strategy results in palpable and quantifiable gains – the shape is achieved with a minimal *environmental rucksack*.

Not unlike in the case of the four aforementioned projects, also the *Swelling Vault* required rethinking of the design process. The predominant design methods are rooted in the Renaissance, when design was concerned with imitation of objects. Quite the contrary, the process captured dynamic relations, where the shape could be specified only within the material limitations. Within the system not all forms are possible, and any simulated design negotiated between the designer and the material is only a simulated approximation. The designer's control is through material selection, shaping of the wooden blocks and laying them out in various orientations and patterns. The simulation as a design method allows only for interaction through a trial and error process. One possible way of development may be application of a strategy called reverse engineering: a shape would be specified by a designer, than computer program would generate the best possible shape match, and choose the appropriate material and pattern.

As a result of the project, two conclusions concerning the design process arose: digital tools are essential for simulation of the *dance of agencies* at the early design stage, and as this prediction cannot be 100% accurate, appropriate tolerances must be embedded in the design.

Cultural performance

Are we, designers, loosing control over the designs by including material *actants* in the *nature-culture hybrid* process? Sharing the authorship with – to some degree – unpredictable, and also demanding *partner*, may seem counterproductive towards achieving design goals. The approach bears resemblances with the *digital turn* in architecture, that

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[8] The concept of *truth to materials* surfaced for the first time in Italy in the mid-18th century when Carlo Lodoli (1690-1761), as a countermeasure to the Baroque and the influence of the Classics, formulated an entirely new notion of truth, not understood in the Classical sense as synonymous with beauty, but associated with consistency. For Lodoli the form of the ornaments must be consistent with the materials in which they were made (Forty, 2000, pp. 294, 296).

have already questioned the Modernist idea of the standard and the Renaissance idea of the author (Carpo, 2009, p. 53). In exchange – besides the aforementioned energy and material savings -- it offers a return to the pre-industrial and pre-modern models: the relation between the subject and object of design in the digital chain mirrors the Medieval master builder approach, or the distributed authorship of *Wikipedia* echoes the Medieval manuscript read-and-write mode. In particular the later brings similar controversy as the *nature-culture hybrid* process due to its inconsistencies and unreliability. Obviously *Encyclopaedia Brittanica* is much more stable and reliable, but cannot match *Wikipedia* in speed of reaction or availability. Analogically, the available *Swelling Vault* shapes are limited by the system capacity to take shapes, and its final shape is a few per cent off the predicted height, but it has been achieved with a negligible *environmental rucksack*. I propose to see it as a necessary trade-off that has to be made if we want to access the benefits that come with this approach.

As the discussed projects may suggest, the unpredictability and idiosyncrasy resulting from the approach is a design opportunity. Design that follows material yields objects that cannot be reproduced, thus resulting in *cultural performance* not seen since the pre-industrial times. Just like the subject-object relation in design process or the question of authorship, the cultural role of material in material-oriented design takes after the pre-Modern and pre-industrial models. Are we ready for the material to take command?

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BACK

Materials Driven Architectural Design and Representation

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Abstract

This paper aims to outline a framework for a deeper connection between experimentally obtained material knowledge and architectural design.

While materials and architecture in the process of realisation are tightly connected, architectural design and representation are often distanced from the material domain in which the construction eventually will happen. In many cases, it can seem that materials play the role of a selection of building blocks from which a determined architectural vision or representation are tried to be build.

Research in materials, materials behaviour and new materials are often quite technical and oriented towards the field of engineering. Often cost, efficiency, optimisation and specific functional properties are the driving forces in material research. While this is extremely relevant in relation to new building strategies, material research can potentially also play another role in relation to architectural production. It is, in this paper, the intention to point at material research as an active initiator in explorative approaches to architectural design methods and architectural representation.

This paper will point at the inclusion of tangible and experimental material research in the early phases of architectural design and to that of the architectural set of tools and representation. The paper will through use of existing research and the author's own material research and practice suggest a way of using a combination of digital drawing, digital fabrication and material experiments to take advantage of experiential, material knowledge in the creation of architectural ideas and design.

Keywords

materials driven design; material research; digital fabrication; exploratory approaches; architectural design

When architects produce a spatial idea or an architectural concept they work and mediate within the field of representation. For centuries, the architect's role has been defined by drawing and design (Sheil, 2005). The intention of the architect will reach a point before realisation where reality and materials will need to adapt to or influence the design in order to facilitate the creation of a building. This situation has sometimes in led to notable divergences between propagated idea and actual architectural appearance. How can a clearer, tighter connection between architectural design and architectural realisation be created? How can an open approach to design and spatial development collide with reality in a productive way?

It is the objective of this paper to point towards the inclusion of materials in the earliest stages of architectural design in order to establish a reality connect basis for design that maintains and even widens the exploring character of a design process.

Material experiment as initiator

To implement material research and material experiments as a part of the earliest architectural design phases, an open minded non-deterministic approach to the material investigations are required (Kolarevic and Klinger, 2008). Discoveries made by studying and exploring materials through machining can be of a highly unpredictable character and lead to many surprises. These surprising outcomes of the encounter of machining and material properties should be considered qualities in the phase of exploring form and design as well as an opportunity to let further investigations shed light on the relations between certain machining techniques and certain material properties.

In order to position materials as an essential experimental way of discovering and initiate design it seems natural to move the existence of machining and material from the end-result oriented construction or manufacturing phase to an early more inquiring phase of architectural design. Results of material experiments made with an investigative objective will contain a type of knowledge that is tangible, but not primarily technical. The outcome will not be a realisation of a design, but instead hold the potential of initiating a design or facilitate the beginning of further research.

An example of a direct material experiment could be the work *Objectiles* (1995) (Figure 1) by theorist, philosopher, architect and industrial designer Bernard Cache. *Objectiles* consists of a series of tiles made by machining different laminated wood sheets. The machining was based on parametric defined digital drawings, instructing a CNC router to where to move in space. The encounter of the tool and the material revealed the layering through the sheets and formed the three-dimensional shapes in the materialised results. Creating a direct tangible relation between information and materials the designing is moved much closer to material reality and has at the same time expanded its means into the virtual, computational power. The material experiment played a key role in doing this. For Cache, and his practice, Objectile (founded in 1996) together with partner Patrik Beacé, this has resulted in interconnected historical, mathematical and philosophical research in today's computational and material technologies and the traditions of the past (Cache, 1995) and creations of series of physical artefacts labelled "non-standard architecture".

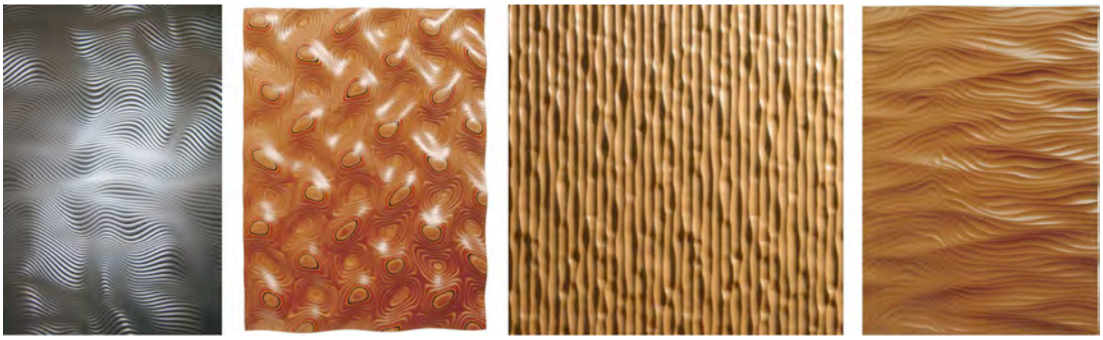

Figure 1: Bernard Cache's *Objectiles*

Another, more recent, example of material experiments in architectural design is the *meteorosensitive morphology* research by Achim Menges in collaboration with Steffen Reichert (Menges, 2012) (Figure 2). This research is based on a systematic testing of wooden fibre's ability to naturally deform in respond to surrounding humidity. Through years of studying the behaviour of different types of machined wood, Menges's research group found relations between the wood's inherent properties, the machining and the wood's reaction to humidity changes. This knowledge made them able to control and design specific machining strategies that resulted in wood with specific deformation features. From these invented processed the material research formed into *HygroScope* (2012) – an installation in Centre Pompidou Paris – and *HygroSkin* (2013)– a pavillion at FRAC Centre Orleans.

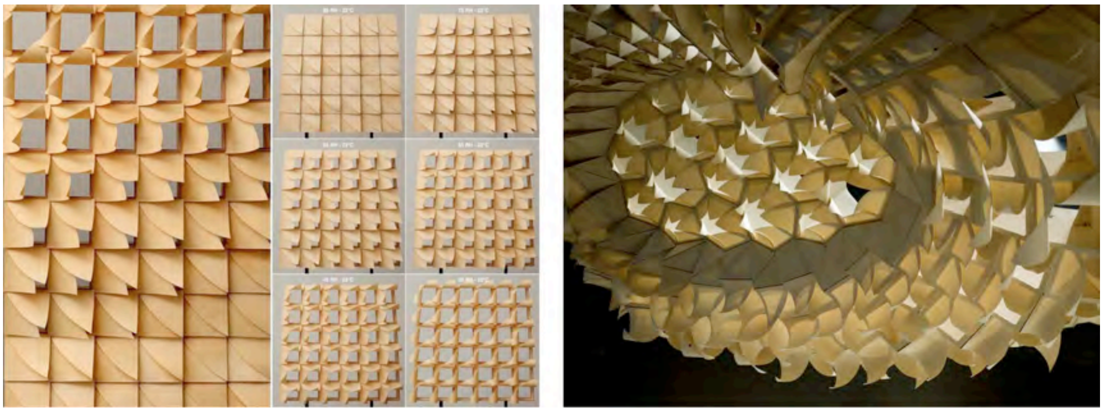

Figure 2: Hygroscope by Achim Menges, ICD Universität Stuttgart

Act of crafting

The relationship between material and design is undeniably connected to the traditions of crafting and workmanship. Good design cannot exist on its own as well as such a thing a ‘good materials’ do not exist (Pye, 1968). It is through the acts of processing and working that design is realised from the substance of materials and those processes are traditionally bound to the experiential knowledge of crafting and workmanship. In *The Nature and Art of Workmanship* from 1968 David Pye defines workmanship by setting up two contrasts: *the workmanship of risk* and *the workmanship of certainty*. The latter is defined by a predetermined output and related to manufacturing and repeating, automated processes. These processes rely on standards and routines securing an endless production of similar products. The other type of workmanship, *the workmanship of risk*, is craftsmanship defined as *…workmanship using any kind of techniques or apparatus, in which the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercises as he works* (Pye, 1968 p. 20). This sort of workmanship is relying on the craftsman’s skills, constant awareness, ability to learn from the material’s behaviour and importantly the willingness and confidence to put his work at risk. The craftsmanship of risk can fail, but the outcome of a failure will still result in a experience that can be utilised in future works.

Even though Pye’s personal preference and admiration for the workmanship of risk and the criticism of the workmanship of certainty are clear in his text, and the fact that his writings are almost a half century old, the twofold definition of workmanship is still referred to nowadays. Today almost everything is mass-produced by automated machining and craftsmanship is something rare and expensive. This could suggest that real craftsmanship belongs to the past. However in order to setup automated processes experience and know-how is needed. Before a mass production is established, an experimental phase, involving risk, must undergo. Furthermore, during the half century elapsed since *The Nature and Art of Workmanship* was written, new kinds of technology have emerged and computational power, capacity and availability have changed the workflow from design to production. Automation does not necessarily need to be a repeating process anymore, it can be based on changing parameters. Furthermore, making and crafting, the events of the workmanship of risk, might not even be limited to the physical world anymore (McCullough, 1996). The possibilities of crafting within the digital, virtual domain have created a new kind of medium that opens possibilities of increasing the communication between digital work and the more traditional craft. Craft can now utilise procedures that before was limited the processes of manufacturing and manufacturing equipment can gain new potential through computational control and continues interaction, opening up for production workflows that easily can shift its manufacturing patterns or even produce series of unique, bespoke or customised elements. It could seem that Pye’s contrasting extremes are fusing together in the middle, blurring the boundaries between design, craft and manufacturing. The potentials of this utilisation of digital craft or design within the digital realm and the use of digital fabrication tools as direct, but uncertain, approaches to the materialisation of computed designs is discussed by Branko Kolarevic in his text *The (Risky) Craft of Digital making* (Kolarevic, 2008). Kolarevic argues that the designer, the practitioner of the digital tools, is in a position similar to that of the craftsman practising the workmanship of risk. The designer is not only designing but also able to test and try the relation between the digital information and the tools and materials in use. This creates a feedback loop that informs the design in development and creates a basis for gaining experience but at the cost of every decision being a risk.

In the continuation of Koleravic's connection of risk to digital making, one could argue that the presence of materials in the combined process of designing and making intertwines the relationship between 'good design', 'good materials' and realisation. Being able to act as both designer and craftsman simultaneously undoubtedly requires an extended set of skills, experience and knowledge, but undoubtedly also brings new possibilities for materialisation and therefore for designing.

Materials and machining driven design – experiences and reflections from own practice

This part of the paper aims to reflect both on the thoughts, the processes and the outcome of the design and production of the construction *Intermediate Fragment* and material and machining driven design as a contemporary architectural tool on a more general level.

Intermediate Fragment was finalised for the exhibition *Engaging Through Architecture* by *Aarhus School of Architecture* as a part of *Milan Design Week 2015* by the author of this paper. The fundamental pool of techniques and knowledge that set the agenda for Intermediate Fragment was established before the intentions of realising an exhibition object was conceived, but expanded, refined and concretised through this process.

The intention here is to guide the reader through the specific process, methods and choices and relate the undergone work to more general contemplations that initiated the work and/or was develop through the work.

The context of the work shown here is an interest in a tighter, deeper connection between experimentally obtained material knowledge and architectural design. The interest takes off by the utilisation of the link between digital drawing and digital fabrication. The opportunity to use digital drawing as information for machine instructions, and the power of these machines to process different materials, creates a unique relation between tools mastered by architects and a range of materials used in buildings and construction. The potential of transgression from drawing to making (Sheil, 2005) makes it possible to introduce material exploration in the earliest stages of design and abandon a deterministic design and realisation approach in return for a discovery of form through the materialisation (Kolarevic, 2008).

Material start

The encounter of material specificities and tool behaviours can be seen as the starting point for the series of material test and experiments that initiated this process. The materials wood, concrete and steel formed a strategic assortment. Varying from heterogeneous/anisotropic to homogenous/isotropic, from liquid to solid these materials provides a range of properties and states. Also, they are all known classics in building realisation, where they are often used in different dedicated situations performing in often repeating, standardised and well-proven ways. Despite their controlled use and refined formats they all offer a number of inherent specific material properties and capacities.

Material properties are defined as objective characteristics that can be listed. Capacities, on the other hand, are relational. A capacity to affect always goes with a capacity to be affected (Delanda, 2007). With this approach to the materials the digital drawing was seen as an instrument to embed information into the materials through fabrication, in that way altering the capacities of the materials on the basis of their properties. This led to a strategy where machining was followed by transformation, creating a workflow where the elements of drawing, machining and transformed result all have an individuality and actual existing, not being a representation of each other. Since this workflow is reliant on experiential knowledge gained through the surprise and uncertainty of the outcome, an iteration-based process here becomes a way of finding relations, defining parameters and a context from where form and construction can happen – opposed to a workflow where iteration is done solely for the sake of debugging or in attempt to achieve predetermined designs.

Exploration and systematisation

In order to create an agile, non-linear workflow without ambition of a specific end result, but instead openness to unpredictable outcomes, places or points of possible interventions was located (Figure 3). Throughout the process – from drawing to materialisation – the ability to evaluate and engage the event in hand exists, creating both tangible way of gathering knowledge as well as the possibility to alter or distort the process on basis on the findings. The potential continuous feedback can be become a tool of both understanding and creating.

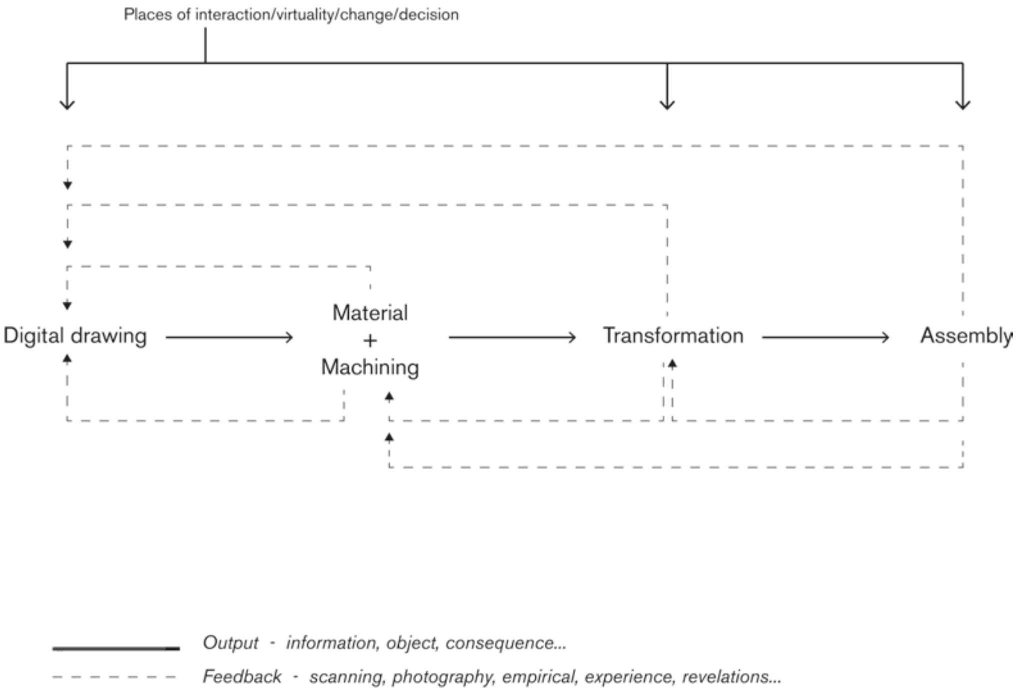

Figure 3: Diagram of workflow

Concretely, series of explorative fabrications in steel, wood and concrete were made (Figure 3). Through these tangible acts, the variables of the established workflow were tested out in order to create an overview of the possibilities and establish a framework to manoeuvre. Each phase of design and production hold a mass of both technical as well as conceptual limits and challenges. It is the intention of this workflow locate and utilised these places of possibility and virtuality in order to promoted design decision and interaction within the process of production.

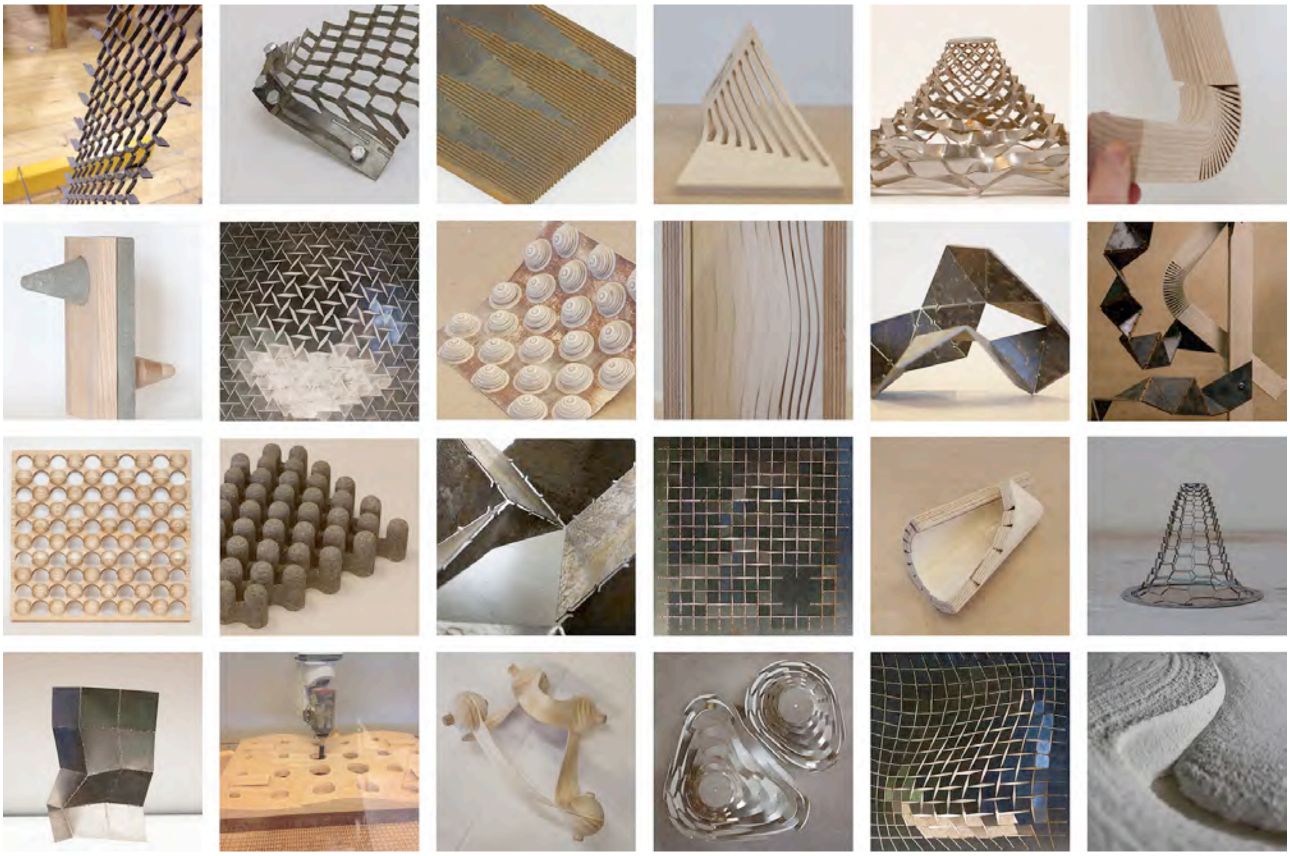

Figure 4: Examples of materials explorations and experiments. E.g. concrete casts, stretched metal and bend wood.

Through the combination of the material properties of different types, sizes and formats of steel wood and concrete and the machining consequences and logics from routing and cutting a quantity of preliminary experiments were created (Figure 4). All experiments were characterised by being closely focused on altering, modifying or editing the capacities in the specific material by embedding information into the materials through digital drawing instructed drawing. Looking at the experiments the non-deterministic workflow shows it consequence; the outcome tends to demonstrate unpredictable performances, textures, forms or uses through either a material transformation practised after the machining or non-designed consequences of the meetings between material and tool. An example is the results in stretched metal mesh (Figure 3). Here custom slitting of thin metal sheets using a CN controlled water jet prepares the wobbly material to be transformed. The transformation itself – the stretching - is variable, non-fixed but results in extraordinary stiffness and load capacity along with the spatial conversion. A parallel set of explorations was done in concrete where potentials of control and uncertainty were tested. In these cases either routed formwork with different elasticity encountered the density of fluid concrete or no formwork. The latter being executed through the dialogue between a scraper tool, moved by a robotic arm, and the fluid, but hardening, concrete.

As shown, and explained, the explorations with different machining and processing approaches to different materials and materiality revealed a number of both unforeseen and interesting discoveries or side effects. One of them was a variation of tradition kerf bending techniques, where a piece wood is cut in order to bend it in a direction normal to the kerf. The unfolding and development of this technique frames the focusing of this paper. The technique is dependent on the remaining wood and the strength and orientation of the fibres in the actively bend length. This finding led to a new series of investigation where a modified circular saw blade was mounted to a standard HSK tool holder on a 5-axis CNC router. With this setup, precise control of cutting directions and orientations are possible. The drawing for these investigations started out as explorative arrangements of lines that defined the tool paths for the saw. These drawings had in their earliest stages no or very little experiential foundation, but instead served as probing instruments in the process of finding relations and defining parameters in the encounter of machine and materials (Figure 5). Through the testing the drawings however gradually build up knowledge around the investigated procedures. Every iteration gave a material feedback to the drawing loop.

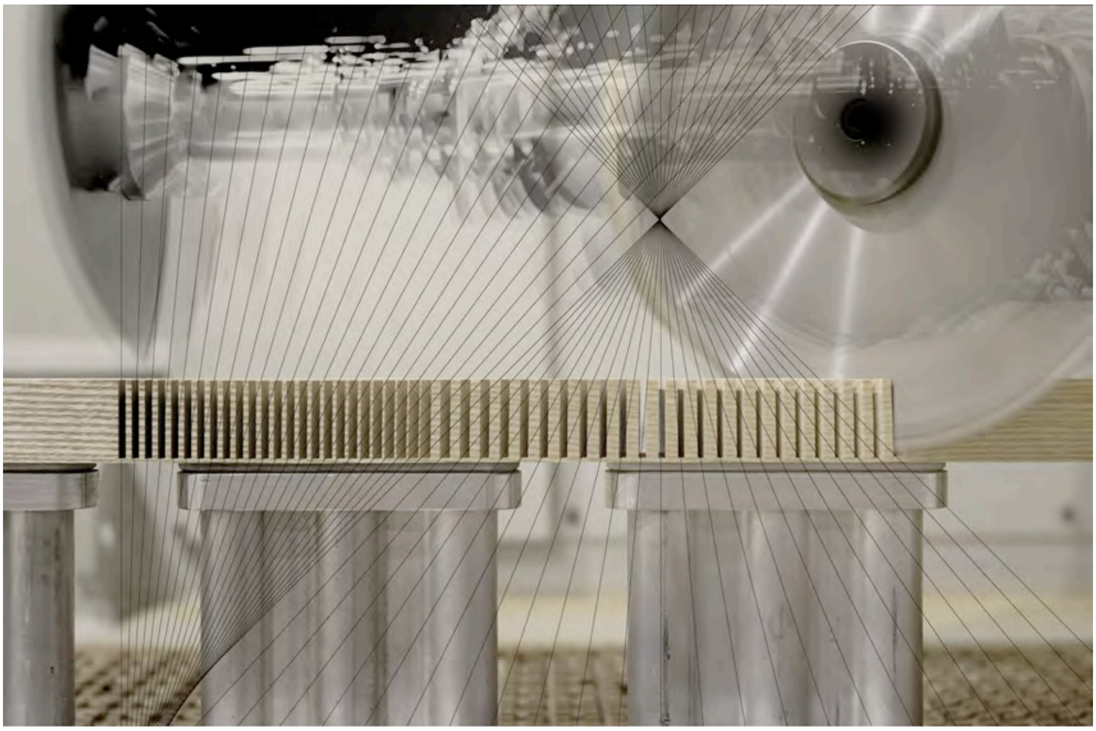

Figure 5: Relation between drawing, machining and material

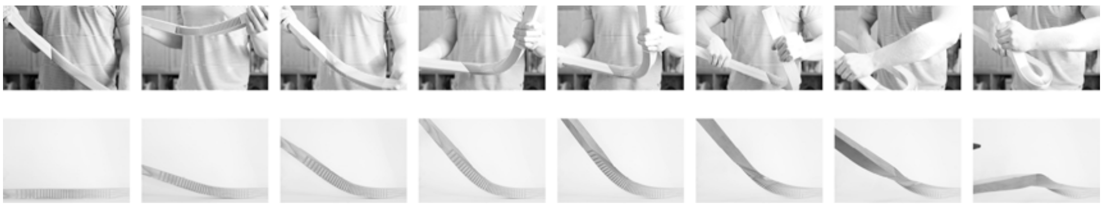

Figure 6: Exploration and systematisation

While defining a field of possibilities, iteration by iteration, the experiential gaining increased, taking the drawings from mainly being uncertain catalysts for surprises, to being vessels for obtained know-how. Increasingly systematic approaches to the fabrication were utilised, creating an overview of decisive parameters, the definition of those and their impact on the results (Figure 6). Kerf depths, cutting angles, kerf distribution and spacing, overall machining length as well as wood type and orientation all have definite impact on the bended shape that the machined piece eventually will be able to transform into. This knowledge, listed as parameters, in interplay with the machined result, was considered a combined design space and structural logic from which form and spatial compositions could be retrieved. This material and machining knowledge made a foundation for creating several versions of kerf patterns that could facilitate the bending of wood into surprisingly agile shapes. Eventually, ash wood was chosen as the prime material because of its long, flexible and strong fibre structure (Figure 7).

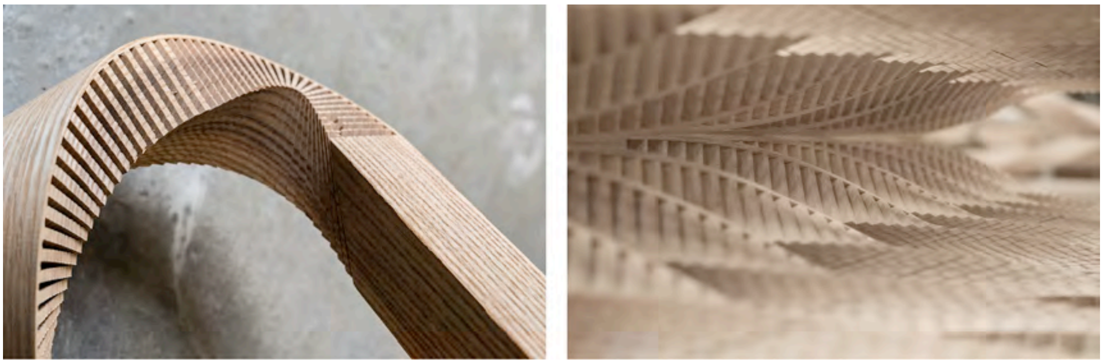

Figure 7: Machined and transformed ash wood

Towards fragment

During the process of investigations in wood further, although less extensive, experiments with concrete and CNC routed formwork was also carried out. These parallel investigations soon joined into a common intention of creating a hybrid component build from both series of material explorations. The concrete experiments, however, gained speed by a time where the wooden experiments already were well developed; resulting in more focused and maybe biassed experiment and design strategy. The concrete investigations eventually acquired a supporting strategy for the design space developed through the wooden experiments. Opposite to the drawings for the wood, the formwork drawings were drawn as explicit solid geometries based on shapes passed on from the results of the wooden transformation. Formwork was routed in expanded polystyrene (EPS). EPS is easy to machine, but the result is miserable for casting due to its open texture. Therefore, surface treatment is needed. The EPS negative solids were looked upon as blank three-dimensional canvases for imposing surface features that could brace the design – and in that way extend the active process of designing, that started digitally, into reality. Different materials, including acrylics, threatened wood, textiles, oils, solutions and more, were tested out. A partial lining with sheet latex cut by a digital cutter in combination with areas treated with an acid-based, retarding solution was chosen (Figure 8). This arrangement offered smooth surface texture where the latex was applied and a rough erosion of the surface where the solution was active. Playing on the capacities of the concrete, the formwork created an inside-out effect to the casting that mimicked and continued the ribbon-like effect achieved by the machined and transformed ash wood.

Figure 8: Formwork and cast concrete – surface test

The result from the combined production and form-finding process turned into a build bespoke, architectural *fragment*, named *Intermediate Fragment* (Figure 9). The fragment exists as a component of coherent transition between an ash wood construction and concrete base. The structure is an intermediate result based on the quantity of experimental results and the experiential knowledge gained from the research process of combining digital drawing and fabrication tools and an investigation in material capacities. While temporary acting as an exhibition piece, *Intermediate Fragment* is not to be considered a final result. It is to be considered an architectural fragment belonging to a process containing a quantity of informative and representation elements. This process is still on-going and the fragment is currently functioning as an initiator for a series of spatial drawings building on top of the experiences made through the preceding work.

Figure 9: Intermediate Fragment, a result of materials and machining driven design

Material and machining driven design

While not driven by or strictly following, the design process of *Concrete* resembles the thoughts of Aart van Bezooyen, described in the text *Materials Driven Design* (van Bezooyen, 2014). Van Bezooyen describes material driven design as being about bringing the materials to the beginning of the design process by using material samples to expand the idea generation or use the materials as starting points for exploring different applications. This approach of *materials exploration* is in contrast to that of *materials selection*. Van Bezooyen explains the difference using the *double diamond design model* (Design Council, 2007) where the process of design is described by the phases *discover*, *define*, *develop* and *deliver*. In a traditional design process materials selection takes place in the develop phase, whereas in a design process driven by material exploration, materials are introduced in the discover phase and thereby utilised to inform the design in a broader way (van Bezooyen, 2014).

The process of creating *Intermediate Fragment* was indeed characterised by being material driven. But just as much characterised as being *machining driven*. The machining of material as a design-driving factor opens up possibilities for material exploration. Without being limited to try to realise a predetermined shape, the machining instead becomes a way to initiate a more sketch-like process. At the same time, because the machining is real and the output is actual, the process also starts to shape a production method and strategy around the design to be. Potentially materials and machining driven design will not only be able to suggest new spatial uses and shaping of materials in architecture, but also be able to suggest the process of manufacturing these in a later construction phase. With this potential the inclusion of materials and machining of materials in the early design process create a two-fold strategy to a tighter connection between design and realisation.

Expanding representation

While many of the techniques, methods and tools used in the designing and the fabrication of *Intermediate Fragment* and its preceding phase of material research and experimentation are well known and established architectural tools, the project, and proposal of a material and machining driven design method, suggest both an expansion of the architect's toolbox as well as an extended idea of architectural representation.

Architectural production is traditionally characterised by existing of a number of different representational pieces altogether bringing forth a collective explanation and understanding of a coherent idea (Leatherbarrow, 2001). Compared to art, architecture is not developed within the same materials and mediums as the results, the buildings, to be (Evans, 1997). Architectural representation is often multifaceted, engaging the project through different mediums and from different perspectives. Scale models, sections drawings, artistic visualisations, detail drawings, conceptual diagrams, material samples – they altogether try to form a notion of what the specific architecture and an architectural idea is about. Individually every piece of representation in this set can be of artistic, professional or technical value but newer alone do they deliver the cohesive understanding behind an architectural project (Leatherbarrow, 2001). The architectural set is representational and altogether forms a domain of individual, but relational fragments. Put together, these elements create the context for understanding a proposed architecture, but also an understanding of the architect's underlying work. In that way, architectural representation often compresses both a conducted work process *and* the idea of a future construction into a complete set.

As earlier noted the use of digital fabrication tools have proven to bridge between digital drawing and material, making the architect able to inform production through drawing. Mainly in academia, but also in office practice, the linkage has resulted in a current era of pavilions and small-scale experimental architecture types. They seem to discuss this coupling while testing out new material and construction system found through these processes (Gramazio et al., 2014). While many of these structures stand on their own and, to a certain degree, can be regarded as autonomous pieces of architecture, they are not buildings and their existence do not replace the need for buildings - and were not intended do to so. Instead they propose new spatial possibilities, through new ways of designing structures and machining material, that potentially could be implemented in future buildings.

On the basis of this existing field established around digital fabrication in architecture and the author's own practice this paper suggests to see this new type of architectural production as an expansion of the already existing set of representation. Tangible, material constructions provides another perspective on both the creation and presentation of an architectural idea and should in that context be seen alongside with drawings, models, diagrams etc. The on-going creation of architectural representation will always play a key role in the designing of architectural space and generation of spatial ideas. Sketching and modelling in any medium will provide a constant, experiential feedback to the design process. Specific for the material representation created through digital fabrication is however its ability to be both introduced very early in the process and throughout the designing continuously evolve alongside with the development of the associated drawing and the machining method. Phil Ayres articulates this process as *persistent modelling* (Ayres, 2012) meaning a process of constant production and evaluating shuttling between digital and physical domains and argues that this way of designing is extending the *role* of architectural representation. This type of representation can drive a design, but also evolve into information that is not only picturing but holds information for realisation itself.

Concluding remarks

This paper is pointing at the potentials of using digital drawing in combination with digital fabrication as a method of introducing materials and materials research in the early stage of architectural design. It is the claim that doing so will result in other types of design than that of a process where materials aren't playing a role before a design is determined. The higher potential of letting materials exploration play a role in architectural design is however to achieve architecture with greater material awareness and quality and furthermore create a much tighter and deeper connection between spatial design and the construction of this. The suggested design method is benefitting from material and fabrication possibilities normally limited to construction and manufacturing while at the same time creating information that eventually will by applicable in the event of realisation.

The paper is pointing at a blooming field within architectural research, but also pointing at the potentials of bringing this field to the general architectural set of representation. Architectural representation can often be distanced from the reality and context of an eventual construction, often leading to a mediocre realisation of the building. By including material exploration earlier in the design process the architects can both benefit from extended design and representation methods, take responsibility for the actual, real appearance of the design they are suggesting and provide knowledge that can benefit construction.

It is the agenda of this paper, and the research project behind, to present material research and digital fabrication as beneficial for architecture in ways that are not solely technical, optimised or rationalised. It is the argument that architectural design can take great advantage of the mentioned connection between drawing and materials through a much more experience, explorative and reflection based approach. In order to investigate this claim and bring novelty to the field, the author has chosen to involve own work, material research and design processes along with the studies on existing work. As well as it is the claim that tangible, experiential material exploration can enrich architectural design, it is the claim that the same is valid for architectural research.

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Anders Kruse Aagaard

Anders is an architect currently in progress with his Ph.D. research project at Aarhus School of Architecture. Both in his research an architectural practice Anders' interest is revolving around materials and the role materials and materiality can have in the design and creation of architecture. In the Ph.D. project, digital fabrication plays a key role in order to link the machining, shaping and use of material to the early phases of designing.

Material knowledge – unlocking the research potential of the 'micro' architectural practice.

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Abstract

Materiality is the medium through which architecture engages most directly with its inhabitants, via their sensory and perceptual faculties. Current understandings of the physical traits, symbolic potential and poetic qualities of constructional materials benefit from earlier theoretical and empirical investigations. Such explorations continue through the work of contemporary architecture practices, particularly at the early design stage of projects and during the building process, when material investigations are undertaken as a matter of course. In the UK, small practices (5 or fewer staff) comprise the majority of the profession, so their collective work can be expected to contain a significant proportion of its material investigations. Their studies provide a body of constantly updated information related to current materials, design practices and constructional techniques, although in general these appear to remain undeveloped beyond fulfilling immediate, single-project requirements. Small practices are often, of necessity, frugal with their limited resources, but a wariness of research culture curtails opportunities to exploit their acquired material knowledge more fully. This paper uses examples from present-day practice to illustrate these points, and to consider how they might be overcome. Favourable possibilities exist through collaborations with teaching and research establishments, who are currently eager to augment the practical impact of their studies through knowledge exchange projects. Additionally, architects' professional bodies are keen to facilitate their members' adoption of a more rigorous engagement with research, through programmes of continuing professional development. Architects' material studies through practice can also benefit from the enhanced credibility offered by recent thinking on the topic of 'design research'. By adopting a more research-oriented worldview, small architects' practices have the opportunity to articulate and exploit more comprehensively the knowledge embedded in their projects; to contribute more significantly to the evaluation and development of constructional materials; and thereby to enhance the understanding of materials in contemporary construction.

Keywords

material; architecture; practice; research; CPD

The aims of architecture remain encapsulated in the ancient Vitruvian triplet 'firmness, commodity and delight' (Wotton, 1903), a synthesis of constructional, design and experiential components. The process starts and ends with abstracted thought - from architects' ability to distil relevant concepts from their knowledge and imagination, through the construction of a physical structure, to the sensual and perceptual responses that mediate individuals' experiences. Although philosophers and historians have addressed these matters extensively and usefully, ultimately, architecture is defined through its corporeal substance. Buildings engage directly with people’s senses and perceptions through their materiality, even in the absence of mediating opinions. As Adrian Forty noted, “to describe the physical properties of architecture only demonstrate[s] the redundancy of language” (2000, p. 23). Architects themselves are prone to blurring the boundaries between the virtual and the actual. Until recently, it was a relatively simple task to discern between unbuilt 'paper projects' and realised buildings in architectural journals. This distinction is now much less clear, as computerised rendering has allowed 'drawn' simulacra the same visual equivalence as photographs of built works. Although these often provide good representations of attributes such as shape, scale and colour, they can at best only hint at the finer phenomenological aspects embodied in even the simplest built form. The nature of materials is very difficult to express properly other than through the construction of an actual building, at which point additional experiential layers - such as hardness, smoothness, heft - come into being. Materiality is the fine grain of architecture, the visual interface with its viewers, and the tactile engagement with its inhabitants. It can be infused with a range of meanings, emphasising or ameliorating the structure's narratives about origin, process, craft, status, religion, culture, affluence, technology, and so on. Each individual who inhabits a building may attribute their own meanings to materials, and develop nuanced understandings by applying values based on personal intellect and experience to the perception of the objects in their contexts, a dynamic referred to by Elvin Karana as a "meaning evoking pattern" (2014, p. 253). In contemporary mainstream building culture, architects are in a position to mediate these various ingredients. If they wish to maximise the material potential of their buildings, they must consider and understand the possibilities of the components used, from their physical properties to more abstract connotations. While the resources of larger offices and academic institutions are more suited to translating material investigations into long-term research programmes, there is also a significant body of potential evaluation and knowledge embedded in the daily work of smaller practices, whose focus is often, of necessity, much more geared towards 'doing' than reflecting. Such reflectiveness can be of benefit at all levels of practice (many iconic buildings have been at the scale of the house, or even the hut), as architectural worth depends on the qualities of contemplation and execution expressed. There are a number of routes through which such knowledge may be extracted and shared for the benefit of practitioners, and of the built environment.

The remit of the architect is expansive, and Ezio Manzini (1989, p. 55) commented that architects "face the entire range of technical possibilities, with reference to a value system that includes social attitudes, linguistic expressions [and] aesthetic considerations". Each practice responds to the possibilities inherent in its own particular situation (through its size, workload and world view), and of necessity develops the types of knowledge that most usefully contribute to developing its potential. There are therefore strong, situation-driven links between a practice's structure, the information and skills it pursues, and its consequent constructional and material output. Larger offices often overtly frame their pursuit of relevant knowledge, as 'research', and the resulting expertise can be useful in promoting the practice's skills to potential clients and other architects. Francis Duffy (2007), who conducted seminal theoretical and technical explorations for large practice DEGW, conceded, however, that this approach requires a shift from the profession's primary concerns - "addicted to physicality, [architects] adore whatever is concrete - structures, materials, places, things. We tend to underestimate abstract ideas" (p. 121). Most UK offices are too small to be able to employ dedicated research staff, instead concentrating primarily on the immediate, practical requirements of finding clients and delivering buildings. A report by the Royal Institute of British Architects (RIBA) stated that more than 50 per cent of British architectural practices are 'micro' in size (having 5 or fewer employees), and commented that the "vast majority of practices are tiny...and focus on the challenge of running really very small, hand to mouth operations" (2014a, p. 1). This is not to say, however, that such offices do not engage in reflection on issues such as materials as part of their everyday design, specification and construction experience. Assisting this is the ubiquity of the internet, where a vast range of specialised information is increasingly available. This has coincided with, and helped reinforce, a wider movement within education from an "instruction paradigm" to a "learning paradigm" (Barr and Tagg, 1995), founded on learning communities gaining access to a continuously developing body of knowledge. Part of the reason why architects' professional bodies oblige their members to follow a programme of continuing professional development (CPD) is to enhance the overall knowledge of topics of interest to practitioners, such as material performance and sustainability (RIBA, 2015). The CPD ethos seeks to encourage architects to develop systematic programmes of understanding, rather than just ad-hoc investigations, and so expand the body of specialist knowledge available for those engaged, directly or indirectly, in design and construction (Binder and Redström, 2006). Christopher Frayling (1994) commented on the fundamental interrelatedness between design and research - "the brain controls the hand which informs the brain" (p. 4), which psychologists would recognise as the mutually reinforcing 'top-down' and 'bottom-up' processing model that is understood to support everyday cognitive comprehension. His argument developed, however, by noting that there are significant differences between research 'into', through' and 'for' (art and) design, and that the relationship between the output 'object' and related knowledge can vary widely depending on the standpoint of the researcher. While Steven Hodder considered 'design research' to be "at the very heart of what it means to be an architect...solving problems and creating new knowledge through the process of design" (RIBA, 2013a, p. 2), a degree of ambiguity may result from the differing skills and aims of architectural practice and research (Binder and Redström, 2006). Architectural education is fundamentally design-oriented, geared towards the production of material, habitable structures, but with relatively minimal teaching of research epistemology - instead, the tools acquired have traditionally tended to be along the lines of "experience, trial and error, intuition and muddling through" (Schön, 1983, p. 43). The professional academic or researcher can generally be expected to have a better facility with, and understanding of, appropriate methodology, and potential means of disseminating their output. Nevertheless, architects' work is located within wider societal movements towards continuous professional learning, and increasing academic recognition that design and research might usefully be combined to exchange ideas and develop new knowledge. These offer a climate in which practices of all sizes can potentially contribute to, and benefit from, new insights into materials in construction.

Most UK architectural practices cite a lack of time and financial resources as reasons for not undertaking research in practice (RIBA, 2013b). How then might they better assess and develop their material knowledge? Practices generally proceed through set stages in the development of their commissions based on recommendations of their professional bodies (RIBA, 2013c), although each practice's situation, and hence material output, will vary. Building projects usually involve a 'concept design' stage, which precedes the preparation of a developed design, and during which outline proposals are considered (RIBA, 2013d). At these early stages (common to large and small scale works), investigations are made into the most suitable materials for the purposes of practicality (such as durability and fire resistance), aesthetics (whether they will complement or enhance the overall proposals), social acceptability (use of prescribed materials in conservation areas, for instance) and cost. Investigations, generally comprising an informal research procedure, are undertaken as a matter of course, and inquiries into materials form a significant element within this. In the context of the 'hand to mouth' existence of many small practices, these are usually undertaken to generate specific knowledge required for a project, and do not require to be placed into a wider context. An example of this narrowness of focus is illustrated by an example from the work of the author's practice. In the course of a planning application for a new-build housing project in Edinburgh, the local council objected to the proposed use of external brickwork, stating that the predominant materials (in a World Heritage site) were natural stone and render. The practice undertook a detailed investigation of the area around the specific site in question, including mapping the historic local usage of materials, and a photographic survey of extant buildings (Figure 1).

Fig 1. Photographic survey of original site. (Image: E&F McLachlan Architects)

This demonstrated that the area of hinterland in which the proposed housing was to be situated had been developed during the industrial revolution, primarily utilising clay brick as a facing material. The oversimplified narrative put forward in the council's objections was challenged and overturned, and the development was subsequently constructed in brickwork, with the design drawing on the information obtained from the survey (Figure 2) (Law, 2000).

Fig 2. Completed housing development. (Image: Keith Hunter Photography)

Other than helping to refine the design response of the new building to its location, however, the output from these wide-ranging studies thereafter remained unused in the practice files. In retrospect, such investigations could have provided a rich springboard for deeper reflection, both in respect of the specific knowledge gained (into the historical use of brickwork in industrial Scotland, for example) and into the practice's approach to the methodology of study. This appears to be typical of the material knowledge gained (then forgotten) by many practices in the course of their normal design activities (RIBA, 2014b), which "don’t necessarily recognise the activity as a research process" (RIBA, 2013a, p. 3). In the course of an architectural project, an individual study may justifiably be an end in itself, but research output is more than a collection of usable data. The process must go beyond established disciplinary modes of inquiry (Binder and Redström, 2006) - it demands a broader context, process, or theme, and a means of broadcasting relevant findings. In fairness, there has been debate about what exactly 'counts' as credible research in the context of architectural practice. Is it, in fact, an intrinsic part of what architects do, or is something that requires different thinking, "a kind of step-change in the way in which architects/academics conceive of and produce their designs" (Fraser, 2013, p. 4)? It seems logical to assume, however, that amongst the great range of the 'micro' practices, there must be a substantial pool of explorations into constructional materials, considered from a range of viewpoints (chemical makeup, aesthetic properties, historical meaning, and so on) that could be usefully developed, if architectural practice and research epistemologies could be more closely aligned.

The means through which small architecture practices' investigations into materiality might generate a more systematic form of research is a part of the larger question of how various kinds of art and design practice might transition into 'design research'. The required leap is not necessarily a large one - Ken Friedman proposed that new knowledge is generated through the "interplay of experience and reflection, inquiry and theorizing" (2000, p. 23), all of which are intrinsic to the process of designing a building. Furthermore, there is a body of useful contemporary discussion around the topic of 'design research' as it relates to architecture. Murray Fraser (2013) notes that architectural processes can be the "central constituent" (p. 1) around which a variety of research activities can be woven, each potentially adopting, where appropriate, the most relevant methodology from other disciplines. There are also useful examples that focus more directly on 'everyday' practice itself as a basis for research. Since the mid-1980s, for example, Leon van Schaik has cultivated a body of practice-based research, which seeks to provide individual architects with tools through which they can reflect on their work in its wider context. The aim is to develop outputs that then feed back into their continuing practice, and are given academic credibility through masters and PhD programmes. The 'scholarship cone' research model developed by van Schaik envisages the individual practitioner's present search for insight being derived from a 'base' that consists of his or her existing body of work, with the 'tip' of the cone representing an aspirational movement towards future work (Schaik, 2011). Architects are encouraged to develop an awareness of their personal design processes (and gain confidence in their intellectual rigour), through articulating them internally, and through peer review. Through iterations of feeding back the understandings gained, the aim is to acquire a deeper, dynamic comprehension of, and hence control of, their future work. Often, however, practitioners have been accused of ignoring the opportunities that might be afforded by integrating a more rigorous research approach in their work, and of raising "cultural barriers" (RIBA, 2013e) to it. A study by the Royal Incorporation of Architects in Scotland (RIAS) notes an institutionalised misunderstanding of the nature and role of research, scepticism as to its usefulness, and an inability to articulate ways in which architectural practice might translate into research (RIAS, 2005). The difficulty appears less likely to be a lack of intellectual capacity or skills available to practitioners, but more a question of how they frame, rather than undertake, their work - "you can...try to be academic, but the real value in the reflective practice process is...not about trying to transform the way that you do things; it's about trying to transform the way that you think about what it is you do" (Hook, M. in Schaik, 2011, p 90). This shift may be easier for large-scale practices to address, as they seek to define a niche for themselves that can define their expertise from that of their competitors. As an example, Stephen George & Partners, based in London, undertook a significant body of investigatory work into constructional materials. In addition to recording this for their internal use, they established a 'Sustainability and Technical Group' within the practice, and published online their evaluations of, and insights into, the environmental aspects of materials (2010). By situating their job-related investigations in the wider context of building sustainability, then collating and disseminating their findings (with referenced sources and links to additional information), they successfully transitioned their concept design processes into relevant 'design research'. This also benefitted the practice's marketing strategy by broadcasting their material knowledge and expertise. For the 'micro' practice, where the scale of projects is small and office means are more restricted, collaborative investigations may offer a way to contribute through sharing resources, as the following example from the author's practice shows. The design for a social housing development envisaged some form of concrete element to separate the adjacent main doors to two dwellings (Figure 3).

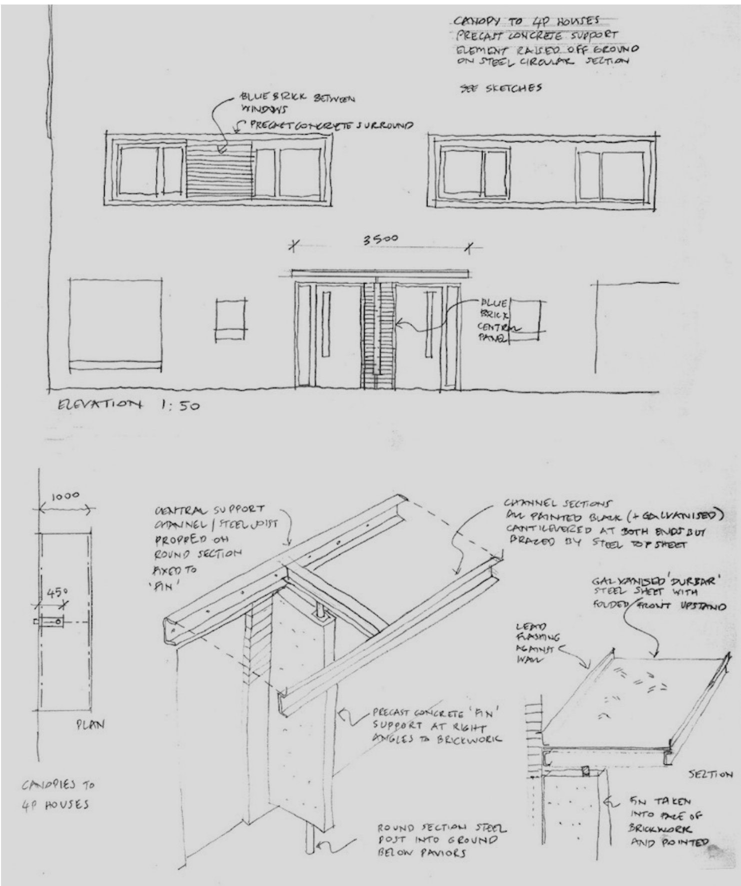

Fig 3. Design sketches of the main door configuration. (Image: E&F McLachlan Architects)

One partner in the office also teaches at the University of Edinburgh, which was undertaking an experimental research study into fabric-formed concrete, and was keen to have the opportunity for a 'real world' test of its output. The housing project was already under construction, and the practice offered to build some fabric-formed components into the housing. In exchange, the office gained knowledge of the university's engineering test methods and data, and an understanding of the effect of specific 'formwork' fabrics on surface hardness and texture. After discussion, a polypropylene geo-textile woven membrane was selected for its strength, low cost and the ability to control water permeability, the precision of the potential shape-making, and the poetics of the simultaneous hardness of the material and the detailed softness of its form (Figure 4).

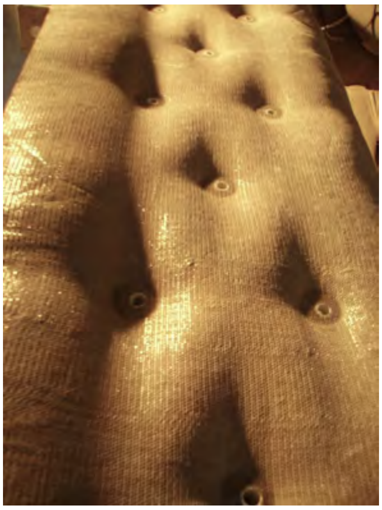

Fig 4. Form and texture of a poured concrete 'fin'. (Image: Professor Remo Pedreschi)

Fig 5. Fabricated concrete 'fin' in the workshop. (Image: Professor Fiona McLachlan)

At the end of the discussion and testing programme, the final components were cast in the University's workshop (Figure 5) then assembled as a part of the housing development (Figure 6).

Fig 6. Concrete 'fin' as part of the constructed building. (Image: Paul Zanre Photography)

Due to the proximity that the practice had developed with the University's research culture, rather than simply close the job files at the point of construction, opportunities were subsequently taken to record the process and publish the project outcomes in a conference paper (McLachlan, Pedreschi & Lee, 2007) and book chapter (McLachlan, 2007). Disseminating knowledge and experience, whether through papers, other documents or websites, is a key step towards the 'micro' practice participating in developing discussions about research topics. Furthermore, it helps to set the agenda for what topics would be most usefully investigated from the point of view of the small office, a "recognition that research is problem-defining as well as problem-solving" (Coyne, R. in Fraser (2013) p. 192). Across the architectural profession in the UK, an immense loss occurs between the quantity of materials information collected and analysed, and the quantity recorded and disseminated (RIBA, 2014b) - a recent study concluded that although 79% of practices consider research publication to be beneficial for them, only 33% had published (RIBA, 2013b). Looked at more positively, this suggests that there is a significant constituency of architects who could be encouraged to bridge the gap between their daily practice and more formal research.

The 'concrete fin' exploration demonstrates one route by which a small architectural firm was able to engage in 'real' research, through collaboration with an academic institution. The project allowed the practice to pursue a greater level of manufacturing exploration than would have been cost-effective for a concrete manufacturer to undertake, and to tap into the university's research culture. The practice was still able to overlay this with its own design philosophy, as it is "inevitable that the procedure, if objective and scientific, will only approximate to the richness of the experience we wish to observe" (Canter, 1977, p. 26). The fabric concrete exercise allowed the practice opportunities to develop their ideas for the experiential aspects of both the 'fins' (their "embedded personality" (Karana, Pedgley & Rognoli, 2014, p. xx)) and the overall housing. The 'fin' elements expressed a loose, crafted, sculptural identity, derived from the contingency of the varying tautness of the fabric mould, in counterpoint to the strict, orthogonal repetition of the facing brick walls. At close quarters, the tactility of the fabric pattern, hand-sized curves, surface sheen and the coolness of the material became evident, and the expression of these details, from visual to tactile, articulated an increasing level of privacy at the house entrances. According to Juhani Pallasmaa, "vision and hearing are now the privileged social senses, whereas the other three are considered as archaic sensory remnants with a purely private function" (2005, p.

18). At a broader level, the practice also envisaged the housing design as sitting within a body of other social housing developments (such as the work of contemporary Dutch practices, exemplified by Claus en Kaan (Figure 7)), that had successfully used precast concrete elements to articulate relatively simple, low-cost brickwork facades.

Fig 7. Housing development, Groningen by Claus en Kaan Architecten. (Image: E&F McLachlan Architects)

In addition, the 'fins' were used to develop the concept of the elaborated doorway, echoing earlier traditions in social housing, such as Michel de Klerk's Eigen Haard development in Amsterdam (Figure 8), and Herman Hertzberger's (2009) explorations of thresholds between public and private domains.

Fig 8. Eigen Haard housing, Amsterdam by de Klerk. (Image: E&F McLachlan Architects)

This example is typical of the small scale at which the 'micro' practice is most likely to engage with organised inquiry, the output (both built and written) being small fry when seen against the research programmes of large offices and learning institutions. It is also the case, however, that "...new knowledge can also emerge through the relatively small increments of knowledge..." (Groat and Wang (2013) p. 6), and the breadth of experience of small practices suggests strongly that new insights and information can usefully be gleaned from their output.

Materiality, then, is at the heart of architecture's communication with those who use and inhabit it, and materials research is one of the principal research topics investigated by architects in the practice context (RIBA, 2014c). In general, however, most appear to have no broader ambitions for this than to meet the constructional needs of the current project at hand, and do not frame their working procedures as research (RIBA, 2014c). What then prevents the wealth of new knowledge and re-evaluations of materials in practice, accumulated by small practices that regard material investigations as being an "intrinsic part" of their normal project work (RIBA, 2014c), from being better utilised? Architects' professional institutions have identified the principal difficulties as being a general belief amongst architects that their working practices are alien to "real research" (RIAS, 2005, p. 4); a lack of understanding of research culture (RIBA, 2013e); and the different perceptions held by practitioners and academics (RIBA, 2014b). What appears to be needed are ways to transition from an informal case study approach, and relatively loose methodology, to programmes of research that can give appropriate theoretical frameworks (whether or not based on Positivist foundations) within which to set individual material explorations, and then to allow useful lines of enquiry to be promulgated between practices. Although a 'snapshot' study by the RIBA found little to suggest that architects' practices and research academics generally interact meaningfully (RIBA, 2014c), confirming that "the focus of academic research is not driven by practice and practical issues" (RIBA, 2014b, p. 11), there are a number of ways in which this might be addressed. The first is through greater liaison between research institutions and architectural practitioners. The programme set up by van Schaik in Melbourne offers one example, providing a vehicle for individual practitioners to learn ways of developing their design work and material output as research. There is also an increasing onus on academics in the UK to expand 'knowledge exchange' programmes through collaborations between universities and other bodies, and to embrace more widely topics that 'impact' beyond academia (National Measurement Office, 2014). Learning institutions can seek to benefit from access to the design office and construction site, while architects can learn from exposure to relevant methodologies and protocols, and the context offered by broader investigative positions (as in the example of the fabric concrete element noted above). While mechanisms to encourage collaborations exist (such as documents that assist practitioners in identifying potential academic partners through their mutual interests (RIBA / SCHOSA, 2013)), funding opportunities to participate in this have not yet been widely taken up by architects (RIBA, 2014b). To encourage the take-up of these, financial inducements for architects to undertake more active forms of CPD could be linked to such collaborations, and research could be recognised to a greater degree through relevant programmes (RIBA, 2013e). Although no specific data appears to have been collated into the numbers of practitioners with connections to educational establishments (RIBA Research Projects office, personal communication May 22, 2015), most practices value these links, and many small offices augment their income and networking opportunities within academia through teaching (RIBA, 2010). It has been reported, however, that while "significant number of practices had some academic links...few practices attempted to access academic research" (RIAS, 2005, p. 6). Nevertheless, practitioners already engaged in teaching would seem to be the most fruitful initial source for the expansion of research exchanges, and a means of encouraging the uptake of more rigorous methodology, processes that demonstrate evidence of original thinking, and avenues for disseminating information widely. Despite the current distance between practitioners and academics, the potential overlap between universities' expansion of knowledge exchange schemes and architects' professional bodies' desire to encourage practitioners towards research makes the outlook for the next few years appear more promising. If the cultural barriers can be dismantled, at least to an extent, then the 'micro' practices may pioneer a significant re-evaluation of materials, and consequent acquisition of new knowledge, in the UK construction industry.

Architecture is a physical expression of thought, design skill, knowledge and culture, articulated through the materials from which it is constructed. Societal understanding of these corporeal elements advances through exploration, debate and the sharing of knowledge. Through their everyday design, administrative and constructional processes, architectural offices acquire a large reservoir of insight into, and understanding of, the functional qualities of materials, and their experiential, environmental, and social attributes. Most practices in the UK are very small in size, but cumulatively, they contribute significantly to this resource. The offices work within a contemporary paradigm where they undertake intense, usually informal, researches to gather and analyse information to meet the specific needs of current projects. Much of the detail acquired is, however, subsequently discarded, when parts of it have the potential to be integrated into a more organised body of research, to expand the knowledge of the profession and the wider research community. Despite the entreaties of their professional bodies, opportunities for collaborations with research-skilled establishments, and the development of 'design research' as a legitimate field of study, most UK architects have been reluctant to address the cultural shift necessary for the expansion of research through their work. The increased practical impact sought by established researchers, and the expansion of architects' continuing professional development programmes suggest that there are sufficient opportunities through which small architects' practices may overcome cultural barriers to 'real' research culture. Through a more rigorously developed debate about the constructional, design and experiential aspects of architectural materials, they may unlock their accumulated body of new knowledge and help to accelerate the architectural profession's transition from a 'learned' one to a 'learning' one.

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Digital Crafting in the field of Ceramics

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Abstract

This article aims to discuss and explore how craft knowledge in the field of ceramics can be utilized through digital technologies. Based on a set of experiments, which led to the development of a computational system that negotiates between the movement of the designer's hands and the 3d clay printing, we propose to leave thinking in diametric positions about technology and craft. Instead, we recommend to see technology as an enabling force and follow McCullough's (1998) idea about a close connection between digital work and craft practice. We base this on similarities we find between the way custom digital design tools are developed and the way craftsmen in the field of ceramics are developing their material and tools for the making of ceramics. The communalities are especially centred on the experimental approach, pursued by both fields. Reflecting on these positions through our own work we identify different modes of experimenting, which are useful to drive design development and to develop the concept of digital crafting in the fields of ceramics. We explore how novel digital means can be utilized for a parametric setup that directly informs ornamentation through bodily engagement and discuss how craft knowledge in the field of ceramics can be utilized through digital technology.

Keywords

ceramics; digital crafting; 3D digital interactive system; 3D printing; experiment; aware models

Novel digital means create new interfaces and processes between human, space and material. Advances in 3d motion capture technology and sensors allow to capture spatial hand gestures and body movement in real-time. At the same time digital technology as 3D printing allows to bridge from the digital design environment to fabrication.

This research investigates how these technological developments open spaces for new expressions and allow rethinking of traditions in ceramics.

Focusing on practices with ceramics, we pose the questions how and where traditional craft based knowledge, routed in skills and experience of making three dimensional objects, can meet and inform novel ceramic processes, which utilize digital technologies?

We present a project, developed through a set of experiments, which aim to create a holistic design environment for the making of a set of bespoke ceramic objects. This environment consists of a computational system that expresses the interactive movement of a designer's hands, a 3d clay printing and firing process and the design and making of a final installation of the developed products.

Craft practice

Craft and artistic practice are in this research based on the idea that the interaction with a responding material guides the ceramicist (Leach 1940, Dormer 1994), and crafting and execution works as a unity that is intuitive and humanistic (Leach 1940).

Following Leach and Dormer we argue that traditional craft can be understood through two parallel levels: its immediate interface to matter, which is able to provide instant feedback, and through the consistency of design logic and material process.

Katie Bunnell (2004) defines craft as: *…an essentially human and humanising process. To craft something involves human interaction with technology whether it's a pen, hammer, or computer software and hardware. In the experience of a maker it involves a high level of autonomous control over a holisitic process of designing through making. (Katie Bunnell, 2004).*

Similarly we propose to abandon thinking of craft and technology as diametric positions, and instead to see technology as an enabling force - following McCullough's (1998) idea about a close connection between digital work and craft practice.

Our project creates the base for a discussion in this article, how craft knowledge in the field of ceramics can be utilized through digital technologies. We argue to see the close link between the creative process and the digital manufacturing based on the observation of crafting and execution as a unity that is intuitive and humanistic (Leach 1940).

Similarities

The outset of our experiments was an observation of similarities between the way custom digital design tools are developed and the way craftsmen in the field of ceramics are developing their material and tools for the making of ceramics.

The similarity is found in the process of iterative experimentation within the chosen media to achieve a desired expression and behaviour of the final outcome.

A novel set of design software brings easier ways for artist, architects and designers to develop tools specific to their own projects. An examples of this is the 3D modelling software Rhino (Robert McNeel & Associates http://www.rhino3d.com/) and its graphical programming interface Grasshopper developed by David Rutten (http://www.grasshopper3d.com/).

Grasshopper, is a visual scripting environment, which is used by artist, designers, engineers and architects to generate geometries for shapes, objects, structures and even highly complex buildings. The core of this activity is to find and encode the generative concept underlying the geometries into custom tools.

While the concept of parametric modelling of geometries in design software dates back to the earliest work in this field by the Computational Design software Sketchpad developed by Sutherland (1963), it is only recently, that this approach is acknowledged across the disciplines with programming API and visual scripting tools widely available in software as Solid Works, Maya, Blender and many other open source tools. While the industries focus is still on the generation of geometries, experienced practitioners and researchers investigate means to implement knowledge on material and process into custom digital design tools (Tamke, 2015).

A distinction can be made between tools, which are adjusting or improving a design after its genesis, in order to fix flaws or make it buildable, and those tools, which interact with the designer during the design process and support him in creating designs, which are just to material, process and eventually later useThese first set of tools are often found in workflows with 3d rapid prototyping, where a design and its representation as polygons is fixed by algorithms found in tools like MAGICS by materialise (http://software.materialise.com/magics) or in more advanced research, where the design is analysed and reinforced locally with FE analysis (Umetani, 2013). The second approach is for instance explored in depth by the Centre for Information Technology and Architecture (CITA). In their research they develop digital models often using Grassshopper, which are able to synthesize design intent, fabrication needs and material behaviour to a degree, which extends finally the space of design into the making of highly specified materials and behaviours (Thomsen et al., 2013). We call this *digital crafting* (Thomsen et al., 2012). Digital design tools are no longer operating in a disembodied space of representation, which take the designer away from matter, but they are a way to extend the designers ability and senses to craft material.

The material and techniques developed by the ceramicist can as well be seen as tools customized to the specific needs of the design project.

The design process for the ceramic artist can be described through the concept of Materialdriven formfinding (Hansen, 2010), which is firstly to develop and identity a potential of a material through experiments, and secondly to transform and actualize this potential in a number of versions. This can as well be described as a dynamic and uncertain process that links a virtual component to an actual one. The actual component expresses a variation of the virtual component (Kvinter, 2002).

An exemplary ceramic artist is Gitte Jungersen (Veiteberg, 2011), who develops her own clay and glaze as a tool that contribute with certain shapes and textures based on the chemical compositions. Through the firing the chemical process will transform the shape and texture based on the chosen chemical compositions. The created material process is the artist’s fingerprint.

Another example is the work of Extrudox which is a collaborative project between the ceramists Anne Tophøj and Steen Ipsen (2011). Their work is based on extruded ceramics, which is in the very moment of extrusion is manipulated, based on the consistency of clay.

We find, that the need and will to develop project specific tools and process, which are becoming finally the carrier of concept and the generator of form is at the core of both ceramic and a computational design practice. The bespoke tools are able to provide immediate feedback through embodied interaction. We will discuss how a close link between the creative process and the digital manufacturing allows both an extension and utilization of craft knowledge based on skills and making through digital technologies.

Method

Design is in our research project used as a method of inquiry, a reflective practice, in which the designer engages. Design inquiries are in our research project used as a method and at the same time, a material practice and a contribution to the production of knowledge (Brandt & Binder, 2007, Koskinen et. al., 2008). Design is for this purpose a powerful form of experimentation: a means for inquiring and of producing knowing (Binder & Redström, 2006). “It is concerned with moving away from the existing and the known, through intentional actions to arrive at an as yet unknown, but desired, outcome” (Downton 2003). The mean to do enter and engage the unknown were a set of consecutive experiments. Experiments are in this context understood in a wider sense, following philosophers of science, as Allan Franklin, who assigns them in his work (Franklin 1986) several key roles:

- exploration of a new domain
- creation of phenomena
- construction of scientific theories
- measurement of physical constants
- testing of scientific theories

We will in this paper show, how different types of experiments can be employed strategically to drive and speculate about a design, develop and validate technique and technology to design and to establish and constantly renew a framework for design decision. The inclusion of the underlying framework and tools is for us an adoption of the understanding of experiment, which Ian Hacking introduced to the scientific community during the Practical turn (Hacking 1983), to the field of design. The emphasis on process and context, which Hacking emphasizes, finds here a natural equivalent in the academic interest in process and a holistic approach towards design.

Context for the experiments

First of all the experiments are situated in a context of skills, which allow the combination of specialized knowledge in processing ceramic material (Ceramicist) and digital technology and making (Computational Architects) in an interdisciplinary platform. Our design ambition was hence to enter the architectural realm with ceramics. Ceramics has a tradition of being used as wall elements. The observation of the filigranity of the extruded ceramic thread inspired us to look at references from Gothic and Arabic windows, whose filigree patterns fulfil functional - the subdivision of a larger wall opening into batches of available glass sizes – performative aspects - to provide shadow – and aesthetic purposes - create local shadow figures.

The experiments are simultaneously embedded in a lineage of research into digital fabrication in architecture. This created precedence for design strategies that make fabrication approaches an integral part of design thinking. This integration is often deep and results in computational design systems, which hold all knowledge of the design and fabrication process and output code that can be directly fed into the production machinery. This code describes the movement of the tool for many machining processes. For example researchers linked the generation of 2d milling paths to the design of the ornamentation of surfaces (Strehlke 2005) or the three dimensional movement of robots to the extrusion of acoustically active expanding foam (Gramazio 2008).

Ceramic printing

Similar to the above mentioned digital tools, the dominant amount of 3d printing approaches focuses until today on the materialization of arbitrary shapes.

Two 3D print techniques within the field of ceramics are usually used. *Powder printing* and what we here will term as *Extruder printing.*

Powder printing can shortly be explained by a two-step process. Firstly the digital representation of a designed shape is digitally sliced. Secondly the shape is physically produced by a machine, which built up the shape by spreading layer by layer of ceramic powder that is glued by a binder in the areas that refer to the wall of the designed shape. This technique for 3D printing in ceramics is introduced already in 1993 in the article *Structural ceramic components by 3D printing* (Yoo, J et al., 1993). Since the powder technique for ceramics has been further developed e.g. by research of John Balistreri (2008), Professor of Art at Bowling Green State University and by The University of Washington Department of Mechanical Engineering in Seattle, Washington (Ganter, Storti, & Utela, 2009).

The extruder printing, which is of relevance regarding our experiments in question, utilizes typically the 3d printers for plastic printing that coils up the digitally sliced model layer by layer. This research built on the use of a RapMan for 3d printing in clay, a technique developed by the Belgian design duo UnFold http://unfold.be/ that originates back to 2009, and introduced into our context by the ceramic artist Jonathan Keep http://www.keep-art.co.uk/ (see figure 1).

Figure 1. The RapMan utilized for 3d printing with clay.

The role of material in 3d printing of ceramics

Beginning with the ground-breaking work on 3d flatbed printing with ceramic powder (Yoo 1993) the role of material is often sidestepped. The typical two-step process favours design representation of shape, without exposure them to the context of fabrication and physical factors, such as gravity. The art of software tools is here typically to help the part through support to defy gravity. While current research focuses on minimizing this support, using for instance inbuilt simulation processes (Schmidt 2014), one can consider this as post processing of an approach that is agnostic to matter at its core. Materiality is in fact removed from the printed part.

In the frame of the presented project “Sensitive Ceramics” (Figure 2), we understand materiality in an extended way, as being the result of firstly the matter; here clay, - and secondly the process; here interventions by the designer, 3d printing, firing and glazing. Our approach aims to include the knowledge of materiality in these levels into a holistic approach.

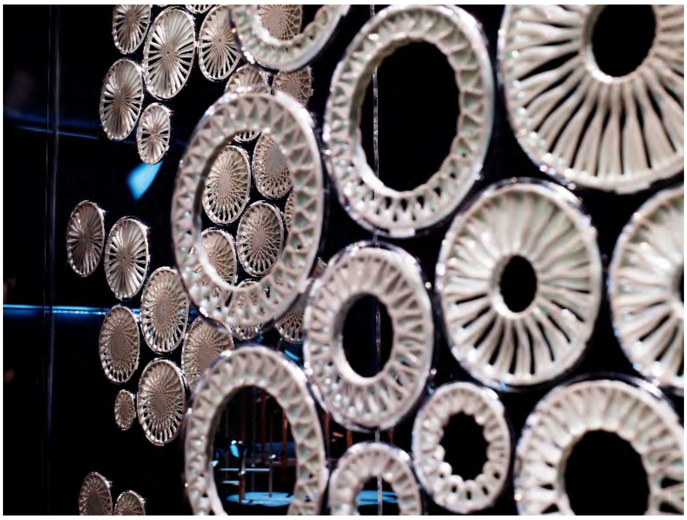

Figure 2. The project Sensitive Ceramics took place as an interdisciplinary collaboration in 2014 and was presented in the exhibition “What does it mean to make an experiment” in 2014

The experiments

The engagement into the creation of an interactive design system, were a series of parallel and interdependent introductory experiments with digital technology and ceramic material. The experiments acted as inquiries into an unknown field with seemingly limitless possibilities. The first experiments were hence almost unguided and undertaken, a general question, was solely: what is possible and how? The only existing restraint, was given through time, the need for a stable configuration of the clay and the possibility of a conceptual link to architectural elements. The introductory experiments gave rise to new questions and experiments, which at the same time helped to focus the research, as they established a growing framework, which helped to evaluate and verify the results, as the experiments grew larger and larger in scale over time.

Experimental exploration of the territory

The process of our early experimentation resulted in a sketch of concept for a computational system for designing wall like composition based on modules in ceramics that modulate light. The idea of a computational system crystalized slowly. A system that negotiates between the design intent, expressed in the interactive movement of the designer's hands, the 3d clay printing process and the following steps, such as firing and glazing that further influence the shape and appearance of the product.

Focused experiments

A continuous process of iterations of focused experiments followed. The making of physical prototypes with the RapMan printer and the careful registration of the results allowed us to tightly link the behaviour of the ceramic material to the development of a parametric module.

The prototyping provided us with an understanding for the need for internal support of the walls. We observed, that modules with straight unsupported 'walls' deform easily. This led to the design invention of inner stabilizing patterns for the modules. These structural needs provided a rich ground to include further functions as ornament and light filter (see figure 3).

Figure 3. Prototypes of the inner stabilizing patterns of the modules, which at the same time functions as ornament and light filter.

Prototypes also led to an understanding of maxima and minima, which resulted from the interplay of technology and material. Here the maximum sizes and height of the modules and the shift of layers were for instance simultaneously defined by the RapMan dimensions, as the shrinkage of the material.

Digital Crafting

The creation of an environment that is able to hold the whole process from capturing the designer's hands movement to 3d printing is a complex endeavour, which we did not want to further confuse through a heterogeneous development environment. The 3D modelling software Rhino/Grasshopper provided a unified environment, which could satisfy all needs. Here it is possible to interface a Kinect developed for the video game console X-box http://www.xbox.com/en-US/Kinect for capturing the movement of hands on one side (see figure 4), and interface the RapMan 3D printer http://www.rap-man.com.au/ on the other.

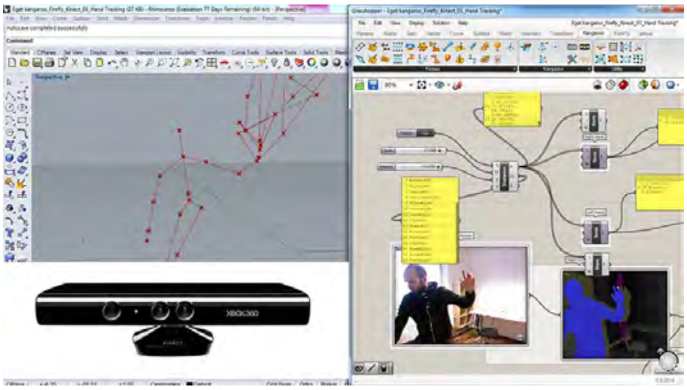

Figure 4. The Kinect captures the designer's hands movement which is input to the computational system developed in the plugin Grasshopper for the 3D modelling software Rhino.

The modules of the wall like composition are based on the material process of the RapMan printer: they follow the logic of a continuous coil, which allows the printer to build all layers in a module without pause (see figure 5). The pattern generated in the computational tool follows the principle of a continuous curve. The undulating curve carries finally all information needed for the printing. It constitutes both the outer boundary of the module and the inner supporting patterns. The inner pattern can be modulated between a pattern of straight lines and curves, both for reason of both aesthetical and light performance.

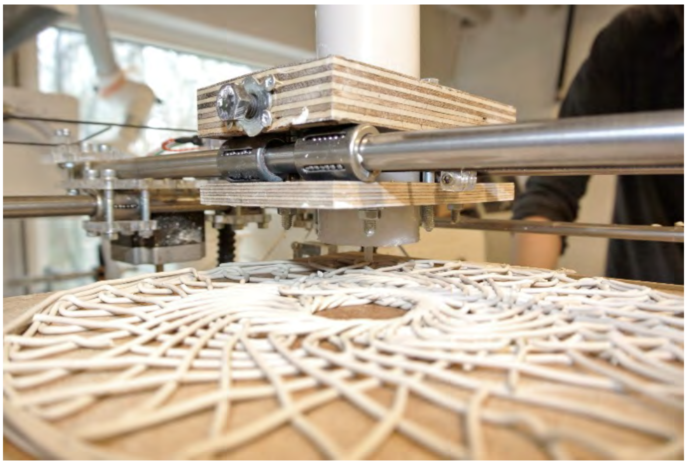

Figure 5. The code informs a RapMan 3d printer to print directly in porcelain layer by layer. The concept of the module and the parametric setup are based on this principle of a continuous curve.

The earlier referenced work by Gramazio & Kohler (see section: Context for the Experiments) creates simply continuous line patterns. Our approach encodes the knowledge of the clays behaviour into the tool. This can be for instance the minimum overlap of two layers of clay, so that overall stability is still warranted. Experimentation allowed us to define a specific value in the context of the scale and design at hand. This parameter could be continuously checked during the parametric design. Potentially instable areas could in this way be detected and highlighted to the designer. This feedback would typically initialize a further design iteration and/or the focus on the detailing of the specific modules to find local solutions without breaking the overall expression.

The interactive system

The experiments to this point focused on the level of the single module. The reference to medieval glass roundels as well as the extensive experimentation with the possible design space in the making of inner circular support structures inspired the team to investigate the packing of circles of different sizes. The packing of a defined amount of different sized circles is a well-defined problem in computation and algorithms to simulate the best fit are working in real-time. We faced however the question how to work with the many experimentally found parameters that define the generation of the macro and meso shape of our project. We found resort in the sorting of the sheer mass of variables into top level and dependent parameters and in the ability of designers to build up intuition through the process of interaction with a digital system.

The interaction is bodily. The movement of the designer's hands is recorded with a Kinect 3d scanner and transformed into a trace of cylindrical modules by the computational system. Through the interaction the size and pattern of the module emerge and change in real time in smooth steps according to the movement of the hands (see figure 6). Over time each module changes pattern and reduces its size and finally it disappears or can be manipulated by new interventions. Finally a trace of modules can be captured (see figure 7).

The development of this part of the system was again guided by exploratory and focused experiments in order to find and define a framework that guides the interaction: The process starts, when the hand enters a specified physical volume in front of the user. The sizes of the modules depend on the speed of the movement in xy coordinates according to the drawing plane. The faster the hand is moving the larger the module will become.

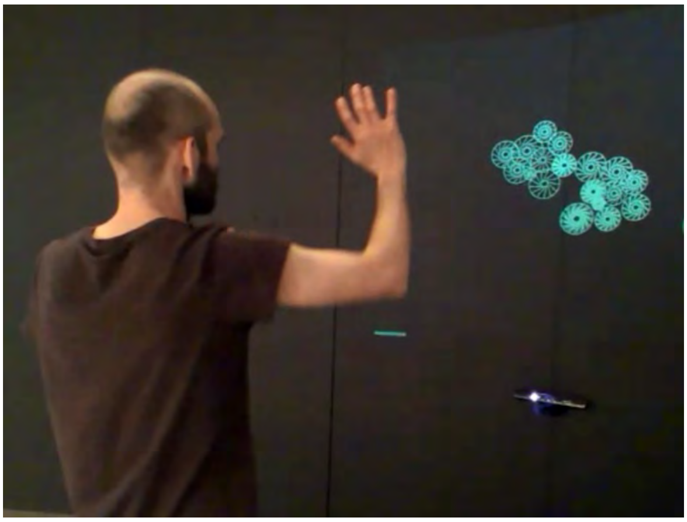

Figure 6. Through the interaction the size and pattern emerge and change in real time and in smooth steps according to the movement of the hands.

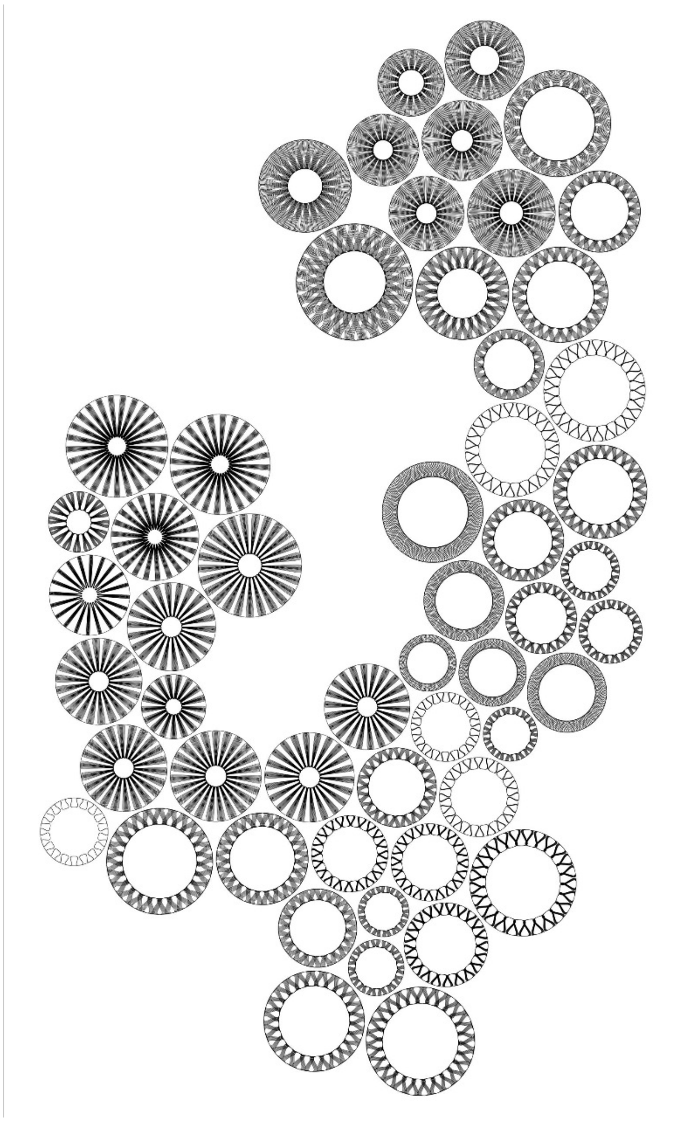

Figure 7. A wall like composition has been captured and each module is ready to be printed directly in porcelain by the RapMan 3d printer.

We interfaced furthermore internal parameters of the parametric module to the movements of the hands: the movement in the z-coordinate to the drawing plane of the separate left/right hand. Figure 8 shows the basic schematics.

1. If the user moves his **left** hand in the z direction the inner pattern will change from A to B to C (see figure 9), thus the inner pattern will gradient from straight to curved.

2. If the user moves his **right** hand in the z direction the inner pattern will change from A to D to G (see figure 9), thus the radius of the inner hole will change.

3. Or the change can be defined by a combination of 1 and 2 as a change from A to E to I.

4. Or the layering can be twisted by a combination of 1 and 2, see figure 9.

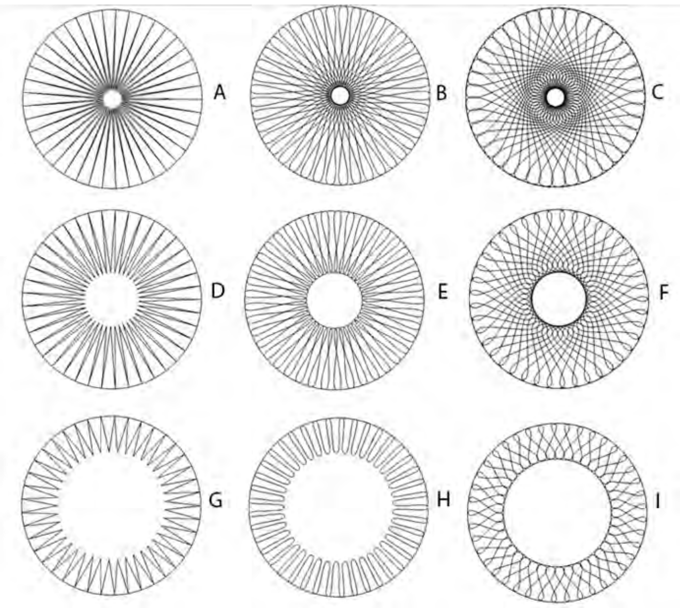

Figure 8 Basic scheme and variations through shift of parameters triggered by design interaction in the z direction.

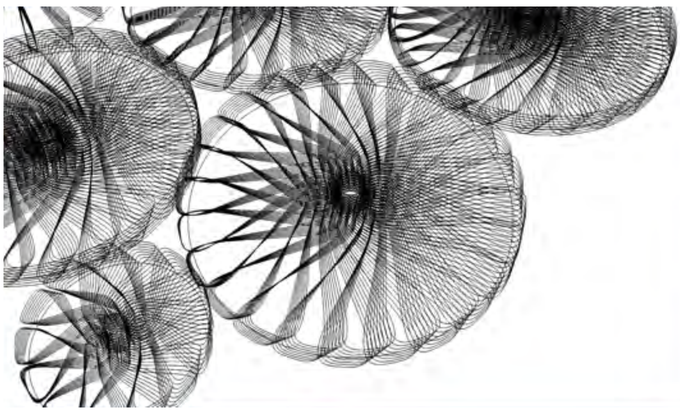

Figure 9. The layering can be twisted according to the position of the hand in the z direction.

Continuous focused experimentation provided insights, which of the parameters for the modules could be linked in a way to the designer's movement that would provide him with meaningful control and feedback from the interactive system.

Rules were implemented that check for instance, whether a module already exists at a gestured position. If so, the already existing modules and any interrelations between them are affected by the movement. If modules are left 'untouched' they will over time gradually untwist and shrink until they finally disappear. This behaviour engages constantly the user and presents an effective means to create a dynamic interplay between user and system, where crafting and execution work as a unity that is intuitive and humanistic.

When a desired layout is formed the user steps out of the drawing volume and stops the system. The captured pattern is then exported as G-Code and sent to the RapMan printer.

Exhibition

For dissemination in an exhibition the compositions of ceramic modules were mounted in laser cut transparent acrylic boards (see figure 10) based on three different captured stills.

Figure 10. The ceramic modules were mounted in a laser cut transparent acrylic board.

The transparent acrylic boards emphasized the lightness and flow in which the modules and the captured composition were made. The light movements of the hands were reflected in the smooth changes in size and pattern of the modules.

At the same time and as a contrast the materiality made the movement of the hands present. The strong materiality was developed in interplay with strong light coming through the ornament as they were light filters playing in and through the glossy glaze. In that way the filigranity made by the printed ceramic fulfilled the performative and aesthetic purposes.

In this way the exhibit showed and emphasized the quality of the computational system to negotiate between the design intent, expressed through the movement of the designer's hands, the 3d printing process and the materiality.

Reflection and Conclusion

The project "Sensitive Ceramics" investigates the relationship between the material crafting of ceramics and the crafting through digital technologies and how experiential knowledge of crafts rooted in ceramics can be transformed and utilized through the use of digital technologies.

Rather than observing a division between the “manual” and the “digital” we see similarities, which allow for the intersection and finally interweaving of both in an informed design system with embedded craft knowledge - specific to design and designer – digital crafting in the field of ceramics.

The similarities are situated in a common practice of tool making, wherein both design computation and ceramic practice are tuned to adopt generic approaches to the context of the project and the process.

In our project we observed that an experimental approach is especially akin to drive this adoption. An important pre-set is here that an experimental approach is established in both the field of material and making in ceramics and computation, where paradigms as agile software development (Beck 2001) push for iterative feedback driven strategies.

Within the process to develop a computational system for designing wall like composition made up by modules in ceramics that modulate light three different types of experiment could be observed:

1) Experiment as speculation

In initial phases and where new techniques and technologies had to be explored experiments served as a way to posing questions. Experiments were open ended and concerned with moving away from the existing and the known, through intentional actions to arrive at an as yet unknown, but desired, outcome (Downton 2003). Understanding experiment as process means that experiment includes the heterogeneous and at times erroneous design decisions that lead to the final experimental object and that the many intermediate “props” (drawings, models, prototypes etc.) become part of the experiment’s body. Experiments were therefore an active process by which the designer poses a question and develops its dimensionality and solution, and in which identified design criteria are evaluated in context of the evolving problem.

2) Experiment for evaluation

Experiments act as material research inquiries by which the concepts and technologies of the project could be tested and evaluated against external parameters, such as the stability of created walls. The emphasis on the material implementation allowed the design experimentation to engage directly with external testing enabling measurement and calibration of results.

3) Experiment as reflection

Experiments served finally as a mean to simultaneously produce and assess ideas. They served as the guide for the design process allowing an ongoing formulation and evaluation of design criteria and the design itself. In this way experiment as a means of reflection allows it to become a productive part of theory building.

In the experiments we have explored materiality within digital technology in an extended way, as being the result of firstly the matter; here clay, - and secondly the process; here interventions by the designer, 3d printing, firing and glazing.

The research provides insights how these concepts can be transformed into current digital practice, when constituting material processes are becoming integral part of the design genesis.

The columns for this process were prototyping, the encoding of the generative concept and the interactive computational system that negotiates between the movement of the designer’s hands and the 3d clay printing process. This link provided a mean to transfer the position that bodily movement and feed-back has in traditional craft processes, into the realm of digital tools. Herein it became meaningful as a mediator of complexity. The bodily engagement provided a powerful mean to gain overall control - a single gesture can control multiple parameters across a full set of many modules. We found however in our exploration of the computational system, that the parameters directly controlled by the hands at a time has to be restrained. The selection of too many can easily create the feeling of random selection and loss of control. Similarly it is a challenge to validate how many parameters make sense in an artistically expression. We found, that too many different expressions weaken the power of the artistic result.

The developed interactive system reached its limits, when the designers focus shifted from the overall to the detail. The notion of gradual refinement, constitutional to many artistic practices, is not supported by the developed interactive tool. This is in contrast concentrated on temporal effects. The setup of the parametric system allowed however, when needed, a shift to more appropriate tools of refinement.

Experiments into the different ways the parameters could be linked provided ground for rich design speculation and unforeseen and exciting results. Craft knowledge in the field of ceramics can be utilized through digital technologies, - and thus make a close link between the creative process and the digital manufacturing based on the idea about crafting and execution as a unity that is intuitive and humanistic (Leach 1940).

Acknowledgments

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A framework for materials knowledge acquisition for designers

Anders Haug, University of Southern Denmark

Abstract

Knowledge of materials is essential for designers in many regards. Materials affect how a product will be manufactured and how it will function, as well as the usability and personality of the product. However, existing materials are subject to ongoing changes in availability, processing methods, price and attributed meanings, and new materials are constantly being developed. Thus, designers continuously need to acquire new materials knowledge to be able to produce designs that utilise available material possibilities and achieve the desired user experiences. That makes it relevant to understand how this materials knowledge can be acquired. To provide designers and design educators with a structured basis for understanding materials knowledge acquisition, this paper proposes a framework that offers twelve distinct ways to acquire materials knowledge.

Keywords

materials knowledge; consumer goods; industrial design; fashion design; materials knowledge acquisition

Introduction

Product material choices affect how a product will be manufactured and how it will function, as well as the usability and personality of the product. The visual and tactile properties of materials play a big role in the way a product responds to user actions, while the personality of a product is related to aesthetics, associations, and perceptions; all aspects that are strongly influenced by the choice of materials and their processing. Thus, designers need to understand the consequences of selecting certain materials for their designs. Materials knowledge is not static, however, since the attributed meanings, availability, processing methods and prices of materials all vary over time, and new materials are continuously being developed. Therefore, designers continuously need to acquire updated materials knowledge in order to make designs that utilise available material possibilities and produce the desired user experience.

Donald Schön (Schön, 1995; Schön and Bennet, 1996) suggests that designing can be viewed as a conversation with materials, through which the designer gets to know materials in the same way that talking to a person produces 'knowing'. However, designers acquire materials knowledge in many other ways, such as texts, pictures and persons. Such sources of materials knowledge each have different strengths and limitations, for which reason it is beneficial to consider several of these. To provide designers and design educators with a structured basis for understanding materials knowledge acquisition, this paper proposes a framework that includes twelve distinct ways to acquire materials knowledge.

The focus of this paper is on consumer goods, i.e., industrial and fashion design. This delimitation has been imposed in order to focus the discussions of the paper, but its contributions may also be relevant for other types of design.

Literature

Materials selection

In product design processes, materials selection can be complex, since it depends on a range of factors such as functional requirements, manufacturing constraints, economics, life cycle aspects, ecological sustainability, sensory and aesthetic material properties, as well as cultural and representative meanings; in most cases, moreover, these choices are interrelated (Zuo, 2010). Thus, the designer needs to balance different factors in the materials selection process to ensure that the designed product fulfils aesthetic and functional goals while also considering the expense of energy, labour and other resources.

According to van Kesteren et al. (2007), most material aspects can be categorised into two groups:

1) Technical aspects: materials affect how the product will be manufactured and how it will function
2) User interaction: materials affect the usability and personality of a product

Traditionally, the technical (or engineering) focus on materials has been dominant. According to Rognoli (2010), however, Manzini's (1986) book, 'The Material of Invention', changed the perception of materials for design and has also had an influence on design education, since for the first time, an effort was made here to translate engineering terminology into clear concepts that are closer to the designer's way of thinking. The studies of descriptive and associative characteristics of materials, transcending their physical properties, was a pioneering aspect of Manzini's (1986) work and emerged as a global research interest from the early 2000s (Pedgley, 2010).

In the user's interaction with a product, the sensory properties of materials influence whether a product provides adequate feedback, and whether it provides a pleasant emotional experience (van Kesteren et al., 2007). Thus, when designing for a specific user interaction, the designer must choose the right materials to support this interaction. This can be difficult, however, since the perceived stimuli from materials are often subjective (van Kesteren et al., 2007). People can be said to live in different sensory universes (Le Breton, 2006), because they perceive sensory qualities differently. Thus, it is difficult to select a material that evokes the same meaning and emotions for everyone. A person's reaction to a material is influenced by a range of factors such as cultural background, trends, associations and emotions, for which reason materials selection implies considering how culture and experience condition perceptive mechanisms (Le Breton, 2006; Rognoli, 2010). Thus, especially in recent years, an important body of research has emerged that articulates how materials selection for industrial design is shifting from a technical subject to a user-centred activity (e.g., Ferrante et al., 2000; Doordan, 2003; Ljungberg and Edwards, 2003; Rognoli and Levi, 2004; Zuo et al., 2004; Lefteri, 2006; van Kesteren et al., 2007; Karana et al., 2008). In other words, materials selection in industrial design is becoming 'softer' and more humanised, aligned with the contemporary goal of providing pleasurable product experiences (Schifferstein and Hekkert, 2007).

When working for clients, product designers use their experience to select candidate materials, which they then discuss with the clients. In these discussions, the clients' preferences and desires often vary over the course of the design process, which can lead to unnecessary delays in the materials selection process (van Kesteren et al. (2007). Furthermore, product designers also often find that their clients are unable to specify the desired user interaction aspects of materials clearly (van Kesteren et al., 2007).

The shift to a 'softer' focus on materials selection has implied a need to modify classical engineering tools in order to render them useful to designers. This issue has been addressed by, for example, Cornish (1987) and Ashby and Johnson (2003) who rethought materials selection approaches. Furthermore, there has been a focus on developing tools to help students and professionals select materials, taking into consideration the expressive-sensory dimension of materials (Rognoli, 2010), including ‘The Material Explorer’ database by van Helmond (2005), the ‘Meanings of Materials’ (MoM) tool (Karana et al., 2010), and the ‘Materials in Products Selection’ (MiPS) tools (van Kesteren et al., 2007).

Sensing

When we interact with a product, our senses are in contact with the product’s materials — we observe the colours of the materials, feel their texture and weight, and hear the sounds they produce when we interact with them. Designers use materials deliberately to create these sensory perceptions (Ashby and Johnson, 2002, 2003). There are many ways to do so, since materials have a wide range of sensorial properties, as illustrated by the classification by Kesteren et al. (2007), shown in Figure 1.

Reflection	**Pressure**	**Sound**
reflective – not reflective	denting – not denting	muffled – ringing
glossy – matte	soft – hard	low – high pitch
transparent – translucent – opaque	fast – slow dampening	soft – loud
not bright – bright	massive – porous	
rough – smooth		**Smell and taste**
regular – irregular texture	**Manipulation**	natural odour – no odour – fragrant
	stiff – flexible	fragrance
Colour	ductile – tough	flavor
hue of colour	brittle – tough	
one colour – many colours	light – heavy	**Temperature**
colourless – colourful		warm – cold
dark – light	**Friction**	
durable – faded colour	sticky – not sticky	**Light radiation**
pattern	dry – wet – oily	low – high light emission
	rough – smooth	

Figure 1. Classification of sensory properties

Several studies have explored how various sensory modalities shape our experiences — for example, Cardello and Wisse (2008) on taste and smell, Sonneveld (2007) on tactual experience, and van Egmond (2008) on sound. It has been argued that richer experiences can be achieved by the stimulation of a greater number of sensory modalities at once (Schifferstein and Spence, 2008).

In relation to product interaction, visual and tactual information are of primary importance (Nefs, 2008; Schifferstein and Spence, 2008; Sonneveld, 2007). However, as pointed out by Schifferstein (2006, p. 60), ‘the role of the senses is likely to depend on the specific products used, the frequency with which they are used, and the importance attached to the activities performed.’ The situation in which the product interaction takes place is also relevant in relation to the importance of the individual senses. For example, vision is often primarily dominant during the acquisition of a product, while the importance of other sensory modalities often increases significantly after purchase (Fenko et al., 2007).

The sensory properties of materials have dual objective-subjective attributes (Zuo, 2010). Objective sensory properties include, for example, colour and texture, which exist physically and can be measured. Subjective sensory properties concern the fact that the perceived properties of a material depend not only on intrinsic material features, such as the material’s physical structure, but also on individual human factors and the particular environmental context. Thus, investigations of the sensory properties of materials need to take a range of variables into consideration, such as user characteristics, product context and environmental conditions (Zuo, 2010).

Material properties are experienced by different senses, which lead to different perceptions. For example, vision typically provides more information about the global impression of texture, but depending on the viewing field and distance, it may not reveal the true nature of a material with regard to three-dimensional features such as roughness, warmth, moisture, abrasiveness, softness, etc. Touch, on the other hand, can more subtly explore the local, detailed features of a surface (Zuo, 2010).

Meaning

According to Karana (2010), we may differentiate between literature on ‘materials selection’ versus literature on ‘materials meaning’. In the materials selection literature, sensory properties of materials, shape, function and manufacturing processes are recognised as the most important factors affecting designers’ material decisions, while ‘meaning’ literature emphasises the role of user, use and context in the attribution of meanings to artefacts.

Product designers select materials with a view to eliciting certain associations (Van Kesteren, 2010). Such associations or meanings are, however, dependent on the context in which the material is used. In other words, like an actor, a material can assume many different personalities, depending on the role it is asked to play (Ashby and Johnson, 2003):

- Wood in fine furniture suggests craftsmanship, while in a packing case it suggests cheap utility.
- Glass in a camera lens has associations with precision engineering, while in a beer bottle, it suggests disposable packaging.
- Gold is often associated with wealth and power but is also used in microcircuits, where it suggests technical functionality.

Using materials to embed meanings in products is increasingly challenging, since traditional understandings, such as ‘wood is cosy’, ‘metal is aloof’ or ‘plastic is cheap’, are becoming less strict in today’s design practice (Karana, 2010). As pointed out by Manzini (1986), the introduction of plastics has led to a ‘loss of recognition’ of materials.

According to Karana (2010), meaning creation encounters three main perspectives in literature:

1) The object as the centre of meaning creation
2) The individual as the centre of meaning creation
3) The interaction between object and individual as the centre of meaning creation

Following the latter notion, Karana (2010) states that ‘the meaning of a material is constructed on the basis of material properties, the product the material is embodied in, how we interact with it, and the context in which the interaction takes place. An individual’s previous experiences, memories, associations, emotions, cultural backgrounds and so forth can all be influential in particular situations.’

Materials are encountered in different contexts in daily life, and such contexts to a large extent affect the way we perceive the meanings of materials. For example, we experience a porcelain teapot differently in our own kitchen compared to the way we perceive it in our grandparents’ kitchen, in the window of an antique shop or in a dimly lit restaurant (Karana, 2010). Thus, it is of great importance to consider contexts in relation to material choices. Here, it should be noted that understandings of materials vary over time. For example, Lefteri (2006) explains how the understanding of plastics has changed from being an ‘environmental criminal’ to a material that comes from nature and returns to nature with the emergence of ecological plastics. It is, however, difficult to anticipate in which particular contexts an individual uses a material, for which reason the literature recommends communicating with people in order to determine in which contexts their products are used and what those artefacts mean to people in their contexts of use (Krippendorff and Butter, 2008).

Education

According to Ashby et al. (2007), there are, generally, two ways of teaching materials:

1) A science-led approach: going from microstructure to macro-application
2) A design-led approach: going from macro-requirement to a specific material with a particular microstructure

Scientists and engineers have a 'technical' language of materials, which is 'numerically expressed, shared and unambiguously understood by the engineering community' (Pedgley, 2010). On the other hand, craftspeople mostly use a 'non-technical' language of materials based on their practical experience. Technical languages of materials have dominated materials selection textbooks and software tools, while non-technical languages are usually communicated through images or verbal descriptions and have not been studied or collated with any degree of coherence or universality (Pedgley, 2010).

According to Karana (2010), materials are predominantly taught as a technical topic for design students without much consideration of user experiences and user contexts, for which reason the sources aiming to support designers in their material decisions are dominated by technical information. It has been pointed out that design students find it difficult to integrate technical materials selection into their design processes, for which reason they usually leave their material decisions to the last phase of their design processes or avoid using new materials or new material applications (Ashby and Johnson, 2002; Pedgley, 2009; Rognoli and Levi, 2004; Sonneveld, 2007; van Kesteren, 2008). According to Karana (2010), designers primarily use their gut feelings or common sense when choosing materials to convey certain meanings. Although design education has been able to make use of some resources developed in the field of engineering, it has had to adapt these tools or create its own (Rognoli, 2010).

According to Pedgley (2010), a useful starting point for teaching materials could be to adopt teaching based on physical material and product samples — so that students can partake in a first-hand materials experience, rather than having their understanding shaped by representations in literature or online. This argument is supported by research which shows that industrial designers often seek to augment their materials knowledge by creating mock-ups and prototypes (van Kesteren, 2008). More specifically, sometimes the only way for a designer to assess whether a material meets design requirements or to explore the as-yet-unknown product possibilities of new materials is to create physical models in the end materials in order to test the suitability of new or newly applied materials for a developing product design (Pedgley, 2010). Material sample libraries also help designers to comprehend material properties through direct sensory exposure. Such direct experience is also important because it allows for visually appraising materials under different lighting conditions and at different viewing angles, smelling the materials, feeling surface qualities and textures, experiencing the weight of the material and assessing its rigidity first-hand (Pedgley, 2010).

A framework for materials knowledge acquisition

This section proposes a framework for the different ways in which designers can acquire materials knowledge. First, however, some basic distinctions among different types of materials knowledge are introduced.

Materials knowledge

This paper proposes the use of a distinction between ‘inherent’ and ‘attributed’ material properties. An inherent material property is a property of the material itself, while an attributed material property is a property that cannot be identified from investigations of the material itself. Inherent material properties includes colour, weight, texture, and similar qualities, while attributed material properties include price, meaning, delivery, demands etc. This distinction may be combined with a distinction between subjective and objective impressions of a material, as shown in Figure 2. Here it should be noted that colour and sound are represented as both subjective and objective impressions. In this context, the subjective impression refers to how an individual experiences the given colour or sound, while the objective impression refers to measurements of colour (i.e., wavelength and intensity) and sound (i.e., frequency and amplitude).

	Inherent property knowledge	Attributed property knowledge
Subjective evaluation	Colour, feel, sound, smell, etc.	Meaning, symbolism, aesthetics, etc.
Objective evaluation	Colour, texture, sound, density, etc.	Price, delivery time, availability, etc.

Figure 2. Material property knowledge types

The examples in Figure 2 are all of the knowledge type ‘know-what’. However, other types of knowledge are also relevant in relation to materials. Lundvall and Johnson (1994) distinguish between four types of knowledge: know-what, know-who, know-how, and know-why. These four types of knowledge can all be more or less tacit and explicit (Scharmer, 2001), as illustrated in Figure 3, and subsequently explained.

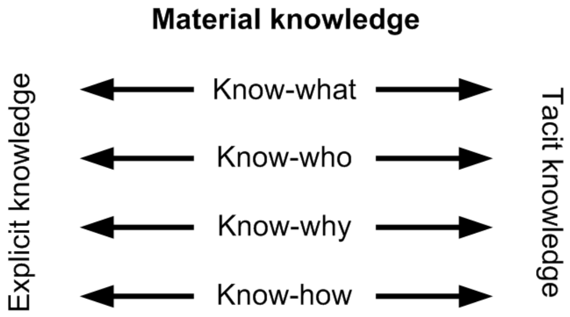

Figure 3. Forms of materials knowledge

The know-what of materials includes information about the material's colour(s), transparency, durability, density, texture etc. Such knowledge is typically explicit, but it may also be of a more tacit nature. For example, getting to know the texture of a material by touching it produces a feel that can only to some extent be explicitly described, while much of this knowledge is tacit.

The know-who of materials includes information about who can supply the material, which is the basis for knowing the price, delivery times, delivery certainty, etc. of the material. Such knowledge is also mainly explicit but may in some cases also have strong tacit aspects. For example, the understanding of a particular person's character (in this case a supplier) is to a large extent a tacit understanding that, obviously, can be very relevant in negotiations about price, delivery, processing, etc.

The know-how of materials includes understanding how to process materials. Compared to the other three types of knowledge, know-how is more likely to be tacit. An example of relatively explicit know-how about how to process materials is instructions for processing certain types of wood to achieve a certain look, e.g., how to dry, cut, sand, apply finish, and so forth. However, just as reading a book about bicycling does not enable the reader to ride a bike without practice, it is sometimes necessary to work hands-on with materials in order to gain the necessary tacit know-how.

The know-why of materials includes understanding why materials behave as they do in different situations. Know-why is typically fairly explicit, but tacit aspects may also be relevant. Know-why about materials makes it possible to predict the behaviour of the material in different contexts, rather than having to rely on a trial-and-error approach. For example, if two identical pieces of wood are found to break under different amounts of stress in different contexts, it will be necessary to understand this phenomenon to be certain of making an adequately durable product. Understanding why the wood broke under different amounts of stress would involve such factors as humidity and temperature, and by understanding the effect of all the relevant factors, the designer will be able to calculate the required dimensions of the wood to enable it able to withstand relevant amounts of stress across a variety of contexts.

Materials knowledge acquisition

Having described four types of materials knowledge, the focus now turns to the sources of this knowledge. This discussion will take its point of departure in Charles Sanders Peirce's (1839–1914) three semiotic elements: object, sign, and interpretant. In the context of this paper, these three elements may be translated to:

- Material (object): the actual material in focus
- Interpreter (interpretant): someone with insights or opinions about the material in focus

- Representation (sign): descriptions of the material in focus, e.g., pictures, texts and models

The acquisition of materials knowledge through representations and interpreters represents two forms of indirect experience, which to some extent overlap, but which may also be very different. For example, a textual description of a material is a representation, but it may also be an interpretation offered by the author of the text. However, there are also important differences between the two sources of material information. Representations include pictures and 3D models, which convey a type of material information that could not be provided by means of verbal or textual explanations. On the other hand, when the information is provided by an interpreter, the interactive aspect implies that it is possible to get thorough explanations about how to work with materials, deep understandings of how other persons experience materials, etc.

Combining the distinction between the three sources of materials knowledge with the four defined types of materials knowledge produces twelve classes of materials knowledge, as shown in Figure 4. Subsequently, these classes of knowledge are described.

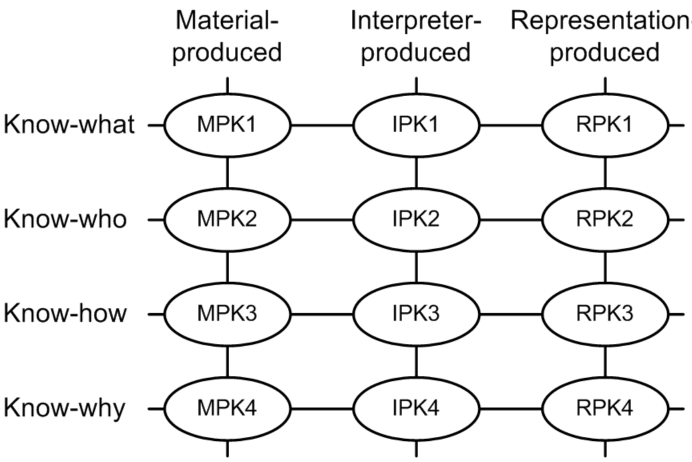

Figure 4. A framework of materials knowledge acquisition types

Material-produced know-what (MPK1) is acquired by observing and interacting with a material. More specifically, observing and interacting with a material can provide information about colour, texture, density, strength, etc. Material-produced know-who (MPK2) is acquired by recognising material aspects that are linked to the designer's existing know-who. For example, when encountering a certain type of wood, the designer may be able to figure out which part of the world it originated from, which in turn suggests potential suppliers. Material-produced know-how (MPK3) is acquired by working with a material. An example of gaining know-how by working with a material is a situation where a designer works with ceramics and through a trial-and-error approach acquires tacit understandings of how to work with this material. Material-produced know-why (MPK4) is also acquired by working with a material. An example is a situation where a designer discovers that a surface finish does not always produce the expected shine when applied to a certain type of wood. By experimenting with different ways of drying and sanding, the designer may acquire know-why about the relationship between such factors and the resulting shine. Such insights may be converted into explicit know-how, i.e., knowing how to achieve a certain shine using a certain combination of materials and finishes.

Interpreter-produced knowledge is acquired through communication with others who share their expertise, experience or opinions. Typical sources of such knowledge are colleagues, collaborators, and consumers. An example of interpreter-produced know-what (IPK1) is a supplier telling a designer about the prices of different materials. An example of interpreter-produced know-who (IPK2) is a colleague telling a designer which suppliers would be able to deliver a certain material. An example of interpreter-produced know-how (IPK3) is a situation where a design student by working with experienced tailors acquires both tacit and explicit understandings of how to craft clothing using various materials — i.e., the acquisition of know-how by being part of a 'community of practice' (Lave and Wenger, 1991). An example of interpreter-produced know-why (IPK4) is a situation where an expert explains the behaviour of a material in different situations.

Representation-produced knowledge is acquired through various kinds of descriptions, including texts, diagrams, pictures, videos, and models. An example of representation-produced know-what (RPK1) is a brochure from a materials supplier describing the appearance and properties of a material. An example of representation-produced know-who (RPK2) is a diagram showing which suppliers offer which materials. An example of representation-produced know-how (RPK3) is an instruction manual describing how to process a certain material. An example of representation-produced know-why (RPK4) is a textbook about materials that describes why they behave in certain ways in certain contexts.

Application of the framework

Designers often use several of the twelve defined types of materials knowledge acquisition to get to know a new material — and with good reason, since the different sources of knowledge provide different types of materials knowledge, which may all be of value. The rationale behind using multiple sources in the acquisition of materials knowledge is comparable to the logic of 'triangulation', which is commonly applied in the social sciences to increase validity. More specifically, the more information sources or methods for data collection are applied, the more confident we can be about the results, provided the findings are aligned (Denzin, 2006).

In relation to know-what about a design material, the three sources of material knowledge each provide different types of insights. Hands-on encounters provide designers with experiences that are essential for understanding how designs would appear in reality; conversations with other persons (interpreters) shed light on the different ways in which a material is experienced; and representations are essential for learning about characteristics of a material that are not observable. Representations are also a necessary way of seeing a material combined with other materials in a design without having to create physical models.

In relation to know-who, the designer may only need to use one of the three know-who sources for a particular material. In some cases, the designer might have preferred suppliers in mind when choosing a material for a design; in other cases, the designer might prefer to draw on others' insights (e.g. colleagues) rather than relying, for example, on internet-based information for making such decisions; and in some cases, the internet or brochures are the only immediate source of supplier information available to the designer.

In relation to know-how, for some materials, it may be relevant to gain knowledge from all three sources. More specifically, the designer may sometimes need to work with a material in order to understand how it works; sometimes it is necessary to work with crafts experts (i.e., interpreters) to acquire the necessary know-how, and sometimes it is necessary to read instructions about how to use a material.

In relation to know-why, it varies what the designer needs to know about a material. In some cases, the engineers and other technical experts that the designer collaborates with possess the relevant know-why. However, without such knowledge, the designer is likely to make poor decisions that need to be corrected by collaborators, which may, obviously, make the design process laborious. Thus, it makes sense for the designer to study material specifications, textbooks, etc. in order to acquire the necessary know-why.

Based on the discussion above, it could be argued that it would be helpful for both design students and designers to become familiar with the twelve types of processes for acquiring materials knowledge. This is illustrated in Figure 5, which shows relevant learning processes for all twelve processes in relation to acquiring knowledge about materials.

	Material-produced	Interpreter-produced	Representation-produced
Know-what	Learning to experience materials	Learning to acquire others' material experience	Learning to find properties information and evaluate materials in context
Know-who	Learning to link material experience to supplier knowledge	Learning to acquire others' experience of suppliers	Learning to identify relevant suppliers
Know-how	Learning to work with materials through experimentation	Learning to work with materials through communities of practice	Learning to work with materials through descriptions
Know-why	Learning about material behaviour through experimentation	Learning about material behavior through conversations	Learning about material behavior through descriptions

Figure 5. Relevant learning processes for acquiring materials knowledge

While the two lower rows in Figure 5 have already been thoroughly explained in this paper, the two top rows deserve some additional explanation:

- Learning to experience materials: understanding what to look for when encountering new materials — for example, observing the material in different lighting conditions, discovering how it reacts to being scratched, testing how flexible it is, etc.
- Learning to acquire others' materials experience: understanding how to use information gathering techniques such as interviews, observations, and focus groups.
- Learning to find information about properties and evaluate materials in context: knowing the sources of material information (books, websites, etc.) and evaluating 2D and 3D models in which a material is used.
- Learning to link materials experience with supplier knowledge: understanding suppliers in a manner that makes it possible to link material ideas or encounters to relevant suppliers.
- Learning to acquire others' experience with suppliers: understanding how to acquire such knowledge through others, i.e., what and whom to ask.
- Learning to identify relevant suppliers: knowing the sources of supplier information, such as particular websites and magazines.

Concluding remarks

This paper has proposed a framework for designers to acquire materials knowledge. Based on a literature review, the paper first defined four types of materials properties knowledge, distinguishing between subjective and objective material impressions and between inherent and attributed material properties. Next, using the categories of know-what, know-who, know-why, and know-how, the paper discussed how materials knowledge relates to these aspects, and how this knowledge may be in a more or less tacit or explicit form. Next, Charles Sanders Peirce’s three semiotic elements were translated into design materials knowledge sources, specifically: material (object), interpreter (interpretant), and representation (sign). By combining the two latter distinctions, a framework of twelve types of design materials knowledge acquisition was developed.

The proposed framework illustrates the wide spectrum of materials knowledge sources, each with their individual strengths and limitations. Combining such sources would often be a fruitful approach to learn about different aspects of a material and crosschecking the acquired knowledge. On this basis, the paper argues that design students (and designers) would benefit from acquiring skills that enable them to gain materials knowledge using all twelve types of materials knowledge acquisition processes.

The proposed framework for designers’ acquisition of materials knowledge refers to a variety of topics within design research. In comparison to the existing literature, the framework represents a more nuanced and structured perspective on the potential sources of materials knowledge. Thus, the framework may be used to organise and connect the insights gained through such studies. Future research would be needed to investigate the prevalence and significance of the various knowledge acquisition forms through empirical studies.

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MADEC: Exploring new methodologies to transfer material knowledge into design disciplines

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Abstract

Due to the increased complexity of materials and production processes, the responsibility of the development of a design is often left in the hands of technicians and production personnel. This lack of knowledge about materials thus effectively creates a barrier between the designer and the product. Bridging this gap represents a challenge to designers and especially to the design schools. (Bak-Andersen 2013, p.69) Designers cannot know everything but they can open their minds and develop a more conscious understanding of this new field of design practice starting from a cultural point of view.

MADEC is a research group based in the Design Department of Politecnico di Milano in 2014 with the initial support provided by FARB founding (Fondi di Ateneo per la Riceca di Base), which deals with the relation between design and materials in design history and actuality. The center carries out researches on the "Italian Culture of Materials Design", intended as the capacity of the Italian design to "interpret" materials and technologies to generate products and environments innovation.

The main goal of MADEC is to develop vocational students' and apprentices' design-related competencies, integrating design into materials' research and development, to better support commercial and societal applications benefiting from a cultural and multidisciplinary knowledge.

This paper will report in particular two significant experiences carried on during the first year of MADEC: the e-journal issue "Italian Material Design: learning from history" and the open lectures cycle "The Ideas and the Matter".

The general project has been basically divided in four main activities: creating a open source on-line platform and a research and co-design network; enhancing academic papers and publications both concerning design history studies and contemporary topics; organizing transdisciplinary symposiums, workshops and seminars; participating to European projects seeking for collaboration between researches, designers and material suppliers and manufacturers.

To the conclusion the paper will try to figure out the points of force and weakness of the research project and to trace future guidelines to improve its research and educational methodology.

Keywords

material culture; Italian Material Design; transdisciplinarity; co-design; design hybridization

We are entering a new era where products and experiences are going to be shaped by invisible forces, complex science and new manufacturing methods. So, to create advanced, sustainable and sensible design for the future, a proper understanding of materials is needed now, so it will become an ever increasingly critical element for designers.

With the 90s, due to the increased complexity of the materials and the production processes (Manzini, 1986; Manzini & Bertola, 2004), the responsibility to develop a design object is no more left only in the hands of designers. Moreover, with the affirmation of miniaturization and nano-technologies, goods dematerialization has considerably reduced the interest of the design theory about tangible material products.

Today with the merging of the physical world of atoms with the new world of digital bits (Gershenfeld, 2005; Dunne, 2005; Anderson, 2010, 2012), a new call for design methodologies started.

In this scenario, that recognizes the relevance of design competences to improve the communication between the different parts of the innovation process both technical or not (e.g. to turn ideas and technological inventions into products and services or to make innovative products commercially acceptable, user-friendly and appealing, but also to explore more archetypical and emotional meanings about objects), there are yet several barriers to overtake: for instance, the distance between disciplines and the scientific knowledge gap (becoming relevant with nano-technologies) that limits designers comprehension and application of advanced materials. This barrier becomes also a major obstacle to the creation of sustainable industrially produced products.

Yet, there are opportunities to create alliances between material suppliers and manufacturers with designers to incubate radical technology-led design ideas and startups that need support from product makers creating front end products which can help this sector have more intellectual control over market tendencies, both using new and old materials.

For this reason is necessary to facilitate the access to scientific researches: the knowledge, unless deployed with engaging licensing models is locked up in research labs. Transdisciplinary approaches can accelerate virtuous innovation, endorsing - rather than “flattening” – the complexity of contemporary technology.

Great emphasis was laid on these themes by several international research centers as the Material Ecology (Cambridge University), Material Beliefs (Goldsmiths University of London), SymbioticA (University of Western Australia), DAMADEI Project (EU) and Materiability research network (ETH Zurich).

To this challenge MADEC wants to respond supporting the evolution of the Italian peculiarity also called the “creative use of technology” (Ferrara & Lucibello, 2008), through a strategy/methodology able to open the action edges into the transdisciplinar debate and into the business dynamism. The Center methodology is based on a meta-design approach starting from the collaboration between actors from different disciplines.

“Italian Material Design: learning from history”

The possibility to restart from the past, studying the consolidate practices of the Italian design, could be a useful strategy to give to *material design* approach a specific Italian connotation, even though its evolution in the international contest. Indeed, history is still an extraordinary source of knowledge that allows focalizing on the cyclic creative and innovative dynamics of the connection between materials, design and production. Several theoretical contributions (Bosoni & De Giorgi, 1983; Branzi, 1983, 1984, 1996; Antonelli, 1995; Doveil, 2002) underlined the specificity of the Italian design material culture, documenting how it emerged over the engineering culture during the XX Century.

For this reason one of the first work of MADEC’ research team concerned design history. From the collaboration with the *Italian Association of Design historians* prof. Giampiero Bosoni and Marinella Ferrara (MADEC’ strikethrough investigators) curated a monographic number of the Association’ e-journal *AIS/Design Storia e ricerche* (www.aisdesign.org/aisd/storiaericerche).

This special issue, titled *Italian Material Design: learning from history* (2014 December) is dedicated to materials design seen trough the historical evolution of industrial design culture, and beyond, in Italy. It is a number rich in contributes, discoveries and insights about design and materials culture, largely based on original archive documents that report history of small and big companies, as well as episodes of handcrafted excellences from different Italian regions during the XX century.

The collection of essays proves the definition of an Italian way to the design system that contributed to express a special talent in interpreting technical knowledge generating innovation in both linguistic and deployment terms and, even in architecture, a myth of this capacity of interpreting materials and productive technologies. This analysis has been possible by examining objects and designers as well as corporate histories, with all their technical abilities and productive interests, and the set of relational and communicative practices, debates, writings and lectures.

Starting form the contributes collected in this issue it emerged the idea of an “Italian way” toward the technological innovation in design practicing that is founded on the thin and historical dialogue between technique and esthetic and on the particular attention of Italian designers for materials communicative and symbolic values. That design modality brought to a descendent of products that wonder, still today, for their sophisticated and surprising techniques and for the elaboration of ideas that broke up the consolidate knowledge introducing discontinuity in current thoughts, anticipating social aspirations and helping to germinate new life styles.

Selected articles

The issue collects eleven original articles with heterogeneous topics. The richest number of contributions deals with the relation between companies, designers and technological innovations lead by material experimentations.

“From celluloid to bioplastic: 150 years of experimentation with materials seen through the activity of the company Mazzucchelli 1849” by Cecilia Cecchini (2014), goes through the reconstruction of the most important steps in the history of the company Mazzucchelli 1849. It is an illustrative history of the Italian know-how, beginning with the processing of the horn, replaced by Celluloid (Fig.1) and finally substituted by the polymer Rhodoid (Fig.2) and other more efficient plastics.

Fig.1-2. Left: Cover from a publication about *Celluloide* material. Right: Advertising about chromatic variations of the *Rhodoid*. (Cecchini, 2014)

“Franco Albini and the ‘Gommapiuma’ Pirelli. For a history of natural rubber foam in Italy (1933-1951)” written by Giampiero Bosoni (2014), regards the unknown and unpublished industrial program adopted by Pirelli, between 1933 and 1940, for the application of the so called “Gommapiuma Pirelli” in the field of home upholstery. The focal point of this investigation is a little book written and edited by Franco Albini titled *La Gommapiuma Pirelli alla VI Triennale* (Fig.3) dedicated to the different applications of foam rubber adopted by the Italian rationalist architects in different exhibitions of the VI Triennale of Milan in 1936.

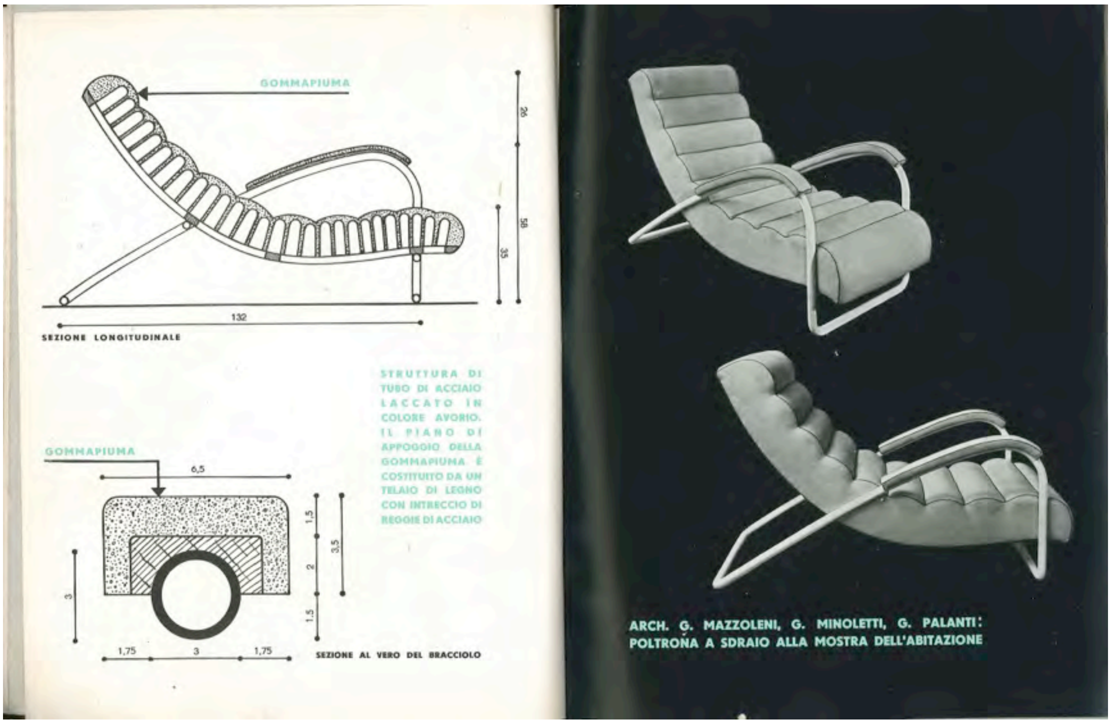

Fig.3: Pirelli Gommapiuma’ applications on furniture, project by Mazzoleni, Minoletti and Palanti, published in: *Franco Albini, La Gommapiuma Pirelli alla VI Triennale Milano 1936 XIV,* editoriale Domus, Milano 1936. Photo Credits: @Fondazione Franco Albini.

Another essay is dedicated to the Pirelli Company: “Rising matter. Pirelli, rubber, design and the polytechnic dimension after World War II” by Marinella Ferrara (2014). The research analyzes the production activity of Pirelli in the period of the second post-war until the end of the 60s (Fig.4).

Fig.4: Pictures from the article “Il mondo della gomma e il colore” (*Pirelli. Rivista d’informazione e di tecnica, 3,* 1955, p.46-47). Photo credits: @Fondazione Pirelli.

The article “Fratelli Guzzini’s approach to materials”, by Valentina Rognoli and Carlo Santulli (2014), focuses on the experience of the Italian company Guzzini that linked its history and image particularly to the use of a material, PMMA. This work unveils an unprecedented history of materic research about the substitution of a natural material, as horn, with a synthetic material, using it as a “surrogate” in terms both of technical qualities and expressive-functional ones (Fig.5).

Fig.5: Salads cutleries made with Galalite material, early 30s. Photo credits: @Fratelli Guzzini.

“Abet Laminates: design of surfaces” by Chiara Lecce (2014) is the last article concerning the relationship designer-company-material innovation. The main goal of this paper is to retrace a deep and more complete discourse about how, when and through which characters, a manufacturing industry of semi-finished materials as plastic laminates, has evolved to become such an important and particular phenomenon in the history of Italian design (Fig.6).

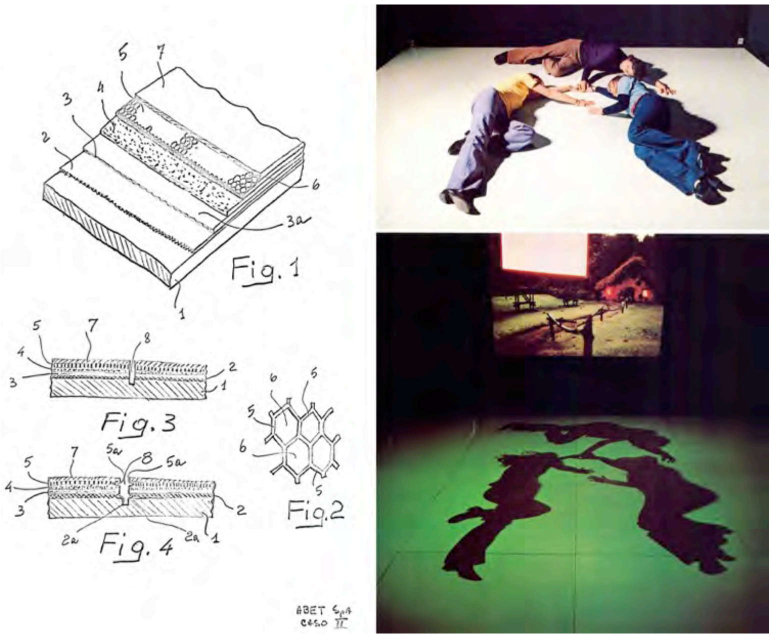

Fig.6: *Lumiphos* plastic laminate by Clino Trini Castelli produced by Abet Laminati, 1972. Photo credits: @ Archivio Castelli Design Milano.

A second common point of view, deriving from the articles review, concerns episodes of handcrafted excellences from different Italian regions that evolved with material experimentation.

An example is the essay “The materials that innovate the culture of industrial product in South Italy. Intentions and experiments in the figures of Roberto Mango and Nino Caruso” written by Vincenzo Cristallo and Ermanno Guida (2014) about the contribution from Campania region to the culture of Italian design as a result of the endemic cultural complexity of the area with its transitory outcomes, its materials, productive traditions, companies, intellectual milieus, and exclusive personalities (Fig.7).

Fig.7: Roberto Mango, wicker chair inspired by the old technique of “nassa” (fish trap). Photo credits: @Archivio Mango.

Valeria Cafà (2014) describes another case with the article “Paolo De Poli (1905-1996) master of fired enamel”. The article reconstructs the research by De Poli about the use of enamel: from the use of different metals (copper, pinchbeck, silver up to iron and steel) to the variety of the color range (Fig.8).

Fig.8: De Poli enamel colors palette (46 x 132 cm).

“Autarkic Materials and Types. The culture of the product between industry and handicrafts in Italy in the early forties” by Federica Dal Falco (2014), is focuses on the Italian autarkic products of the years 1940 – 1943. The essay selects groups of materials, glasses, reconstituted woods and textile providing an overview of furnishings and artifacts conducted by looking at the main magazines of those years.

The latest referee is the contribute of Giulio Ceppi (2014) with the article “Material Design in Italy. Domus Academy Research Centre and its contribution: 1990-1998”. Ceppi tells from the inside as one of the founders of the *Domus Academy Research Centre* that had primary importance in the formation of an Italian culture for the design of materials (Fig.9).

Fig.9: *Neolite* material sample, 1990. Photo by Giulio Ceppi.

Therefore, we think that “Italian Material Design: learning from history” with its heterogeneous stages and different entities, characters and dimensions, constitutes a stimulus to develop soon, in other occasions, wider and more articulated research perspectives, based on the historical relation between Italian design culture, and beyond, and materials quality in a technical, esthetical and symbolic correlation.

“The Ideas and the Matter”

Sciences and technologies are extending design fields, modifying materials and everything that surround us, even our body, redefining on a perceptive level the boundary between things and us.

To identify the actual evolution of the relationship between science knowledge and design, MADEC started in 2014 a wide debate with a series of open lectures entitled “The ideas and the matter: What will we made of and what will the world made of?”.

The project has been organized in parallel with Giulio Ceppi, Fortunato D’Amico, Massimo Facchinetti and Francesco Samorè form the Politecnico di Milano School of Design, involving their students during the Final Synthesis Design Studio - Interior Design Degree. 2014/2015. This collaboration has been very interesting in order to see the results of student’s projects as a proof of the influence of the different notions brought from the lectures at the end of the semester.

Therefore, “The Ideas and the matter” (Fig.10) involved keynote speakers form several disciplines (art, biotechnology, engineering, anthropology, architecture and design), becoming one of the most significant experience conceived during the first year of MADEC (form October to December 2014).

Fig.10: “Le Idee e la materia” program manifest.

Contributes were organized in three different sessions: *Extension*, *Osmosis* and *Inclusion*. Concepts that act as metaphors of the complex polarities like body/space, artifice/nature or interior/exterior, that are increasingly characterizing the contemporary design world. Today these conflicts tend to dissolve tanks to the capacity of contemporary research to hybridize, integrate and coagulate experiences.

The emerging scenario sees design as the principal interpreter of transdisciplinarity, able to give meanings and aesthetic values to scientific and technologic discoveries. Design enters into laboratories and operates with biologists and doctors; it proposes itself as a strategic stimulus for innovation in different fields, going beyond that disciplinary barriers which continue to separate the fields of knowledge, stopping cultural evolution.

Extension

The first metaphor is referred to the relationship between the *quality of the sight* and the *quality of the project*. The related lectures, in fact, demonstrates how innovation trajectories empowered the ductility of our sight (its deepness and its wideness) disputing in which way designers “read” –and consequently design- the relation between “interior” and “exterior” worlds. Innovation and development in biotechnological sciences is redefining both ourselves as human beings, but also the space and the artificiality that surrounds us, shaping new scenarios and possibilities for the design profession.

So the first section, named *Extension*, is developed as an itinerary.

It starts from the inner of human body with a lecture of the prestigious molecular biologist Giuseppe Testa, director of the Laboratory of Stem Cell Epigenetics of the European Institute of Oncology and European School of Molecular Medicine (Milan).

During his lecture titled *Naked Genes. Reinventing the Human in the Molecular Age,* prof. Testa argues:

Evidently design students that will generate the products of the XXI Century should familiarize with the capital fluxes of this century and in this case in which way the capital fluxes intercept life fluxes. (…) We are entering the age of biologic control, and control is an essential element of design, when someone design and produce something then he would also in some way control them. (personal communication, October 7, 2014)

What Testa assumes is, in synthesis, that the molecular life sciences are making visible what was once invisible. Yet the more we learn about our own biology, the less we are able to fit this knowledge into an integrated whole. Life is divided into new sub-units and reassembled into new forms: from genes to clones, from embryonic stages to the building blocks of synthetic biology. Referring to the world of design he says “(…) The new frontier probably is the so-called *synthetic biology* that is programmatically the nearest to the world of design”. (personal communication, October 7, 2014)

Then the journey continues arriving to the human body “boundaries”, reflecting on how technology, needs and wishes are combined together to design human prosthesis (Fig.11) thanks to the contribution of the biomedical engineer Pietro Cecini, one of the founders of Roadrunner Foot Company.

Roadrunnerfoot is nowadays one of the leaders in research, development and production of devices for disabled people thanks to specific operational process. In fact, Cecini explain that each product is conceived meeting the user’s needs as a healthy limb. This modus operandi requires vanguard and high cost technologies, like: optoelectronic systems and measurements from a piezoelectric force platform generated by healthy limbs and by amputees applying commonly used prosthetic components, or tridimensional Analysis of kinematic and dynamics of able people walking and running, structural analysis, prototyping and mechanical testing according to ISO 10328.

Fig.11: Prosthetic foot in carbon fiber, returning energy, laminated in autoclave with aereonautical process. Photo credits:@ Roadrunnerfoot

Now the world of prosthetics is trying to go beyond simple mechanic replacement for the body, to take in account the important psychological necessities related to the esthetic of an artificial limb.

The section ended transiting over the human body surface and with a reflection on the implications of wearable devices for medical uses tanks to the lecture of Matteo Lai CEO of Empatica Company. Strictly connected with the rise of the Quantified Self is the success of wearable technologies. Products connected to our bodies and to the internet, are now able to transform different aspects of our lives (such as physical activity) into data. The Embrace smartwatch (Fig.12) from the Italian brand Empatica represents one of the best examples in the international panorama of wearable technologies. Created after research on the medical application of wearable computing (in collaboration with MIT), it is able to predict seizures and monitor stress. In the near future electronic devices attached to our skin will play a fundamental role in healthcare.

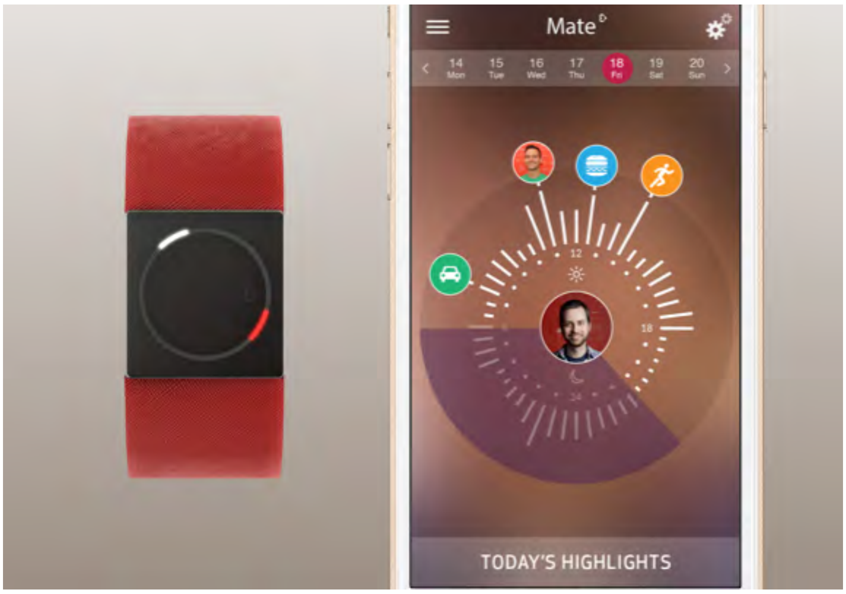

Fig.12: Embrace smartwatch. Photo credits: @Empatica.

Concluding, we can assert that lectures collected into *Extension* underlined how designers today are seen the less as “instruments suppliers”, the more as “co-decision makers”. (Bassetti, 2004)

Osmosis

Osmosis as generically defined by the dictionary is a gradual, often unconscious process of assimilation or absorption. This definition well fits the aim of this second section of lectures that try to give a correlation between different disciplines similar to an osmotic movement.

Osmosis starts with the artist Michelangelo Pistoletto’s lecture on the *Third Paradise*. He explains:

The basic idea of the *Third Paradise* is the overcoming of the current worldwide existing conflict between the two polarities of *nature* and *artifice*. The *Third Paradise* is symbolically represented by a reconfiguration of the mathematical infinity sign. In the “New Infinity Sign” three circles are drawn: the two opposite circles signify nature and artifice; the middle one is the conjunction of the two and represents the generative womb of the *Third Paradise*. (personal communication, November 10, 2014)

He concludes “We live in a specific scientific and technologic epoch. (...) *Cittàdellarte* - foundation instituted in 1998 proposing to place art in direct interaction with all the areas of human social activities - is a place were we try to put together esthetics and ethics; we don’t care to see all the great inventions, that are beautiful, but it is necessary to understand how they are used” (personal communication, November 10, 2014).

Fig.13: Michelangelo Pistoletto drawing the symbol of the *Third Paradise.* Photo Credits: @Fondazione Pistoletto.

The second appointment titled *Mater Materia* with the designer Clino Trini Castelli. Castelli is the founder and principal of Castelli Design Milano, a firm whose work explicitly addresses user experience and perception. Most of his professional activity has involved researching and advising on color trends. Along with his work on color, Castelli has also addressed the role of a number of other “subjective” aspects of space, including light, sound, microclimate, texture, and scent. In 1972 he coined the term *design primario* for this work:

When we work in the *design primario* way we use very subtle effects - in smell, in light, in color, in many manifestations of reality - and we amplify them to a degree that becomes significative at the figurative level - very significative, very expressive, and very important. So this has guided a sort of poetics, a minimalist poetics, that expresses one phenomenon at a low level of energy, at a low intensity, but that becomes very significant when taken on very large scale. (personal communication, November 11, 2014)

Castelli has in his work focused more on the effects of design than on physical form, he remembers “Instead of designing objects like all my colleagues, I started my career designing laminates with glowing lights and things like that. I cannot say exactly why, but to me there was a kind of natural sensibility to that kind of dimension.” (personal communication, November 11, 2014) In order to better describe his work, Castelli coined the word *qualistic*. It is a dimension where the *perception* of quality can be shared in an objective way by any person.

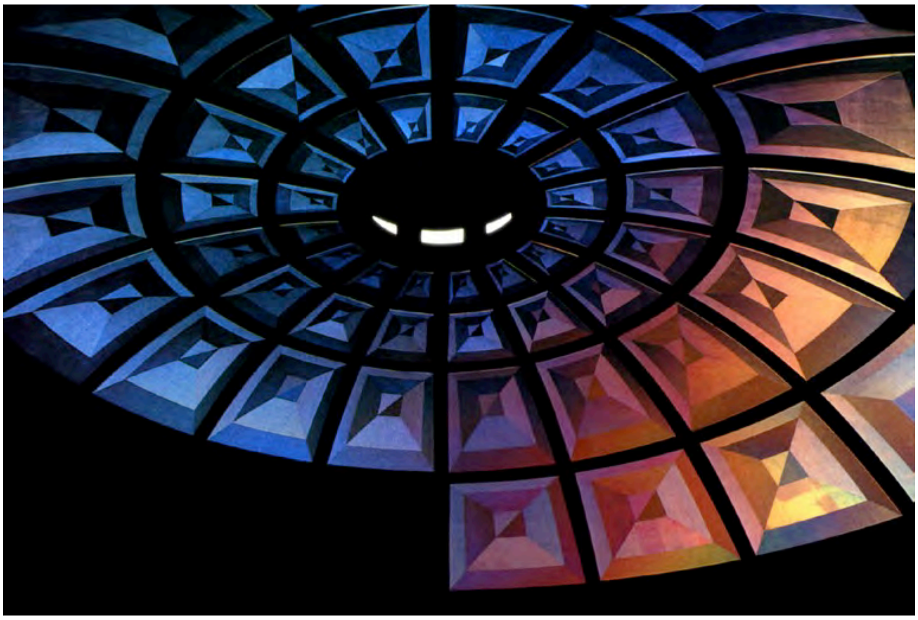

Fig.14: Clino Trini Castelli, showroom Cassina “Virtual Lantern / Grey Light Pavillion”, realized with reflective 3M panels 1985. Photo credits: @Archivio Castelli Design Milano.

Artifactual Elegance by Roberto Cingolani and Chris Bangle is the third combined speech of the *Osmosis* section. They presented separately their work experiences under a common vision that brought to a real collaboration between science-technology (Roberto Cingolani) and design (Chirs Bangle).

Cingolani is a physicist and the Scientific Director of the Italian Technology Institute (IIT) in Genoa from 2005. His work includes different field of scientific research as: *Advanced Robotics*, which concentrates on an innovative, multidisciplinary approach to humanoid design and control, and the development of novel robotic components and technologies (iCub project Fig.15); or *Nanophysics* dedicated to research and support activities related to the design, characterization and application of nanocomposite materials, and to the design and construction of new technologically advanced instruments for imaging, microscopy and spectroscopy.

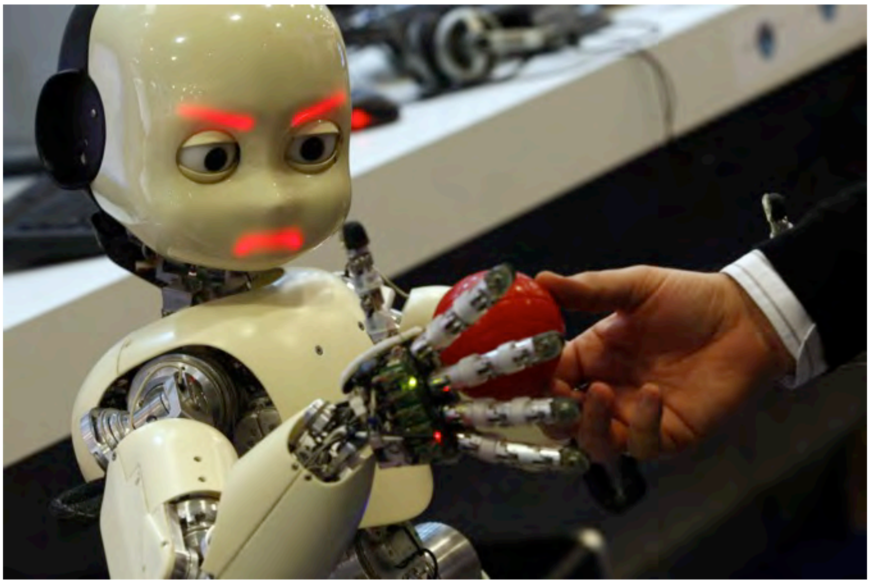

Fig.15: *iCub* humanoid robot developed at IIT as part of the EU project RobotCub and subsequently adopted by more than 20 laboratories worldwide.

Chris Bangle is an American automobile designer, he known best for his work as Chief of Design for BMW Group, where he was responsible for the BMW, MINI and Rolls-Royce motor cars. In 2008 he introduced *GINA Light Visionary Model*, a fabric-skinned shape-shifting sports car concept for BMW. In 2009 he founded the studio Chris Bangle Associate (GBA) in Italy that works on innovative concepts and production design extended beyond cars to all manner of products and service constructs.

Bangle and Cingolani reported during the lectures their collaboration experience. In fact, CBA has partnered with IIT to study and propose consumer applications for robotics. While the IIT context is focused on scientific and engineering research the CBA is an immersion into a designer-visionary studio. Together they teamed to explore the future of consumer applications for robotics under the theme of *Artifactual Elegance* – and approach to human-machine interaction (in all ways: functional and aesthetic) that attempts to renegotiate the idea of "robot" away from that of industry and into an arrangement of emotional and functional interpretations similar to those practiced in car design.

The last session of Osmosis was dedicated to the work of Maurizio Montalti, a young designer and founder of Officina Corpuscoli studio in Amsterdam. His lecture, titled the *The Growing Lab: Fungal Futures*, is an interesting example of design driven by materials experimentation. In his opinion one of the main challenges of the current Century is to transform our consumption-oriented economic system into an eco-friendly and self-sustaining society, capable of minimizing energy consumption, carbon emissions and the production of waste, while reducing production costs. In his specific case the material used is *Mycelium* (Fig.16).

Mycelium is the fast-growing, vegetative part of fungi, consisting of a tight network of interconnected filamentous cells, called hyphae. Thanks to such structure, the mycelium is capable of harvesting, transforming and re-distributing nutrients, both for his own benefit (mushroom growth) and for the larger ecosystem. The *Mycelia* of mushroom-forming basidiomycetes are highly attractive because of their tendency of growing on a wide variety of substrates (e.g. agricultural waste), with the potential of converting waste products into novel compounds, characterized by diverse qualities; depending on the species and on the growth parameters, in fact, it is possible to develop materials with peculiar properties, as for instance in relation to strength, elasticity, thickness, homogeneity, water repellency, etc. (personal communication, November 25, 2014)

Fig.16: The Growing Lab project by Officina Corpuscoli. Photo credits: @ Officina Corpuscoli.

Montalti concludes his lectures describing the *Mycelium Design*, an on-going, long-term research-project, initiated by Officina Corpuscoli, together with partners such as Utrecht Universiteit and Mediamatic (Fig.17).

The project seeks to study and analyse the mechanisms underlying structural and decorative properties of the mycelium as well as their improvement, while exploring and assessing natural variations, environmental growth conditions and genetic qualities of the selected mycelia, aiming to identify tailor-made mycelia for use as building blocks or as both structural and decorative material. (personal communication, November 25, 2014)

Fig.17: Maurizio Montalti, grown materials, Utrecht University lab, 2015. Photo credits @Fondazione Giannino Bassetti.

Closing the section of *Osmosis* we can assert that the interaction between different actors enables to see beyond what has been already seen, opening our sight as designers toward a less-known but equally stimulating and inspiring world in which it is necessary to involve different professions to fulfill our goals.

Inclusion

Our inner vision amplifies our capacity to perceive and absorb the outer. In the educational field, the encounter of different knowledge, before separated, could become an ideal procedure to implement participatory approaches and sharing processes. Innovative explorations complained everyday terms as “interior” and “exterior”, sometimes apparently invert their meaning. Therefore, today it is possible to move our activities and our knowledge into the network system that is globally managing our work contacts and social relations.

The project *Campo Expandido* presented by the Mexican artist Raymundo Sesma in the first session of *Inclusion*, is a good example of an amplified work process, inclusive of a wider logic of the contemporary city problems. His architectural painting, dedicated to the regeneration of buildings facades in degraded urban contests, demonstrate that is possible to redevelop environments, to reconnect disconnected urban tissues, raising the esthetical value on the city exterior to improve the inner quality of the local neighborhood life. Interdisciplinary trespassing has always been pertinence of art.

This section introduces also another topic connected to importance of the designer role inside the complex production system whom will be committed to requalify our planet. Designer responsibilities to society and environment have to be constantly in evidence, especially today that we are facing to a continuous growing of dumps also because of uncontrolled design objects productions.

Tiziana Monterisi and Marco Baudino combined lectures are collocated in this direction.

Tiziana Monterisi is an architect and founders of the project *N.O.V.A.Civitas* (acronym for Nuovi Organismi di Vita Abitativa – New organisms of housing life), born inside the Michelangelo Pistoletto Cittadellarte Foundation. The project promotes a sustainable culture in the architectural and environmental sector. Architect Monterisi explained the system of sustainable building technics use by *N.O.V.A.Civitas* that principally investigate and experiment with the construction technology of rice straw. In this way, the project promotes a return to rice cultivation and the use of straw as a building material, starting a virtuous process in terms of social, economic, environmental, agricultural and architectural. The experimental architectures are made with frames laminated wood infill with straw bales. All finishes are natural: clay and lime plaster, pine wood cooked, cocciopesto and natural oils.

Marco Baudino is the managing and technical director of Future Power Company. As *N.O.V.A.Civitas* use rice straw this company carried on a specific experimentation on recycling rice husks. For the first project presented rice husks are used to manufacture biodegradable pots, named *Vipot*. Mixed with natural amalgam, rice-husk results in a material that makes the pot solid and consistent, one that is not derived from chemical processes or processing and that is finally 100% biodegradable.

Fig.18: *Vipot* recycled rice husks pots by Power Future.

Another interesting project by Future Power is the Greenhouse Gases. Baudino explains:

Rice husks are burnt in an incinerator, heat, water vapor and large quantities of CO2 are produced. When rice husks are composted, some methane gas is also released to the atmosphere. Furthermore they compost slowly because of their high lignin content. When rice husks are digested anaerobically in a biogas installation the methane generated is converted to electricity, heat and compost. (personal communication, December 2, 2014)

The last day of the cycle sees two lecturers by the renowned designer Stefano Marzano and the famous French anthropologist Marc Augè. The session faces two different disciplinary field tiring to analyze the contemporary world with the tools of their relative professions and cultural approaches.

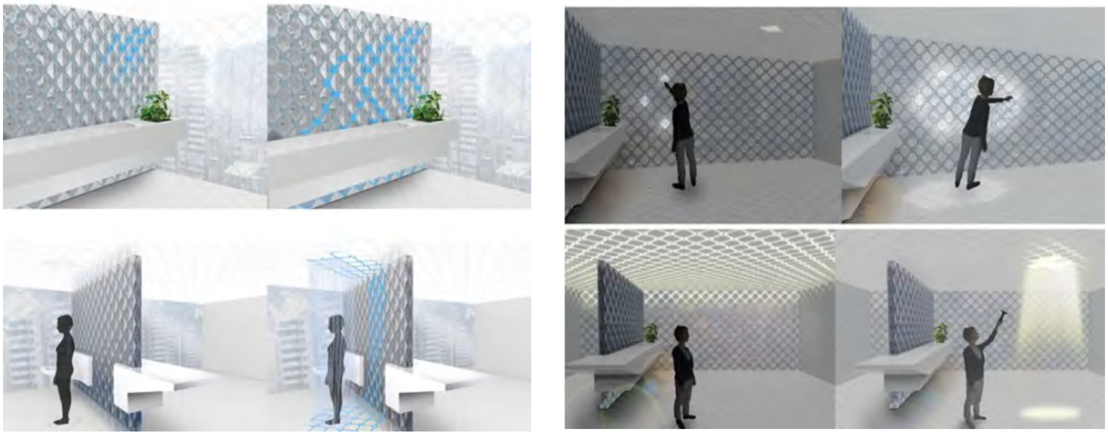

Fig.19: *Off the grid: Sustainable Habitat 2020*, Philips Design Probe, 2010 (project presented by Marzano during his lesson). Photo credits: @Philips Design.

Stefano Marzano during his lecture brings his long lasting experience as Chief Design Officer and CEO of Philips Design in Philips between 1991-2011.

(..) True innovation has to be recognized by people as such, and should advance the interests of the company while contributing to the quality of life by giving people something they really enjoy, or really need, or really appreciate. (..) Being innovative is also about being a protagonist of the future. Therefore we have to be active participants, innovating in a way that helps us direct the future, contribute to it and make it that little bit better. (personal communication, December 9, 2014)

Professor Marc Augé is one of France's leading intellectuals. His work has revolutionized his primary discipline of anthropology and serves as a key point of reference for work inside and outside of this field.

Using one of his most famous concepts, namely the idea of the "non-place" (Augè, 2009) in this lecture Professor Augé examines concepts such as globalization, urbanization, "city-world" and "world-city". He opposes the "City World" (*monde ville*) of global business, tourists and architects to the "World City" (*ville monde*), the megacity where all differences become apparent - social, ethnic, cultural and economic - and a space where "misery and opulence rub each other".

Results and dissemination

Simultaneously to the open lectures cycle "The Ideas and the Matter", 44 students of the Final synthesis Laboratory, arranged into 30 groups developed 30 concepts related to product innovations and new interior scenarios, the same was done by 35 students from another class of Politecnico di Milano. Meanwhile all the lectures were recorded with the support of the Giannino Bassetti Foundation, and published on-line as an open source material (Dipartimento Design – You Tube Chanel)[1]. At the end of the project, MADEC started to transcript all the lectures in order to collect them into a final international publication together with five adjunctive essays specifically written for the publication by MADEC' research group components. Actually we are going to close the first year with this publication. During this period MADEC team has supported workshops and seminars[2].

Conclusions and critical observations about MADEC research project

All these heterogeneous contributions demonstrated that design is a tool for innovation in new or emerging markets where user-friendly, sustainable and appealing design is a must to create or enter the market.

But is obvious to add a pragmatic consideration, how can design educators use the technology and techniques available today to embed an ethos of inventiveness driven by curiosity?

In fact, beyond the cultural and theoretical stimuli, bringing advanced and smart materials to design schools is as challenging as facilitating the processing equipment and domain expertise needed to create meaningful collaborations.

There is a lack of knowledge on how to use a material in a system and see its use as a cyclical process. Small and medium sized material suppliers are looking for new markets and new applications but it is limited to new business partners or new processes. The process is long, and they may not move on to expand the application base. They need the support of technology centers and technology transfer companies to facilitate this largely. Material experts from the design world can also play an important role in facilitating the required network.

MADEC moved the very first steps in this direction organizing other activities, but much more has to be done to fulfill this goals. The first step was to built an open access web site (www.madec.polimi.it) in order to publish updated news about interesting case studies and researches focused on materials design in the international scenario. Recently it has been added a new section of the website called "Making of", in which there is a selection of practical tutorial to let better understand smart materials manipulation to almost everyone. And, of course, all the activities of MADEC are constantly updated together with innovative students projects contributions form the School of Design of the Politecnico di Milano. MADEC website is also a useful platform to collect the entire contacts network that is gradually grown during this year, although it is necessary to bring it to a more widespread diffusion. In fact, almost all materials produced till now are written in Italian language except for few academic papers.

All the activities conduced by MADEC with a wider vision of the concepts "matter and materials", "design and meta-design" had a double role: to enlarge the fundamentals of our knowledge with several visions that came from different design fields, with a common idea of cross-pollination between disciplines and to demonstrate how much boundaries of human knowledge have been expanded form the macro-world to the micro-world. The researches underlined also what have changed: the depth of our look inside the matter is augmented, the real matter on which we focus our look has changed and the places and actors of knowledge production have changed too; the complex relation between technology and

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1 https://www.youtube.com/playlist?list=PL_sN_A0uSn03jeVB-Z_bwVgaKJzAKeYuk

2 http://www.madec.polimi.it/

nature, considered hostile, could be skillfully managed by humans trough all the “meanings” that creativity could contribute to conceive and express avoiding obsolete models; today nature could become the measure and method for designing the artificial, guaranteeing sustainability and beauty, therefore competitiveness; the gap of knowledge that high specialization contributed to create could be overtaken trough a wider multi-disciplinarity; opened and shared knowledge is the only way that will enable us to pin ourselves toward the future.

Actually the main goals of MADEC project are: to open a wider network for European researches collaborations; to develop the “creativity-driven material design methodology” (Fig. 20) as evolution of the Italian way of material design; to develop new tools for materials knowledge open access able to spread open knowledge between digital creation and physical making. This tool can be develop for design practice and for teaching activities with a specific focus on a possible develop of a more social model of decentralized production. We introduce this approach as a complementary approach to industrial production. Access to knowledge through cross-disciplinary comparison can accelerate virtuous innovation, enhancing (rather than flattening) technical complexity. The new method could apply some special tools like *open source platform* for sharing and developing knowledge. At this regard we are observing some other international centers focused to develop design process based on new scientific concepts. We are looking forward to launch a process of cross-pollination between disciplines and also with manufacturers/suppliers of raw materials, specific research centers for different materials, technology centers, material libraries and scouts technologies.

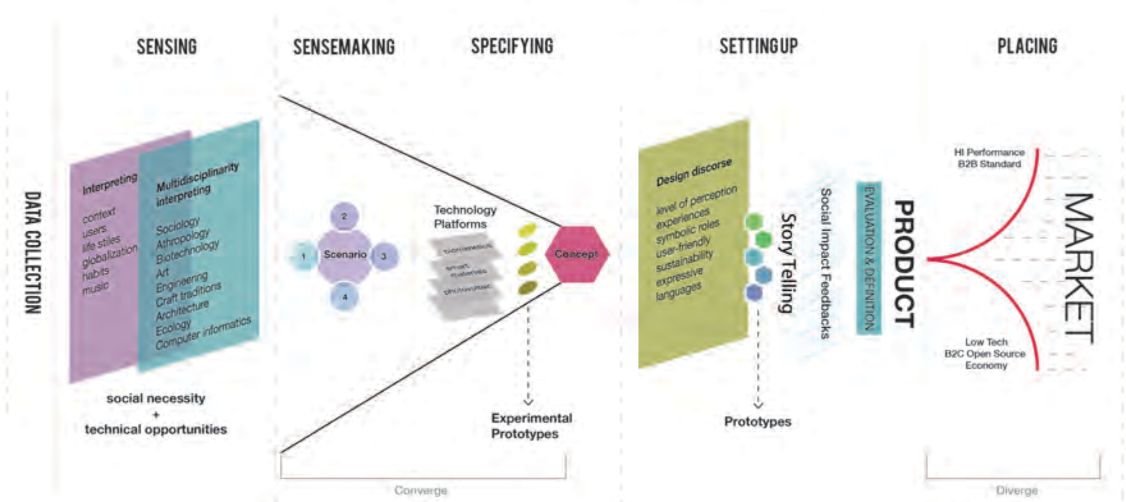

Fig. 20: “Creativity-driven material design” methodology by MADEC.

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Making sense of dress
- on sensory perspectives of wardrobe research

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Abstract

In this paper, I wish to exemplify how research on bodily experiences of dressing within research on fashion and dress research might be combined with user-oriented approaches from design research. By doing so, I wish to point my finger at the unfortunate wall between these two scholarly areas which to my mind has created a limited understanding of the connection between dress design, the body, and people's day-to-day routines of getting dressed. The case through which I wish to debate this is a wardrobe study of men in the age of 40-50 years old that I conducted in the period of 2010-12. Being a former fashion writer and trained as a fashion scholar within the humanities, I had learned that the logics of fashion is *the* overall explanatory framework through which people's dress practice is understood. However, issues came up during my research that did not relate to logics of fashion at all, why I had to start searching within other disciplines for alternatives. Issues, which had to do with bodily and temporary aspects of dressing that seemed to be far better explained within so-called user oriented design research. To clarify these standpoints, the paper is structured as follows; after a positioning of the dress-body connection within fashion and dress research I place my own research within the so-called 'wardrobe method'. Next I elaborate on the way I have tried to bridge my methodology with my epistemological departure, through applying methods from user-oriented design research. As I go into my case study, I show examples of how I experienced the dress-body connection of my informants in their wardrobes, and in my final discussion, I suggest how my analysis might cast back potential new endeavours for the scholarly fields with which I engage.

Keywords

wardrobe, sensory experience, fashion, dress practice, temporality

Epistemologically, this study is placed in a position between an objectivist, realist approach such of that of Schwandt, who proposes that: "Scientific realism is the view that theories refer to real features of the world. 'Reality' here refers to whatever it is in the universe (i.e., forces, structures, and so on) that causes the phenomena we perceive with our senses" (Schwandt 1997:133 in: Maxwell 2012).

In combination with this lies a departure in Tim Ingold's definition of 'dwelling', which posits that people are themselves part of the physical world (Ingold 2000). This implicates that design objects are not merely 'instruments' to use for various purposes, but are rather *extensions of self,* through which we experience the world[1]. Furthermore, Ingold emphasizes that this interaction is not frozen in time. It is processual, and takes place in on-going movements of interaction. Hence, this contribution to the EKSIG conference must be seen as a hybrid study positioned in the intersection between fashion and dress research and design research. As such, it aims to enrich both disciplines, as it simply makes sense to do so: to enrich design research, because this area has been surprisingly disengaged with

[1] I am here referring to the discussions between Tim Ingold and Daniel Miller as they can be found in Miller (2007)

fashion and dress design, and to enrich fashion and dress research as this area has been surprisingly absent in the development of design research.

Dressing the body - positions within fashion and dress research

What is particular about dress design is that it is always proportioned to relate to the human body. Dress manipulates the body into making certain gestures and movements that are considered appropriate in a social context, and shapes the body into the ideal of a given place in space and time (Hollander 1994). As such, it intimately connects bodily behaviour and social structure. Still, up until the around the mid-1990s, the body was surprisingly absent within research on fashion. Building largely on an art history- or costume history tradition, there has been a tendency to focus on the visuality or the *look* of dress design, rather than the shape, texture or *feel* of it, within fashion studies. As argued by Wilson, this poses a problem since studying dress objects alone, without taking the body and the senses into consideration, is like studying "the world of the dead":

"Clothes is so much part of our living, moving selves that, frozen or on display in the mausoleums of culture [museums], they hint at something only half understood, sinister, threatening; the atrophy of the body, and the evanescence of life" (Wilson 2003 [1985]:1).

In Joanne Entwistle's book: *The Fashioned Body. Fashion, Dress and Modern Social Theory* (2000), she addresses how dressing has been neglected as an embodied practice because it is positioned between a structuralist and art historical interest for surfaces and sign-making on the one hand, and, on the other, a sociology of the body that is disinterested in fashion and dress. Entwistle insists that the unfortunate neglect of the dressed body discloses a glaring lack in (particularly sociological) literature that can *"give an account of dress within everyday life that is not reductive or theoretically abstract, but theoretically complex and empirically grounded"* (here from Entwistle in: Wilson and Entwistle 2001:76). A very similar approach can be found in the way Jennifer Craik sees dress practice as a 'body technique'. Building (as Entwistle does) on Bourdieu and Mauss, she argues that: " Codes of dress are technical devices which articulate the relationship between a particular body and its lived milieu, the space occupied by bodies and constituted by bodily actions. In other words, clothes construct a personal habitus." (Craik 1994:4).

A significant contribution that pushes to bridge this gap is the concept of *dress* by anthropologists Joanne B. Eicher and Mary Ellen Roach-Higgins, which they define as the following:

An assemblage of modifications of the body and/or supplements to the body
(which is about) more than appearance for it includes aspects of body modifications and
supplements recorded by all the senses - not just sight alone as the term
appearance implies. The blind people, though sightless, do have impressions of dress that
depend on tactile, auditory, olfactory, and gustatory responses (Eicher &
Roach- Higgins 1992:1+3).

The work of these scholars represent well how dress historian Lou Taylor has pointed out that during the 1990s, a 'postmodern turn' was taking place within the human sciences which directed more research attention towards issues of the body, and of materiality. In Taylor's mind, theories on fashion have been in lack of actual fabrics and dress objects, why she argues for more 'object-based research' and thereby following sensory aspects (Taylor 2000:85).

The above attempts to understand the dress-body connection have had a huge impact; thus, the whole area is now often defined as I do it here, as "fashion and dress research", this way highlighting how dress design is referring to the phenomenon of fashion, as well as to its particular connection with the human body. What is missing though, is how these connections are played out in the everyday routines of people, and how the body and the senses play a vital role in such routines. While the interest for the dress-body connection has grown, fashion research at large has showed little interest for the role of the body in ordinary day-to-day routines in which people get dressed. Most likely, this is because fashion is often about idealisation - as sociologist Elizabeth Wilson has worded it, fashion is all about being *Adorned in Dreams* (Wilson 2003 [1985]). As Buckley and Clark have pointed out, this point of departure has left very little space for the interest of ways people interact with dress in their everyday lives (Buckley & Clark 2012).

Hence, by using the term, *dress object,* instead of words like 'clothing', 'fashion clothing', 'apparel', 'garment', 'attire', 'costume', or 'outfit', I have made an attempt to amalgamate Eicher and Roach-Higgins' definition of dress, with the term, 'design object'. This way, I aim to place my focus on the design qualities of a given dress object, and on how these qualities play a role in the way the given dress object is sensed in the wardrobe by its wearer.

The wardrobe method, the body and the senses; approach of study

As a response to the above described development within fashion and dress research emerged the so-called wardrobe network that was active from around 2008-2013. The network represented a line of British, Dutch and Scandinavian fashion and dress researchers that looked into the day-to-day practices of dress users. Scholarly approaches have included, for example, economic history (Ulväng 2013), ethnology/consumer studies (Klepp 2010/Laitela 2014), gender studies (Warkander 2013), social anthropology (Skov 2011), art history (Sigurjónsdóttir et al. 20011), and design research (Skjold 2014). Very important contributions for establishing the wardrobe method were made prior to the establishment of the network from within consumer research (Kleine, Kleine & Allen 1995), anthropology (Guy, Green & Banim 2001; Tranberg-Hansen 2003), design research (Raunio 2007; Fletcher & Tham 2004), costume history (Turney & Harden 2007), and material culture studies (Woodward 2007; Miller & Woodward 2012). What these studies share is an interest in the materiality and physical storage of dress objects, and an interest in the way the objects are handled, worn, maintained, acquired, and discarded by their wearers in the wardrobe. When taking the rich presence of various disciplinary approaches to the wardrobe in the wardrobe network into consideration, it is obvious that the objectives of study have varied.

In my own research I have been very inspired by the anti-elitist approach of user oriented design research that has developed since the 1990s, within which I am particularly interested in *user oriented design research* (Sanders & Stappers 2008) and *practice-oriented design research* (Shove et al. 2008). These approaches vary in relation to method and aims but are basically addressing the relation between time, subjects and objects, as they are played out in routine-like practices in everyday life[2]. User oriented design research is interesting in relation to research on dress practice because they all engage with the bodily aspect of interacting with design objects, much in line with Latour's idea of the human-nonhuman hybrid (Latour 2005); design thus gets to be an *extended self* not only in relation to the mind and also to the body. This is why they are so applicable to understand dress-body connections, and yet to my knowledge they have not been applied in fashion- and dress research at large.

Method of study

My wardrobe research must be seen as an attempt to bridge the two above scholarly approaches, which I have tried to follow up in my research method. Hence, in my interviews

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[2] This development can be perceived as closely connected with the so-called *practice turn* taking place within sociology/organizational theory in the same period of time, represented by i.e. Gherhardi (2009) and Hernes (2007)

I made use of the concept of *clustering* from design research. According to Gelting & Friis, who have tried to map out methods engaged by designers, clustering is a method of visual and tactile mapping of colours, textures, shapes, or various sources of inspiration. The act of clustering often takes place at the design studio, typically on mood boards, where fabric samples, colour palettes, pictures and other kinds of objects are placed in categories or timelines, for the purpose of detecting visual and tactile patterns of coherence (Gelting & Friis 2011). In this way, the clusters aid designers in making rapid design decisions. The technique of sorting, or of categorising, is well known in design research, as well as in qualitative research. Within design research, it has been approached by, for example, Wurman, who suggests that in order to grasp the world, people sort all kinds of information through five levels; Location, Alphabet, Time, Category and Hierarchy - hence his term, LATCH (Wurman 1989). A similar approach can be found in the so-called 'repertory grid' method, originally developed within the area of psychology in the 1950s to help people recall and understand trauma. Basically, the method builds on sorting processes, and on the idea that if people are asked to sort objects, people, events or activities through various 'grids' such as making a ranking, assigning grades, for example, ranging from 1-10, or making dichotomies, they will reach new levels of understandings through finding patterns of coherence or difference (Tan & Hunter 2002). Within recent decades, the repertory grid method has been applied in the field of design research as an 'innovative' method, such as in the work of Bang. In her PhD thesis, *Emotional Values of Applied Textiles,* she uses the repertory grid method to explore decision-making processes among textile designers: processes that are often based on tacit, emotive valuations of, for example, tactility and textures (Bang 2010). In this way, Bang's project stands as a textbook example of how to address sensory aspects of design such as touch, sound, smell, sight or taste, through facilitating various sorting processes, together with informants (in her case, designers). The term, 'clustering', is also known within qualitative research. Miles & Huberman define clustering as a tool for analysing fieldwork data, based on the way 'we all have cognitive frames that let us clump things rapidly' (Miles & Huberman 1994). Equally, Spradley's taxonomies work as a similar aiding tool for researchers to code patterns of coherence (Spradley 1979).

What I literally did in my fieldwork was to draw on such methods and reasoning when I interviewed my informants in their wardrobes; when I asked about their relation to a specific garment, I would always make them touch it, and this way establish a dialogue which included their sensory experience of dressing. I also made them categorise dress objects in any way they felt connections emerging, this way establishing a platform to discuss likenesses and differences between the various dress objects. If an informant wished to categorise his shirts, he would place them in heaps according to the way he felt it made sense; how he used them, whether he liked them or not, if they were active or passive in the wardrobe etc. Based on that, the dialogue could approach the issue of sensory experience, because the dress objects were literally at hand. Even if a given informant had no professional language for a fit or specific fabric, the important thing was what it meant to the individual user; whether he/she liked a fabric to be 'soft' or 'firm', a shape to be 'pointy' or' round', or a fit to be 'tight' or 'baggy'. In this sense my interview-technique much resembles the so-called 'organic wardrobe studies' of Warkander, formed as an upshot of these reflections:

> The term 'organic' refers to the process of letting the garments become the starting point of improvised and personal conversations about style and dress practices. The organic wardrobe study allowed the participants to discuss more freely their feelings about specific garments, showing me what clothing combinations they appreciated, or how favourite outfits were stored. [....] To discuss events and feelings while looking at, sometimes even holding and touching, an actual garment in a person's closet helps articulate feelings which otherwise would have been hard to get at (Warkander 2013:61-62).

Here, the senses and the materiality of dress is central to the research method, because the informants literally touches their dress objects, or tries them on, in order to "sense" or express their feelings and aspirations.

To sum it up, I applied on the one hand the semi-structured anthropological interview with the user's experience in focus, as promoted by i.e. Spradley (1979) who talks about informants as "teachers" and researchers as the one who "learns" about the logics, aspirations, routines and dreams of individuals. On the other hand, I drew from the principle of clustering and conducted a semi-structured dialogue that had its departure in the materiality of the dress objects in my informants wardrobes, and through game-like structures of categorizing and comparing I strived to keep focus on sensory experiences of dressing.

In the wardrobe

In the wardrobes of my male informants, I encountered how the sensory experience of dressing seemed to be affecting to a large degree not only what they would typically wear at the time period of the interviews, but also how their dress style had developed throughout their adult lives. In the case of Michael, who was 48 years old at the time of the interview, one of the first categories he took out of his wardrobe closet and placed on the floor in his bedroom was a range of brown, woollen trousers (fig. 1). Michael has conflicting relations to these kinds of trousers. On the one hand, this is what he has favoured to wear for many years. Michael considers himself to be a "brown" guy ("brown is a winner in my world"), and he has a particular love for what he refers to as "DDR style" - a style inspired from the typical male dress style of 1970's/1980's East Germany that has fascinated him a great deal throughout his early adulthood. Michael's problem with his woollen trousers is that he hates how the wool scratches his legs. He tells me that when he was a boy his mother forced him to wear tight, woollen trousers that "scratched like hell". And how since then, he has hated wearing woollen trousers. He owns seven pairs that are almost alike, and of these, one is his favourite pair (fig. 2). They appear torn and worn, and he tells me how he has actually had them customized at more levels. For one, he has had linen sown inside of the trousers legs to prevent them from scratching, which meant that these were the trousers he would wear most frequently. As such, this represents a solving of a conflict between his style preference, and his preference when it comes to physical comfort.

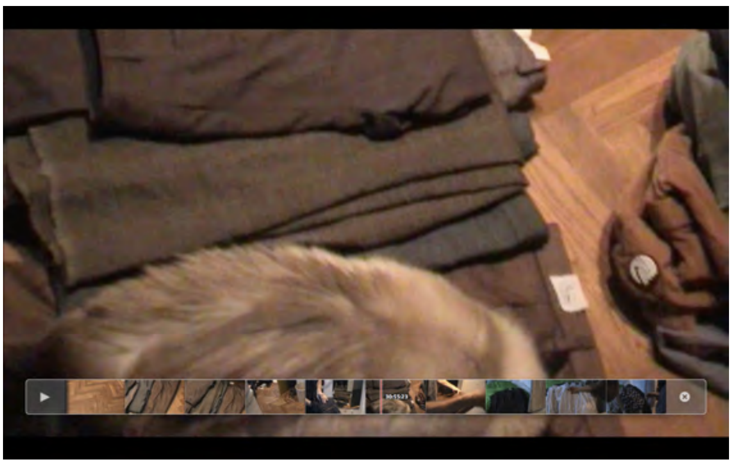

Fig. 1 Michael has placed the category of brown, woollen trousers on his bedroom floor. They are almost similar in style, type of material, and cut.

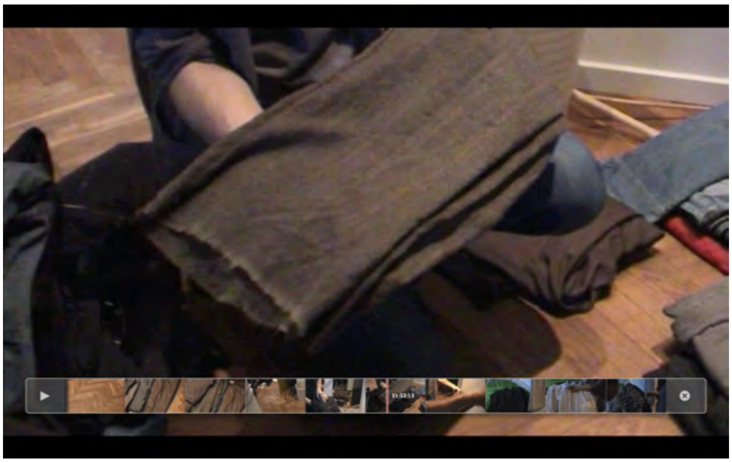

Fig. 2 This is his favourite pair of brown, woollen trousers; they are very worn, and he has had linen sown inside the trousers legs to stop them from scratching. Also, he has at one point cut them shorter.

Secondly, he had cut the trousers legs shorter at some point, which seemed to be connected with other mattes of dress sensing. He tells me, that some years ago he would prefer to wear dress objects that were a little too short. Shirts with short-ish arms, a trenchcoat with short arms that he would fold up to make them even shorter, combined with the short-legged trousers, and together with this, he would typically wear a pair of robust-looking Dr. Martens boots. As the interview sessions progress, Michael refers repeatedly to this silhouette and particular dress style as something he is about to leave behind for something new. It appears more and more how he is in a phase of transition that in his own opinion started 5-7 years before the interview took place. The "old" silhouette would typically comprise of a pair of slightly baggy, woollen brown trousers with shortened legs, together with a slim-fit shirt. When asked why he preferred slim-fit he tells me that he finds how "it creates a nice flow on the body, well, shirts that are too baggy they kind of dissolves the shape, or disrupts it. Also, slim-fit shirts are sufficiently long. They are perhaps 3-5 cm's longer than the other brown shirts I have, so then they get a length that for once fits my upper body, which feels really nice". The same theme comes up at a point where we look at a heap of his favourite T-shirts, of which some are quite small in the size. Michael says that he doesn't use them much, as they have become too small. I ask him if his body has changed, and he answers: "perhaps my idea of "too small" has changed. I sincerely believe they have become smaller since I bought them [smiles]. I think it is something that I am just imagining, possibly because [name of girlfriend] has started telling me that I wear things that are too short. I just haven't paid attention, that's it". As we discuss this further, it comes out how he used to appreciate wearing dress objects that were too small. But that he is now experimenting with a "longer" silhouette that adapts better to the taste of his girlfriend (fig. 3).

Fig. 3 Compared to the silhouette he typically wore until 5-7 years ago he now prefers a silhouette that matches the actual length of his arms, upper body and legs.

A similar encounter took place with the informant Jonas, who was 38 years old at the time of the interview. Jonas has approached the conflict between dress, body and taste of style in a different way. Just like Michael, Jonas has a tall and slender body that has not changed a lot since his early adulthood. But opposite of Michael who has transformed his dress style from wearing "short" dress objects and into wearing "long" ones, Jonas has managed eventual conflicts and problems through refining the same type of silhouette over the years. As if he found the perfect template for how to dress when he was young, and now wears the same with slight alterations. As he says himself, he is "more into classics" (as opposed to being into trends). But these classics are not necessarily what everyone else would understand as a classic. It is a 'classic' in his own, personal style of dressing. In that way changes and transformations *has* taken place in his wardrobe, but in a more subtle way than was the case [with Michael. As if he found some basic themes when he was quite young, that he continues to work with, because he believes they fit his body type and his taste.

What is interesting in relation to the dress-body connection is how Jonas' development, as seen through the dress objects he stores in his wardrobe, refers to specific types of textiles and fits that he has come to prefer, which feels 'right to wear'. For example, he prefers desert boots made out of crude rubber and suede that he describes as 'soft', and with a rounded nose (fig. 5). Throughout time, he has purchased quite a lot of them, and other shoes that looks very similar, and feels similar to wear. Much the same way, Jonas prefers to wear textiles that feels and looks 'soft'. This re-emerges in dress objects such as hoodies, types of knitwear, suede shoes, or his Harrington jacket (fig. 4).

Fig. 4 Jonas looking through his shirts, cardigans and hoodies. Some are from his student days, some of them he has purchased recently. What meets the eye is how the same types of material, cut and style re-occurs repeatedly over the years.

Fig. 5 One of Jonas' pairs of *Wallabee Desert Boots* of the brand *Clarks*. He is very loyal to the brand, and to this model. He likes how it is soft-looking with the suede surface, and round in the nose. He does not like shoes that are long or pointy, and he also doesn't like sneakers. He has settled with this type of shoe to be simply the best one for him and his style.

The body in motion; dress sense and processual understandings

In my wardrobe research, I found how repetition of style, cut and material seemed to be a key to understand how my informants had developed their dress style in their adult life. As it appeared, they had found these themes after a principle of trial-and-error, and throughout their lives these themes are constantly re-evaluated and transformed. Not to something new, but to new versions of the same. What I found highly interesting was that the senses played a role not only with regards to a specific garment, but also to the entire wardrobe. It actually seemed as if my informants had developed and refined their wardrobe with the aid of their sensory apparatus, guiding them decide what to acquire, what to keep, and what to discard. As such, I experienced much in line with Woodward how the wardrobe represents people's 'personal collection' built over timeless 'wardrobe moments' in which they decide whether their outfit, or individual garment, is "right" for them to wear or not (Woodward 2007:3). As I saw it, decision-making in these 'wardrobe moments' were very much based on touch, smell, sound, and whole-body sensations. This bridges the processual view that I have tried to implement in my methodology as well as in my analysis; how through a lifetime, each person develop and refine his/her wardrobe on the basis of sensory and cognitive experience. I here understand sensory experiences of dressing as being related to what former ballet dancer and choreographer Twyla Tharp has called 'muscle memory' (Tharp 2006). Tharp is addressing how the body of a dancer will remember certain moves and steps for decades, even if these steps are lost in memory. Through the continued repetition, over and over, of these moves through training, a dancer will only need to make a few gestures with a hand and then the body will remember the exact moves – even many years after a performance. Much the same way, I experienced how my informants had a sensory memory through which they 'remembered' sensory experience of success and failure, based on which they developed and refined their wardrobe. Hence, through repeting themes of cut and material in their wardrobe, they seemed to bind together past, present and future ideas of self, including ideas about how it should feel to be dressed.

Even if I found it difficult to detect such understandings within fashion and dress research, wardrobe research seems to be the exception that proves the rule. Through a museological perspective, Turney & Harden (2007) has showed how 'ordinary' women have appropriated 'fashionable' floral-printed dresses into their own wardrobes, thus displaying how they have made these dresses their own through use. Through interviewing people and quoting from media, Cole (2000) similarly displays how dress objects worn in the past continue to have a huge importance for the wearer. Also, Ingun Klepp has showed how people seem to be more occupied with already existing dress patterns, what is "old", than they are interested in what is new and fashionable (Klepp 2010). Fletcher plays out how the 'craft of use' help people transform their style over age, even if they might hold on to particular dress objects and use them for a very long time period of their lives (Fletcher 2014), and as such she is in line with the way Tranberg-Hansen explains dress practice as the 'hard work of consumption' (Tranberg-Hansen 2003). As such, these scholars do touch upon how issues of bodily comfort and style play a role in the way people develop their personal dress style. Still, there seem to be shutters that separate understandings within fashion and dress research and design research. Just like Otto von Busch, I am surprised about this. In his text "Revisiting Affirmative Design" (2009), he states how both in fashion industry and research on fashion "little focus is put on how garments live their lives with the consumers", and even proposes how the whole area should conduct a *Copernican Turn* away from lead users.

In my own quest for doing so, I have pursued ways of interacting with the so-called *emotional turn* in design research as defined by i.e. Norman, who in his book: Emotional Design. Why We Love (or Hate) Everyday Things (2004), distinguishes between various levels of cognitive and emotional systems at work when we interact with design objects. Or Jordan (2000) who operates with the levels of *pleasure* that emerges in the interaction between design objects and people. However, I fully follow Shove et al. in their book: The Design of Everyday Life (2007) as they criticise the idea of emotional design, arguing how this line of thinking misses out how people actually make use of design products in their everyday lives. In their mind, this gap exists because the whole concept of emotional design has its focus on establishing a close connection between objects and user, but not *between objects and user practices*. Pursuing the idea that 'competence is at once embodied in humans *and* in things', the authors point how the whole theoretical landscape, in its search for ways of understanding our interrelation with objects, has missed out on targeting adequate focus on use, making, and doing in people's everyday lives. And how such focus would entail exploring more deeply how people's competences and knowledge in relation to objects are temporally ingrained in their daily routines and aspirations.

In relation to my own studies of people in their wardrobes, I have approached these ideas by looking more closely at the daily practices engaged in my informants' dress practices. I have asked myself what kinds of competences it actually takes to be able to get dressed every day, on what grounds people base their daily decision-making processes, and how dress objects as material entities play a role in these processes. And not least, how all of this develops over time. I have therefore been looking at ways of understanding how people establish criteria and 'rules' for how to dress in ways that they feel are appropriate and in tact with their own ideas of self, and how this takes place in the daily, routine-based act of getting dressed. As such, the 'wardrobe moment' can be perceived through the words of Elizabeth Sanders, who perceives consumer experience with design objects as 'a momentary flash, taking place in time' (Sanders 2002, in: Mattelmäki 2007:31). By merging approaches on body-dress connections from fashion and dress research with a user oriented design research methodology, I believe it is possible to open up more for what Fletcher has called the "'deep landscape' of use practices of clothes experienced in the course of life" (2014:22).

While other related design areas have been applying user oriented methods largely to understand user experience and user practices around design better, dress design has been left behind in these endeavours, and as a fact quite little is known about how people engage with dress objects in their daily life. In particular, the dress-body connection as it is played out in time is under-researched, which I find unfortunate since dress plays such a vital role in our identity work, and the way we experience the world.

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Else Skjold

Else Skjold holds a PhD from the Doctoral School of Organization and Management Studies at Copenhagen Business School and Design School Kolding (2014). Prior to doing her PhD, she has worked as a fashion journalist for various Danish fashion magazines, and as a research assistant at Design School Kolding where she conducted the report *Fashion Research at Design Schools* (2008). In the period of 2008-12 she was actively engaged in devloping the so-called wardrobe method together with a line of fashion and dress scholars from Scandinavia, Britain and Holland who were part of the Wardrobe Network funded by NorForsk and NOS-HS. In her research she is working with ways of understanding dress practice as both symbolic discourse and physically embedded practice, and as such her research must be seen as a hybrid between cultural studies, user-anthropology, and design research. She is currently working in a collaborate project between Design School Kolding and Kopenhagen Fur, where she looks at fur and use experience in a sustainable perspective. In particular, how her view on dress practice and temporality might fuel into fur as a long-lasting material.

Materia Prima: The Rough Guide

Megan Walch, University of Tasmania

Abstract

This paper describes a suite of ten paintings titled *The Rough Guide* and discusses them as an alternative form of cartography that maps subjectivity in flux. It is an autoethnographic account of the material performativity of paint and the interplay between base materiality, chemical interactions and my improvised embodied action. This echoes the ancient alchemical practice where transformation of substance became transformation of self: in alchemy the perfection of Man was aimed at unity with Divine nature. *The Rough Guide* suite forms the central component of a studio based PhD investigation titled *Viscosity, Fluidity, Plasticity: Reworking Pictorial Conventions in Paint*, which investigates painting's materiality in both form and content.

The research project began with the physical medium and characteristics of paint and the proposition that its material properties enable the exploration of a transformation in material thinking. The body of paintings is the 'tangible means' of giving form to paint's materiality as a model for fluid and plastic thought. Paint's substantial properties therefore create models of an alternative subjectivity, as a visceral analogue performing the plasticity of mind and body. Its vocabulary is suited to a discussion of non-dualistic connections to the physicality of substances and thereby to the world around us. Jane Bennett's (2014) notion of 'vibrant matter' proposes that materiality is a rubric where the relations between things are flattened and read horizontally; she proposes that this is a step toward a more ecological sensibility.

The Rough Guide painting creates pictorial spaces that re-present a change in perspective. I propose that horizons, grids and linear perspective no longer provide us with tools for navigating a globalised world where cultural borders are porous and new technologies have the capacity to expand, compress and invert spatio-temporal relations.

Synergies discovered between Jane Bennett's (2014) theory of 'vibrant matter', Francois Jullien's (2009) notion of 'the foundational fount', the alchemists' 'materia prima', (Elkins 2000), George Bataille's 'base materialism' (as cited in Noys, 1998) and readings of Bataille's *informe* by Yves-Alain Bois and Rosalind Krauss (1997), acknowledge the non-duality, potency and instability of inchoate form. These theories straddle categories of thought, as does Sartre's notion of viscosity. This supplements gaps in a Western art history that has been founded upon an ontology of stable concrete objects. The performativity of the painted medium becomes a theme and is used as a method to construct paintings that enact a relationship between destruction, repair and transformation. Base qualities are employed in the paintings. The vacillation between compelling and repelling, between lush lustre and ruinous fluidity generates movement and turbulence. Velocity rather than objects is being depicted, and the works are successful when they continue to visually transform.

Framing, fixing and suspending uncertainty on a surface – whether it is canvas, wall or screen – can construct a territory of flexible material relations, which may in turn transform the very material of ourselves.

Keywords

fluidity of paint; viscosity of paint; plasticity of paint; surreal cartography

My studio is located in an old boat-building shed on Australia's island of Tasmania. It has a tin roof and timber walls that register conditions of sun, wind and rain that locate me in the southern part of the world. My family comes from a lineage of boat builders, explorers and sea captains: I learnt to paint on canvas, a material that my forebears used to sail around the Pacific. I am constantly aware of canvas's relation to colonisation and the notion that materials are not innocent. "The rectangle is the template of world conquest", declared Peter Schjeldahl (September 2011) in a discussion about Australian aboriginal painting. Australian artist and art theorist, Barbara Bolt (2004), proposes that by first recognising the encoding of materials and processes within conventions, artists can then move beyond such 'rules' to find alternatives. Thus I choose to work with and against conventions in painting.

This paper describes a suite of ten paintings, 130 cm x 130 cm in enamel and oil paint on composite aluminium panel, titled *Materia Prima: The Rough Guide*. Composite panel is a sign writer's material. It is composed of a plastic core sandwiched between 0.5 mm aluminium sheets coated with high gloss plastic. The paper discusses the dynamic material performance of paint as an active modality of material thinking that works between skill and abandonment. *Materia prima* – first matter – is the inchoate substance required for alchemy. In *The Rough Guide* the medium of paint is *materia prima* and metamorphosis occurs through the plasticity of the medium. The title references the *Rough Guide* travel book series and emphasises mobility as well as textural and visceral qualities in paintings as an alternative form of cartography that explores fluid thinking. *The Rough Guide* suite forms a central component of a studio based PhD investigation titled *Viscosity, Fluidity, Plasticity: Reworking Pictorial Conventions in Paint*. This studio-based project is an exploration of painting's complex materiality in both form and content. Paint's protean nature is exploited to demonstrate the mutability of its tradition.

Medium, n, adj.

Something which is intermediate between two degrees, amounts, qualities, or classes; a middle state.

An intermediate agency, instrument, or channel; a means; esp. a means or channel of communication or expression. ("Medium", OED, 2001).

Paint is my medium; it is unctuous, sticky and messy. It can be smeared like grease or dripped like thickened cream. Paint conforms to the laws of gravity and movement. If I let fluid paint fall it naturally forms blobs and curves. When I position fluid paint vertically it drips. When I spill fluid paint on a horizontal surface it moves laterally to form a pool. When I mix enamel paint with solvent they interact creating turbulent eddies, pustules and vortices. The grounds in the paintings perform a chemical mimesis of earth, sea and sky, repeating Warlick's (2001) truism that in alchemy these environments reflect the mirrored relationship between macrocosm and microcosm.

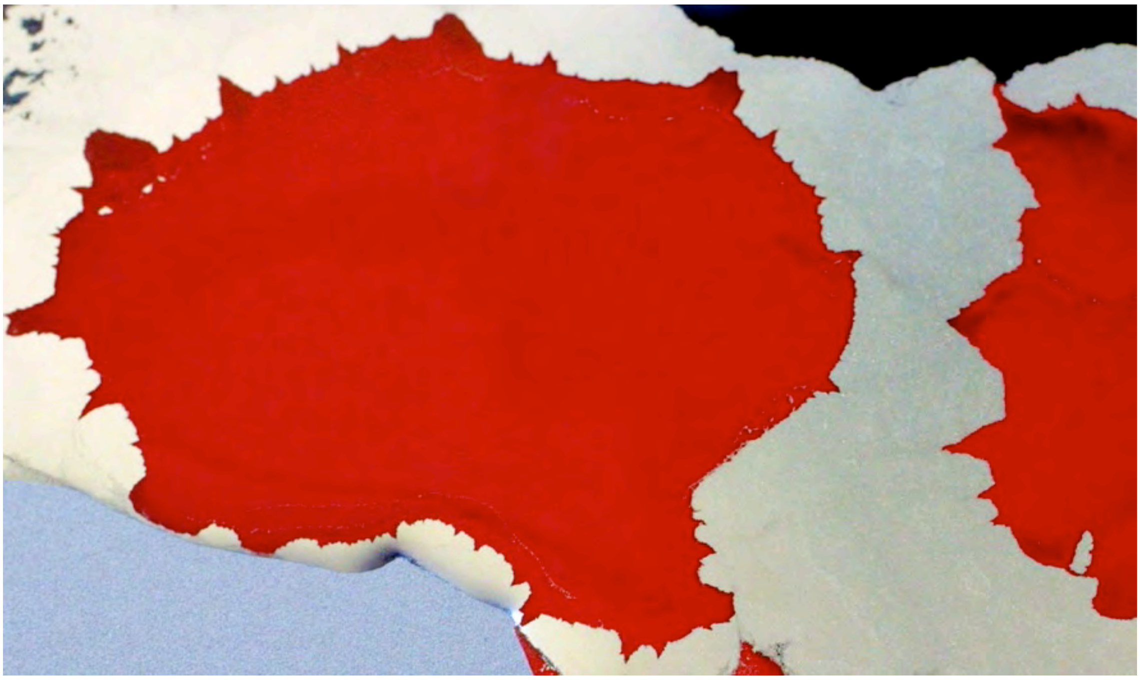

Fig 1. Detail of poured enamel paint mixed with solvent 2015

In alchemy the Philosophers' Stone, was said to be made from a common substance, found everywhere but unrecognised and unappreciated. The Stone was sought by alchemists for its supposed ability to transform base metals into precious ones. Alchemy was concerned with the perfection of the human soul, the philosopher's stone was thought to prolong life, and bring about spiritual revitalisation (Cotnoir & Wasserman, 2006). The quest for the stone encouraged alchemists to examine substances and their interactions in laboratories.

Materia prima is formless base material, akin to chaos or *dark* matter – the nastier and stickier it is the better. My project acknowledges the base qualities of the painted medium, as approached by Georges Bataille (1897-1962), as those that are unrefined and foundational. Bataille's notion of base materialism (as cited in Noys, 1998) destabilises existing hierarchies by acknowledging that the base and vulgar supports that which is elevated or ideal. Base matter can be regarded as general instability and this resonates with Sinologist Francois Jullien's (2009) translation of a traditional Chinese philosophy of painting. His term the *foundational-font* is the undifferentiated material and the origin of all possible configurations of the image.

Synergies discovered between Jane Bennett's (2010) theory of 'vibrant matter', Francois Jullien's (2009) notion of 'the foundational fount', the alchemists' 'materia prima', (Elkins 2000), George Bataille's 'base materialism' (as cited in Noys, 1998) and readings of Bataille's *informe* by Yves-Alain Bois and Rosalind Krauss (1997), acknowledge the potency of inchoate form. This supplements gaps in a Western art history that has been founded upon an ontology of concrete objects. I propose that a philosophy of absence and flux is now the project of a contemporary form of painting that embodies a relationship between destruction, repair and transformation. In the *Rough Guide* series the performativity of paint as a medium becomes a theme and is used as a method to construct paintings. The interplay between the artist and the medium is active and contingent. The risk of failure and uncertainty is embedded in the working process: from the pouring of paint and interplay between painted layers to the interaction of fluid colour and the awkward compositions that often result. In the alchemical process lies the constant risk of failure because the quest for the Philosophers' Stone is doomed from the outset.

Fluidity, n.

The quality or condition of being fluid. ("Fluidity", OED, 1897).

Rheology, *n.*

1. The branch of science that deals with the deformation and flow of matter, esp. the non-Newtonian flow of liquids and the plastic flow of solids. ("Rheology", OED, 2010).

James Elkins writes that “paint is liquid thought” (2000, p. 4). He argues that “thinking in painting is thinking *as* paint" (2000, p. 5). The grounds in *The Rough Guide* paintings are created by pouring a suspension of fluid enamel and solvent. I pour the paint onto the panel positioned horizontally on the floor, tilting it to direct the flow and viewing it from all four sides and in reverse, using a mirror. This occurs in one extended session before the paint forms a skin. This is a collaboration with gravity, temperature and chemistry. I am able to direct the way that the paint settles, but its ultimate performance is not in my control. I am a conduit: a conductor and manipulator of paint, and I need to know when to leave it to do its own thing. The resilience of the composite panel lends itself to multiple painterly languages of addition, subtraction, abrasion, pouring, masking, washing and the application of glitter. The surface becomes a register of pressure and erasure. The viscosity of paint on the surface of the panel is held in tension, there is no absorption. Once they are dry I work back into the poured enamel grounds and I allow their topography to direct how form will emerge. My improvised response is a plastic operation. I am directing the paint and it is directing me.

Fig 2. Back to the Bones. Oil and enamel on composite panel 130 cm x 130 cm 2015

In *Back to the Bones and Skullbone Plains* (Fig 2, Fig 3), I use blue to create a recessive space that is naturalistic and registers as sky. A painted layer merges with the fluid ground in some areas and contrasts to it in others. The undulating interaction between the two matrices contributes to movement in the painting to create ambiguous forms and spaces. Adding a painted layer has a transformative effect on forms and spatial relations. It allows me to discover forms and spaces that are unexpected. This operation resonates with Max Ernst's claim that collage created an alchemical transformation of the image (Warlick, 2001).

Fig 3. Skullbone Plains 1. Oil and enamel on composite panel 130 cm x 130 cm 2013

Silver is used to reflect light in the paintings (Fig 5, Fig 6, Fig 9). It holds us on the picture plane and it shimmers as we move in relation to the work. The images confuse figure and ground but they coalesce into a sheen that connotes a mediated screen space. The sheen on the surface of the pictures pushes us back from the surface of the image. Hung in the gallery, these paintings are hungry for light, due to the highly reflective silver particles suspended in the medium. Silver is added to the solution to register movement as metal filaments flow and curdle to generate a macro–micro topography of surface. The shimmer sets up a movement and instability in the image. These highlights flash and gleam: reacting differently in varying light conditions, they mimic life in inert material. Silver is an exemplar of Jane Bennett's (2010) 'vibrant matter'. The shimmer of silver choreographs the viewer to move in front of the painting. This dispersal of light works against a singular gaze being located in one coherent viewer, it creates instability of form and operates as a signifier of 'the formless'.

Fig 4. Skullbone Plains 2. Oil and enamel on composite panel 130 cm x 130 cm 2013

The Formless is not a lack of form. It is a resistance to form and the alteration of form. *Informe* is a para-surrealist term, derived from Georges Bataille. It denotes deformation, reformation, alteration and instability. *Informe* works against constructing meaning through binaries because it disrupts stable distinctions between alternating opposites. Writing of the *informe*, Elkins says, “Nothing is secure and forms and figures vacillate or shimmer rather than oscillate in a regular motion” (1998, p. 106).

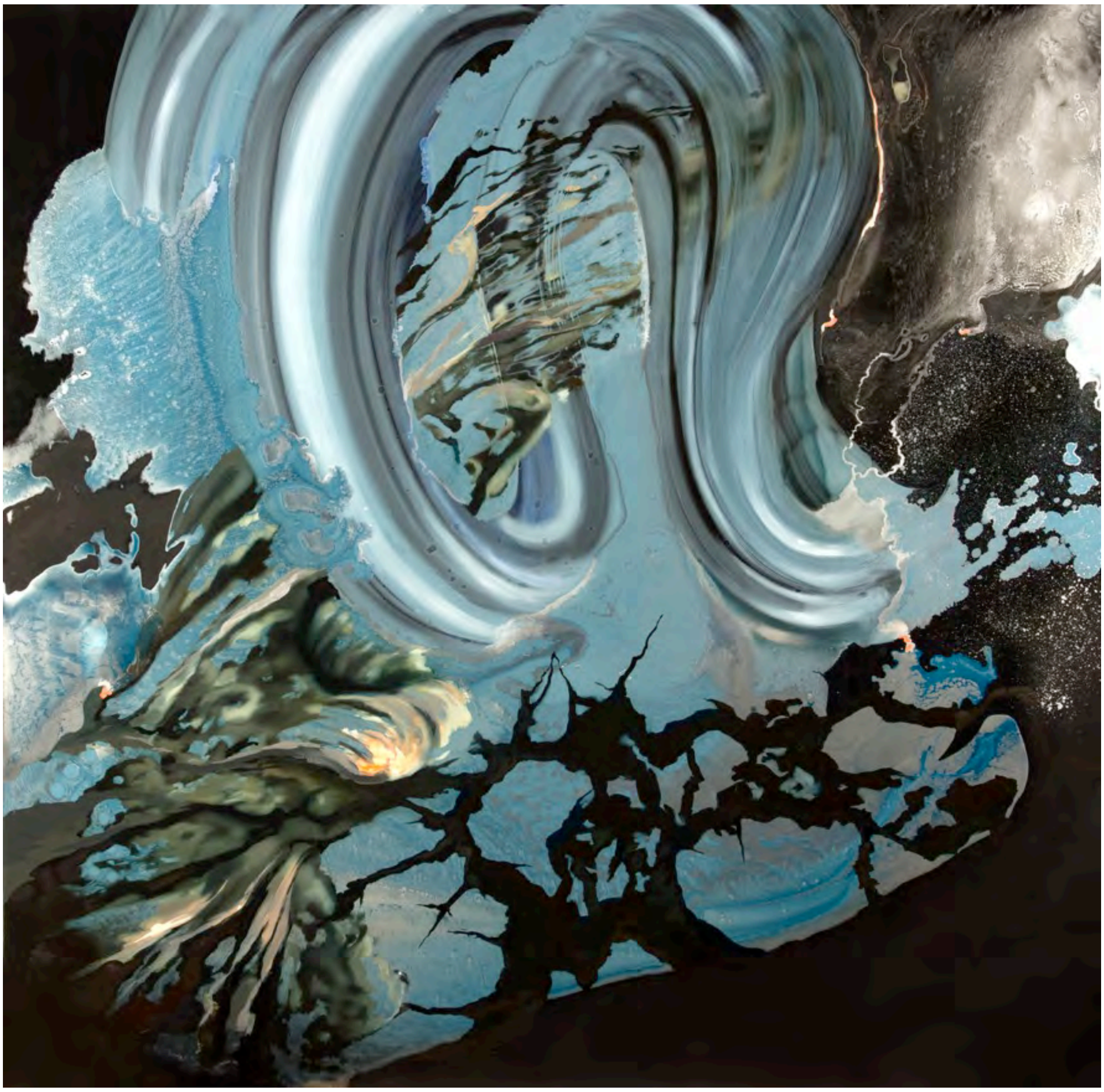

Fig. 5. Sabesan Skytree. Oil and enamel on composite panel 130 cm x 130 cm 2015

In *Sabesan Skytree* (Fig 5), a calligraphic smear morphs into splattered atolls and then into stars in a celestial night sky of the black picture plane. Different perspectives co-exist in the painting and each encounter with the work yields different combinations. The forms may be fixed, but their readings are not. At the pictorial level these images are still moving and they appear to continuously transform. Cognitively we can recreate them differently with each visit, an objective reading of them does not exist. An enlargement of perception can occur when we are open to collaboration with fluidity in images.

Barbara Bolt (2004) examines knowledge gained through the handling of materials in her book *Beyond Representation: The Performative Power of the Image*. Bolt suggests that it is in the process of handling materials that artists acquire insights significant to knowledge creation, and she argues for a practice where the artist is a collaborator with materials, weather conditions and gravity. Bolt says that cooperation is a relationship that is not centred on the self-conscious subject, and this constitutes an alternative form of subjectivity. Jane Bennett (2010) proposes that non-human bodies are active agents that shift humans from the center of an ontological hierarchy**.** Bolt (2004) cites Heidegger's notion of 'handlability' where the spontaneity of practice has its own rhythm and logic and through handling materials, tools and objects we are in the middle of possibility (Dasein) where the fixity of representation can be loosened.

Viscosity n. *The quality or fact of being viscous; viscidity.*

In scientific use, the tendency of a liquid or gas to resist by internal friction the relative motion of its molecules and hence any change of shape ("Viscosity", OED, 1917.).

Viscosity dictates how fluid enamel paint will flow, mix or repel. It is a measure of a fluid's resistance to liquefaction. When paint becomes tacky it develops a resistance to being altered. In viscosity form is still attenuated. The result of colour mixing depends on pigment saturation and viscosity in the medium. High viscosity produces colour with a greater resistance to becoming grey and muddy. Low viscosity can mean that colour is easily dispersed. Paint's viscosity is used in this project as analogue for resistance to liquefaction, dematerialisation and homogeneity.

Viscosity is a substance between states, between fluid and solid: it sits between categories of form. Sartre (2003) explores the ontological region of viscosity as one of ambiguity and lack of equilibrium. It is a combination of physical and moral, masculine and feminine, continuous and discontinuous, fluidity and solidity. Sartre (2003) writes that viscosity and, by implication, stickiness, is a threat to our subjectivity due to its state of in-betweenness. Painted mediums are sticky; they range in viscosity from fluid to glutinous. Mediums suspend pigment and are a vehicle for painted expression. According to their viscosity mediums perform different tasks in painting.

Viscosity increases as fluid paint dries or becomes tacky. This is an act of congelation that is the process by which something congeals or thickens. Elkins states that the alchemists saw this act of 'congelation' as a violent process: "Imagination is fluid, or it wants to be, and the very act of painting is an act of violence against the liquidity of our thoughts." (2000, p. 124).

The 'pour' becomes a register of horizontality. The square is chosen as a format that is neither portrait nor landscape. Pictorial constructions favour asymmetrical cropping and framing to reinforce movement that centres on continuous dissolution and recreation. They are turbulent images. Forms coalesce and then disperse to become partial and outlined. Shapes shift to share attributes and exchange places as they metamorphose into each other, suggesting the exchangeability or non-separation between objects: a transformational system where hair rhymes with brush and branch with bone. This is a historiography of form and its transformation. It is how form undoes and transforms itself.

Plasticity n.

1. The quality of being plastic; specifically the ability to be easily moulded or to undergo a permanent change in shape.

2. Biology. Adaptability of (part of) an organism to changes in its environment; specifically the ability to alter the neural connections of the brain as a result of experience, in the process of learning. ("Plasticity", OED, 2006.).

Catherine Malabou's (2005) theory of plasticity is a theory of form and its transformation. Plasticity of form is that which is malleable. It retains shape but does not deform to the original. In *The Rough Guide* plasticity is materialised in the painterly medium and it occurs by allowing liquid enamel grounds to direct how subsequent forms will emerge.

Fig 6. Extreme Ikebana. Oil and enamel on composite panel 130 cm x 130 cm 2014

Plasticity embraces elasticity. In *The Rough Guide* there is a conflation of a number of painterly languages, they meld and overlap. Figuration is elastic until it snaps into abstraction and back again. In *Extreme Ikebana* (Fig 6, Fig 7) the figure-ground relationship exists in constant flux and they often appear to wrestle with each other. I stretch figures and fragment them through grounds. I use grounds to smother figures. I inflate forms to become pneumatic before exploding and shattering them as if shot from the side by a gun in a violent computer game (Fig 7).

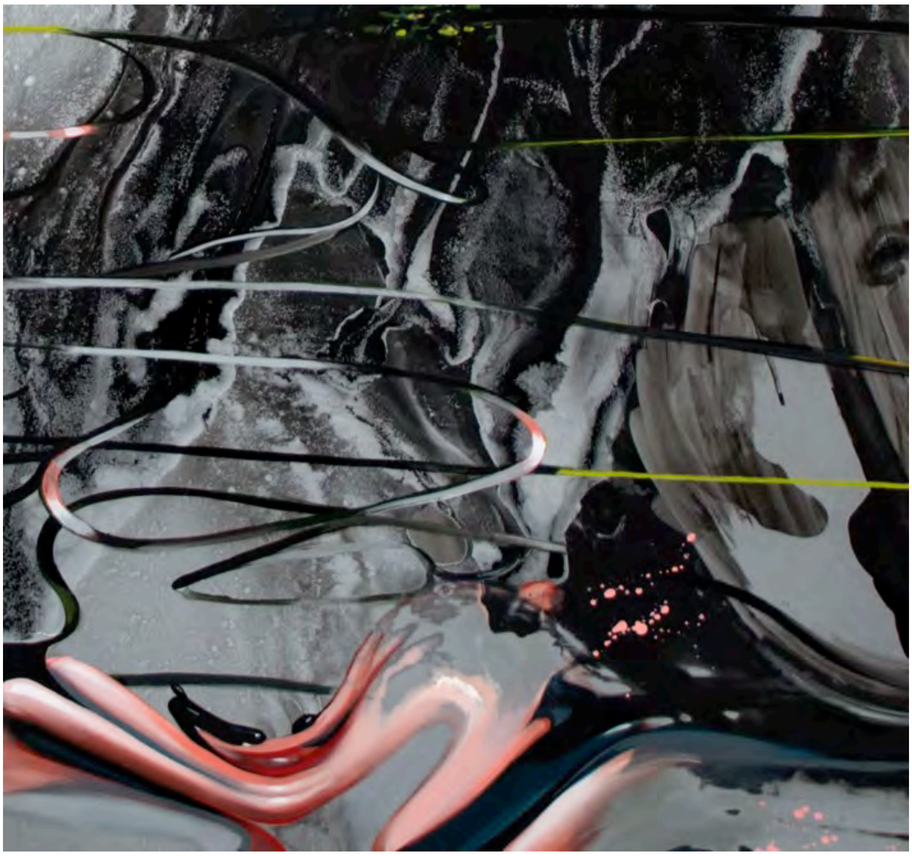

Fig 7. Detail: Extreme Ikebana. Oil and enamel on composite panel 130 cm x 130 cm 2014

Breaches of form occur in a number of ways through different demarcations of edges. My acts of partial erasure embed figures into the base layer and they appear to cohere (Fig 2, Fig 7). I erode and then merge them to create a new amalgamated foundation. I disperse form's colour until it weeps into aqueous fractal blooms like culture growing in a Petri dish (Fig 8). Moulded objects coalesce, coagulate and warp, before I transport them via a tangled thicket of ligature or calligraphic slag to project at simulated speed to exit the painting (Fig 6, Fig 7).

Fig 8. Detail: Extreme Ikebana. Oil and enamel on composite panel 130 cm x 130 cm 2014

There is no indication of the sequence in which fragmentation occurs or in which order layers are constructed, the process is non-linear and the conflation of space between forms reads as a distorted a sense of time. Erasure is my key method for subtracting paint from the surface of the work before adding paint again in select areas. The pressure of sanding the paint fixes a form into its surroundings leaving no evidence of a seam. The boundary of the form is indistinct due to the desiccation of edges. Areas of the ground emerge through and merge into the sanded layer. This is a form of plasticity.

Plasticity holds extremes together and they in turn act upon each other. Plasticity of thought is to hold contradictory positions at the same time without creating binaries. This is a space of non-dualistic thinking. In *The Spill* (Fig 9) I populate the painterly pour with minute dots to disperse in a laval flow prior to plummeting into a deep void of blackness. Fragments like platforms of rock hover over the precipice of a gravitational vortex whilst defying gravity. These operations are like abstractions of screen energy and its attendant excesses that accompany obliteration and reconfiguration.

Fig 9. The Spill. Oil and enamel on composite panel 130 cm x 130 cm 2015

The figure ground distinction is fundamental to our reading of images as a visual index for defining our sense of self. The existence of a separate ‘Self’ is contested, but contrast *creates* meaning and without difference an object has no limits. The figure ground relationship can be an analogue for how we exist as separate or non-separate from our environment. In *The Rough Guide* images the figure ground distinction is elastic and full of tension.

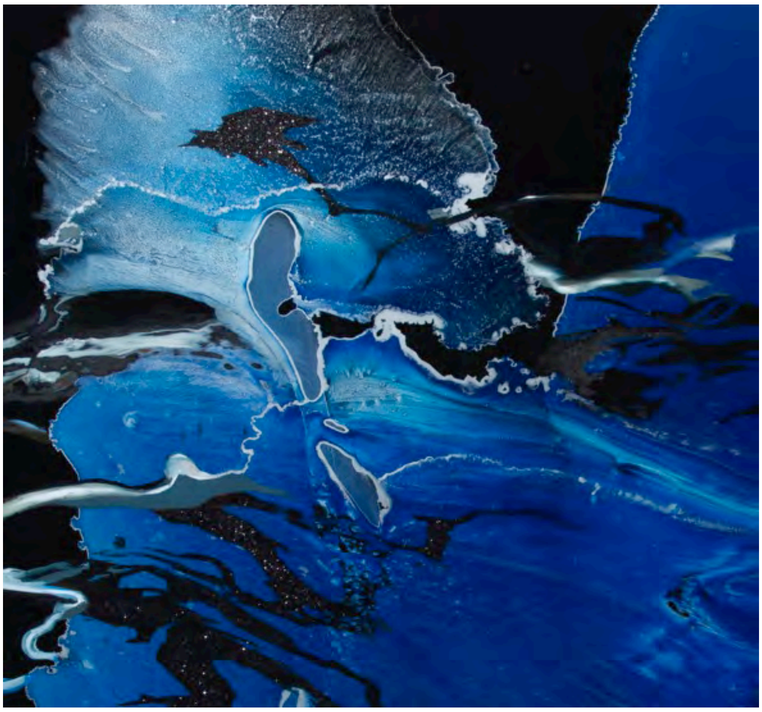

Fig 10. Detail: *Foam Atlas* Oil and enamel on composite panel 130 cm x 130 cm 2

Patches of pearlescent matte silver and reflective black mark the picture plane (Fig 6, Fig 10). Silver pools of paint catch the light as I move in front of the work. Pockets of mixed silver and blue plunge the viewer into oceanic drifts of recessive illusionistic space. In *Foam Atlas* (Fig 10) I sprinkle fine trails of black glitter as sparkly sirens to beckon the viewer before transporting them by way of one of multiple vortices to a place where the figure is completely dissolved.

Fig 11*. Analogue of the Unknown*. Oil and enamel on composite panel 130 cm x 130 cm 2013

The blurring of boundaries occurs in the territory between edges of colour (Fig 11.) The collision of pigments creates a meeting point where a new colour is created. Colours coalesce and congeal contingent on their viscosity. Mixing colour of varying viscosities provides me with an analogue for the cross-cultural: some colours mix harmoniously, others do not. In order for paints and pigments suspended in a medium to mix there must be an exchange of physical properties. The properties of each suspension: medium: warm, cold, wet, dry, dense, less dense, cause turbulent convection patterns that boil and flow like weather. My experimentation with mixing colour opposites began in 1996 as I observed the band of orange smog on the horizon out to the sea off the city of Los Angeles. The interaction of blue and apricot mixed to create a greenish hue that was at once repulsive and beautiful. When I mix a colour with its complementary, the chroma of the colour breaks down. This neutralisation of colour creates shadow tones, complex tones, distant or ‘minor’ tones and it reads as a recessive space. When I mix harmonious colours together they become voluminous and luminous. Working wet into wet results in a seamless mingling of colour edges and the paint forms a skin that mimics photographic emulsion. Artificial space relations conflated into a sheen also connote a screen space. The outcome may result in colour that is lifeless and dull, or it may infuse colour with radiance. I am constantly toying with blending colours to create luminous greys, and I risk merging them too far, which results in colour breaking down to become like chalky mud.

The collision of colour opposites creates nuanced colour. The colour grey is one of contradiction: it can be a progression towards homogeneity, or a colour of complexity as a result of its multiple colour constituents. In Western culture grey may be associated with conformity, boredom, and uncertainty. Writer, composer and filmmaker Trin T. Min Hah (1996) discusses the complexity of the colour grey. She refers to architect and theorist Kisho Kurokawa to point to what is called Rikyu grey in Japan: a combination of four opposing colours; it is a mid-way between colour of collision, multiple possibilities and emergence.

When I add white highlight I can create what James Elkins (1998) refers to as ‘the splendour’: the Western illusionistic trick that creates 'light and lustre'. The splendour mimics life and movement in material. Its non-naturalistic opposite is referred to by Elkins as the 'anti-splendour' and it is illogical form that disturbs naturalistic goals. I work with both illusionistic devices: one to create naturalistic illusion and the other to destroy it. Rather than sit in opposition they mutually configure each other to alter form and this alteration generates a sense of movement in the image.

Fig 12. The Rough Guide: Glossary. Oil and enamel on composite panel 130 cm x 130 cm 2015

Red, silver, black and gold are colours of the alchemical palette. After multiple processes to transform base materials, red was a signifier of purification. In *The Rough Guide Glossary* (Fig 12) colour edges curdle, they are not harmonious combinations. Black threatens to deaden the chroma of any colour that it comes into contact with. In the limited palette of the paintings *The Spill* and *Glossary* (Fig 9, Fig 12) colour is visceral and interior but flesh colour is mediated, it is anglo-toy-pink, hyper and contrived, as if shining a torch through your own hand or as if peeling the skin back.

These paintings are created from an interaction between material performativity and the artist's actions. A form of improvisation begins with the pouring of fluid enamel and the Interplay between base materiality, chemical interactions and embodied action. Improvisation is contingent on what occurs before an action and it directs the actions that occur in response: a flick or spatter of paint, a section of carefully moulded form, a calligraphic gesture or wipe, a patch of sanded paint, a patch of glitter, a patch left empty. There is an evident choreography between control and the momentary relinquishing of control. The body of the maker is perceived through the marks made by hand in the painting. This is neither a form of Surrealist automatism nor the impulsive gesture of Abstract Expressionism. The relationship between form and deformation is a conscious interplay of different pictorial languages of manipulation and spontaneity. They are separate realms in collision that express the tension between states that are associated with polar entities. But these two states are no longer separate nor dualistic, and, the boundary between them is porous.

Conditions of non-duality are at play in Giuliani Bruno (2014) and Jane Bennett's (2014) references to the plasticity of material relations. Bruno (2014) proposes that a material and cultural transformation is taking place and that the properties of a substance can morph into another medium without the loss of their physicality. Bennett (2014) asserts that all bodies are modes of a common substance. Bruno (2014) proposes that surfaces whether they be canvas, wall or screen can frame a territory of flexible material interactions.

The project harnesses the material properties of paint and uses them as a model of thought. The unpredictable fluidity of the medium is tested and suspended as a method to create new forms and ambiguous spaces. This is an entropic liquid territory where forms are fixed, but they continue to visually transform with each encounter. The paintings depict a process that has been paused, suggesting that there is potential for it to continue. The forms may be fixed but their readings are not. An oily, sticky viscosity pervades the work as moments of mutation are frozen during movement from disintegration to reconfiguration and back again. Velocity rather than objects are being depicted: waves, matrices and dynamic vortices invoke instability and the threat of obliteration, suggesting that fluidity has the potential to be utopian or ruinous. There is an associated mourning for destruction accompanied by elation at the potential for transformation as a result of collapse. The paintings are successful when they continue to visually transform, when forms oscillate and remain unstable. The paintings fail when they remain static.

Metaphysical references become understandable through a tangible relationship in these paintings as they are grounded in visceral terms of the body. *The Rough Guide* paintings hint at the fear of the fragmentation of body and mind, and of separation from our environment. They function as visceral maps for experience and identity in flux. The luxury of sustaining ambiguity allows us the enlargement of perception; it trains us to be attentive to nuance, to regenerate meanings and search for alternate schemas to the formerly utilitarian structure of linear perspective and the modernist grid.

I propose that painting has a new role to play in the de-piction and destruction of western pictorial conventions in order to generate new ones. A liquid and non-linear mode of representation can reflect an alternative way of thinking and of interacting with the world. It offers a counterpoint to the hitherto dominant tropes of history painting. Paint is a visceral analogue that materialises the plasticity of mind and body. Its vocabulary is suited to a discussion of elastic and non-dualistic connections to the physicality of substances and thereby to the world around us.

Framing, fixing and suspending uncertainty on a surface – whether it is canvas, wall or screen, can construct a territory of flexible material relations, which may in turn transform the very material of ourselves.

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Megan Walch is a PhD Candidate in painting at the University of Tasmania's College for the Arts where she received her undergraduate degree. She is a Samstag Scholar and an alumnus of the San Francisco Art Institute, California, USA, the Skowhegan School of Painting and Sculpture, Maine, USA and the Marie Walsh Sharpe Space Program in New York, USA. Her work has been exhibited in the United States and Australia: Her PhD practice lead research is titled: *Viscosity, Fluidity, Plasticity: reworking pictorial conventions in paint.* Megan’s art practice spans more than twenty years and her research interests have developed through undertaking residencies in South East Asia.

Choreography of Surface Materiality from Nature, Culture, and Time

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Abstract

This paper proposes the emergence of surface materiality of architecture from nature, culture and time. The emergence of surface from the choreography of nature, culture and time offers an understanding of surface materiality beyond the common, modern building materiality. A case of design research project in the context of a natural site with challenging topography illustrates the process of generating various forms of architectural surfaces from the elements of nature and culture, articulated with the elements of time. The process of choreographing the elements of nature, culture and time becomes more important than just the physical crafting or constructing of building elements. While the latter merely concerns with the physical realization of the architecture, the former might enhance the performativity of material surface.

Keywords

surface; materiality; nature; culture; time

Surface from substance

The concept of surface is an important one in architecture, both in terms of physical materiality and conceptual ideas. In discussing surface in architecture, ones can refer to the surface in terms of its appearance as well as its construction (Leatherbarrow & Mostafavi, 2002). The creation of surface is also inseparable with the programming of what is enclosed by the surface (Benjamin, 2006). This paper addresses the process of generating materiality of surface, by focusing on expanding material possibilities of surface beyond the common use of building materials.

Surface encompasses a range of physical entities: “skin, surface, threshold, liminal space, edge, boundary, photographic image, and interior space” (Chatterjee, 2014, p. 1). The term surface is often used to explain the interface between two different materials: “surfaces and interfaces exist where different materialities are juxtaposed” (Forsyth et al, 2013, p. 1016). In architectural space, surface may perform as boundaries separating the interior and the exterior, or as an exchange between two different substances or entities, thus surface has a quite significant role in defining the existence as well as character of architectural space.

Surface in architecture is generally made up of certain kinds of materiality. Gibson (1986) proposes a triad of medium-substance-surface, as a way to describe the environment that we perceive. He defined surface as the entity that separates the substance of the environment from the medium. For example, the surface of the water is what separates water substance from the air as the medium. Gibson further emphasized that surface is the most important in the triad because “The surface is where most of the action is. The surface is where light is reflected or absorbed, not the interior of the substance. The surface is what touches the animal, not the interior” (Gibson, 1986, p. 23). When we perceive any objects in our environment, it is the surface of the objects that we actually perceive, and this perception occurs due to the light reflected by the surface and reaching our eyes. As our eyes register such information from the reflected light, we perceive the surface and its properties.

Our surrounding environment comprises many kinds of surfaces. The characteristics of a surface could be identified from the kind of information registered to the observer when perceiving the surface. Gibson proposed a tentative classification of surface: surface could be luminous or illuminated; more or less illuminated; volumes or sheets/films; semitransparent or translucent; smooth or rough; homogenous or conglomerated; hard, intermediate or soft (Gibson, 1986). What is interesting from Gibson's classification of surfaces is that no kinds of substance were necessarily mentioned – he did not classify surfaces based on the types of substances, such as water surface, sand surface, wooden surface, cotton surface, etc. Although the texture characteristics of certain surface could vary "depending on the composition of the substance" (p. 29), yet the characteristics of the surface seem to be more significant than the kind of substance it is generated from. Such characteristics could be understood when one actively perceive the surface, in other words, register the information regarding its characteristics.

The emphasis on the characteristics of the surface suggests a possibility that surfaces could be generated from various kinds of substances and not limited to certain types of materials that are commonly used in the practice of architectural design and construction. In this paper we will argue on such possibility through a case of architectural design research project that elaborated on different ways of generating surface materiality.

Designing for surface performativity

Our design research project attempts to enhance the performativity of architectural surfaces by exploring various possibilities in the materiality of the surfaces. The idea of performativity in architecture is essentially a change of orientation "from what the building is to what it does" (Leatherbarrow, 2009, p. 7). The performance of surface as an important aspect of architecture becomes the main issue addressed in this design research project. To enhance the performativity of surface, we attempted to generate surfaces from any kinds of possible materials. Nevertheless, what is more important in the process was in defining *what the surface does.*

Performativity of the surface suggests "a conception of the surface as that which will have an effect rather than simply being the consequence of the process of its creation" (Benjamin, 2006, p. 3). Having been created from certain processes of production, a surface might have potentials to create further effects to what it encloses or contains. Therefore the making of surfaces is not limited to the production of the surface materials, but extended to the making of the architecture, interior or landscape which the surfaces define, limit or enclose.

The possibilities of materials could be understood in at least three different ways. "In the first instance, the potentiality of a given material; in the second, using the properties of one material to open up architectural possibilities within other materials; finally, allowing drawings or diagrams to suggest spatial relations given through material possibilities as opposed to form creation" (Benjamin, 2007, p. 14). The process of generating a surface requires the the understanding of different possibilities of materials. Designing for the performativity of surface requires the ability of the designers to see the potentials offered by different kinds of surface performance.

Gibson (1986) introduced the terms *affordances* to explain what the environment offers to individuals – what it could support, what it could provide. Surface may perform both as enclosures and as objects, and each might offer different possibilities; "differently shaped enclosures afford different possibilities of inhabiting them. And differently shaped solids afford different possibilities for behavior and manipulation" (Gibson, 1986, p. 29). Thus the performativity of surface, both as enclosures or as objects, cannot be separated from the potential of the surface – and also the *affordances* of the surface.

Understanding the performativity of surface should not be limited to the knowledge on the substance and the medium that it separates. Surface should be understood from the point of view of the observers: “A *potentially visible surface* is one that could be looked at some place in the medium where an animal *might* be” (Gibson, 1986, p. 23). Therefore a surface may perform when it can be perceived by the observer, through the process of registering information emanating from the surface – whatever the substance and the medium are. Defining the materiality of surface thus should not only be limited to defining the substance generating it but also incorporating the positioning and orientation of the surface. The surface position in relation to the source of illumination and in relation to the observers is important in determining how a surface is perceived.

We will now turn to further discussion on how the idea of the performativity of surface and the possibility of extending the surface materiality could be relevant to design practice, as demonstrated by a design research project of a holiday retreat space – *Svarga Resort* - located in Lombok, Indonesia.

Defining the surface materiality: nature, culture and time

The brief of *Svarga Resort* project was to design a holiday retreat space in a natural site with a quite challenging topography. The aim of the project was to promote healthy and meditative experience for the visitors, by bringing them closer to nature, and encouraging them to actively engage with the natural surroundings. In defining the materiality of the surface in this project, what we did was basically choreographing different forms of surfaces throughout the project, by referring to three main sources of surface materials: nature, culture, and time. The challenging site natural topography, rather than being a constraint, offers many potentialities to be explored in the choreography process of surface material. Leatherbarrow (2011) emphasized on the performative aspects of topography: “topography is important to landscape, architecture and urban design due to its attention to the materiality, spatiality, practicality and temporality of terrain.” (p. 211). The design of architecture in integration with landscape provides possibility to enhance the topography of the natural site context. In our design research project, this was achieved by experimenting on three possible surface materials (nature, culture, and time) within the contextual topography.

Surface of nature: contour, landscape and horizon

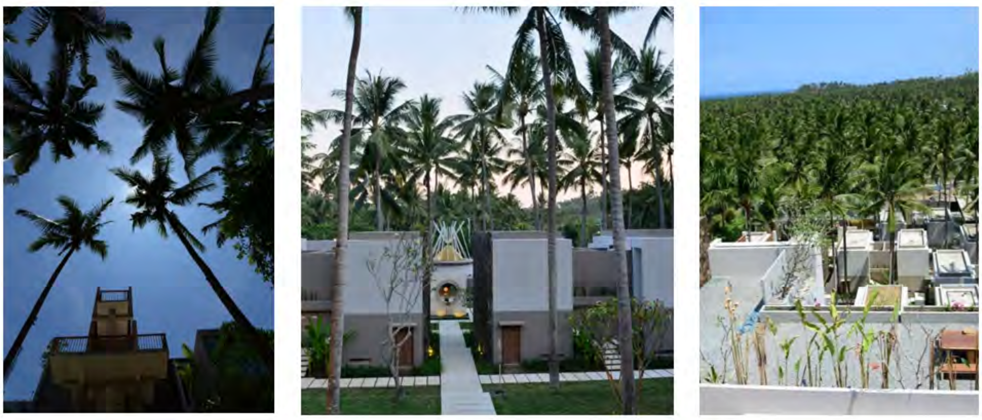
Surface materiality could be generated from what is already there on the site. This project was built on a natural site with the extreme contour, which becomes the main potential of materiality. Understanding the landscape with various aspects of its materiality as potentials, offers an alternative to typical approach that tend to be merely pictorial or aesthetic (Leatherbarrow, 2011). The site was perceived not merely in terms of its topography profile or configuration, or in terms of the picturesque characteristics of the surrounding view, but it was perceived as comprising various entities and characteristics that together define the landscape. “Attention to the spatial aspects of a place – its enclosures, continuities and extent – can thus lead to interpretations of its potentials for occupation and use” (Leatherbarrow, 2011, p. 211).

The arrangement of the building units was designed in such a way to be in line with the ground of the site that was defined by extreme topography. The architecture was literally carved into the site, creating spaces of activities in between the natural landscape (Figure 1). The insertion of the building units into the contour results in different levels of spaces, each defining different functionality depending on the relative position against the contour.

Figure 1. Surface configuration from contour, landscape and horizon

The existing landscape with the presence of hundreds of coconut trees also provides another source of surface materiality. We perceived the coconut trees not simply as trees *per se*, rather they contain elements of verticality and elements of horizontal surface. The verticality was manifested through the appearance of the rows of tall coconut tree trunks perceived from horizontal direction, when looking at the coconut trees as rows of vertical lines (Figure 2b). Meanwhile, the horizontal surface was manifested through the appearance of coconut leaves seen together from below (Figure 2a) or from above (Figure 2c).

The existence of coconut trees and how they are perceived could be explained in relation to the idea of nested units of environment (Gibson, 1986). Perceived as a single entity at a smaller scale, a coconut tree has a number of leaves, but perceived collectively at a larger scale, the leaves of hundreds of coconut trees may be perceived as a homogenous, green surface, with the individual leaves forming the ‘texture’ of the surface. The texture was generated by the composition of all the individual leaves at the similar height level, which together perform as ‘the ground’ for the rest of the spaces, which was built on higher level orienting downward to this ‘ground’. We consider the presence of the coconut trees to be so important in this project that we attempted to build with minimum disturbance to the trees. We kept almost all of the trees, and the arrangement of the buildings literally followed the position of the coconut trees, whether they were perceived from below, from the front and back, and from above.



(a) (b) (c)

Figure 2. Coconut trees as surface materials perceived from different direction:
(a) from below (b) from horizontal direction (c) from above

The project also responds carefully to another kind of surface that surrounds the site – the horizon. Horizons generally refers to "planes of reference, or, more fundamentally, of existence" (Leatherbarrow, 2000, p. 28); it has a deeper understanding than the horizon that we usually conceive as a line where the sea meets the sky. This project treats horizons as planes of reference, as something that define the orientation of the spaces throughout the site. Horizons may appear as a faraway line of sea and sky, but they may appear as visual sightline directing the experience of the eyes while looking from the site to the surrounding and vice versa (Figure 3).

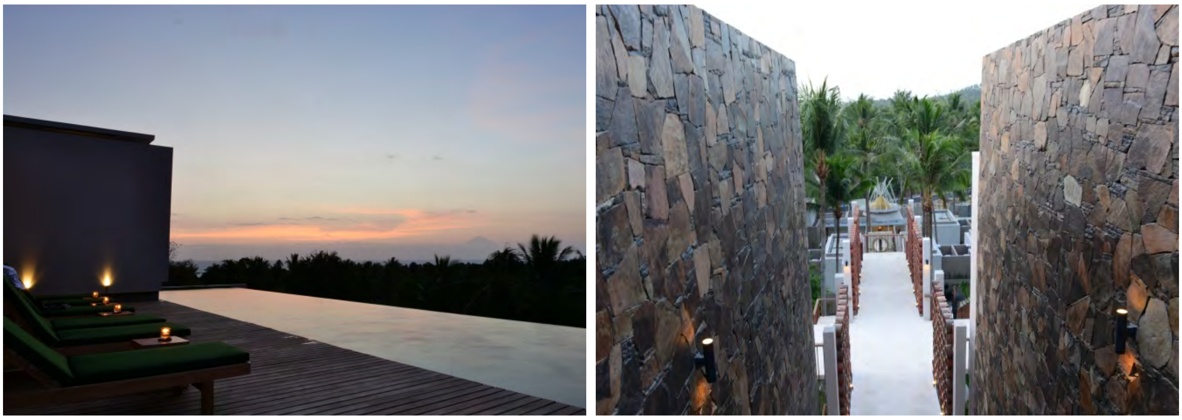


Figure 3. Horizon and orientation of spaces

The awareness of the horizons becomes a key aspect in understanding the existence of self while experiencing the space and how the space is integrated with the surrounding. The design attempted to provide different scenarios of interacting with horizons that surround the site: the scenarios were manifested through the experience of looking at the faraway mount, the experience of looking at the surface from coconut trees further below and the visual connection (as well as disconnection) among the units. Careful attention was given to the positioning of the openings of each unit in order to ensure optimal experience of the faraway horizons, the closer surrounding landscape and the minimum visual disturbance from one unit to the others.

The above description suggests the interaction between the elements of nature and the making of architecture in two different ways in terms of surface materiality. First, the topography of site and the awareness of horizons demonstrate how the nature could perform as certain kinds of surface, which trigger certain spatial architectural intervention through the insertion into the site and the orientation of the space toward the surrounding. Secondly, the elements of nature could perform as certain kinds of surface which is then perceived as surface with certain characteristics, as in the case of coconut tree trunks and leaves that produce different materials for architectural surfaces.

Surface of culture: crafts, objects and patterns

The project also attempted to enhance the locality as the cultural contexts where the project was constructed. The design of the architectural elements was enriched by the materiality coming from the traditional culture from the surrounding local community. The representation of local culture was manifested through the physical material surfaces found in many parts of the spaces, both the interior and the exteriors, through various forms and techniques.

Figure 4. Surface from local crafts and cultural objects

Some surfaces of the boundaries were generated by aggregating local craft products (Figure 4). For example, the local clay pottery products were composed either horizontally or vertically to form the surfaces that defined the horizontal or vertical boundaries of the spaces. Some of the surfaces were created by inserting or attaching the craft objects on the existing wall surface, hence the craft objects functioned as the embellishment of the surface. The embellishment of the surfaces was also created by adopting the traditional weaving motifs into the textile surfaces of the interiors. Some surfaces of the furniture or spaces were also characterized by the handmade rough and raw finishes. The purposeful roughness and rawness of the finishes projected the image of traditionally produced crafts.

In the above examples, the representation of cultural artifacts into the creation of architectural surface was manifested by composing craft elements and objects as patterns of surface. Pattern is understood as a repeating array of similar – not necessarily identical – units. When the pattern is assimilated into space, it has the capabilities to hide or release the clearly identified physical forms (Taylor, 2010). The integration of pattern in the making of surfaces contributes to the making of identity of the surfaces where the patterns are applied. In this project, the patterns generated from local culture – as repeated objects, as repeated motifs and as textured finishes, created certain surface identity, which eventually generated the cultural atmosphere of the space. “To construct architecture is simply to prop up a surface that produces an atmosphere” (Wigley, 1998, p. 20). Here the surface of culture produced the atmosphere of the architecture.

The emergence of cultural atmosphere was also articulated by the appearance of the surface (Figure 5). The patterns generated from the local culture are often rich in details and ornamentation, as a result of sophisticated crafting techniques. The materiality of surface thus incorporates the detailed composition of the substance of the surface (as created by traditional carving, weaving and other forms of crafting processes) that determines the information registered by the observer (Gibson, 1986). Meanwhile, some surfaces with handmade, raw finishes also emanate the unique characteristics of surface and conveys the honesty of the surface material.

Figure 5. Cultural atmosphere from detailed and roughly finished surface

The surface of culture, when perceived by the observers, creates the visual ambient of space that conveys the cultural meaning. The surfaces generated from various cultural objects and crafts define the characteristics of the project in its attempt to be integrated with the locality. Cultural meaning is strongly represented through the surface materiality of both the exterior and the interior.

Surface from time: light, change and movement

In addition to surfaces generated from the nature and local culture, the presence of surfaces could also be defined by the temporality. Time plays a significant role in defining the dynamic of the spatial experience. In relation to landscape, time becomes “the medium of one’s experience of landscape, for terrain is known most fully in the duration of spatial passage or movement” (Leatherbarrow, 2011, p. 211). The landscape is experienced dynamically across different times of the day, and different seasons of the year.

In this project, the surfaces were generated in accordance to changing experiences through time – the surfaces emphasized the change of experience from morning, afternoon, evening, night (Figure 6). The awareness of time was mingled with the consciousness of the horizon and the landscape, the sky and the ground, the above and the below. The awareness of time was also built into the making of surfaces by considering the changes of the surface geometry due to the interplay of light and shadow. Light and shadow have capabilities to articulate and to manipulate the surfaces (Batar, 1992), and this potential becomes important in defining the architectural spaces in this project.

Figure 6. Surface resulting from the interplay of light and shadow

Time also becomes apparent through the surface that carries the flow of movement from one part to another; from above to below and vice versa. Movement is a natural part of spatial experience; an active body move around in space as a part of their experience of the world. Movement cannot be separated with perception, since human body is an active body which keeps moving during the process of experiencing space; “we must perceive in order to move, but we must also move in order to perceive” (Gibson, 1986, p. 223). Surfaces generated from movement are the surfaces that incorporate the changes of experience of the body when moving in space. In this project, the position and orientation of surface boundaries respond to the possible movements of human body, while experiencing going up and down, coming in and out, moving from one point to another, and being in between (Figure 7). The surfaces of the boundaries, both vertical and horizontal, were composed in accordance to the movement experience throughout the building and landscape.

Figure 7. Movement throughout the surfaces of building and landscape

Time as the material of surface interacts with the other elements of surface previously discussed: nature and culture. The presence of time enhances the surfaces that are generated from nature and culture; time allows them to be more visible and more articulated. The cycle of morning-afternoon-evening-night enhances the experience with the contour, landscape and horizons. The interplay of light and shadow articulates the cultural patterns with the details of traditional objects and crafts. The movement of the body becomes the manifestation of dynamic experiences with all the surfaces.

Techniques of choreographing the surface materiality

The project has demonstrated the possibilities of emerging surface materiality from nature, culture and time. This alternative perspective on surface materiality has further consequences on the needs for particular techniques in design, materiality and representation. Generating surface from nature, culture and time requires the act of choreography as a way of putting them all together into integrated architectural forms. Since surface is an inherent part of architecture, the process of generating surfaces should be in conjunction with the programming of architecture and at the same time involves the choreography of materiality of those surfaces.

Attention needs to be given to the details of how the surfaces could be emerged from the nature, culture and time. The affordances of surfaces become the primary consideration to define what the potentials of the surfaces are, in the making of the whole design and the whole image of architecture. Attention also needs to be given to how things become – how the production of surfaces occurs through the process of materialization. Such materialization is not merely attempted to achieve certain expression, but it leads to the functionality of the surface materials. “Interest in the physical aspects of land can also lead to an awareness of its functional potentials, what the materials of a site can do, how they can act or perform in service of some purpose other than expression or representation.” (Leatherbarrow, 2011, p. 210)

The choreography of surface from nature, culture and time also has some consequences on the representation techniques. Since the surface of nature is derived from the topography of the site, “The most direct way to grasp the role of the ground or floor plane in spatial definition is to envisage an ensemble in section rather than in plan” (Leatherbarrow, 2000, p. 29). There is a need to change the way of representing surface, from the primary dependence on plan to the significant role of section, in order to capture the emergence of surface in three dimensional contexts. The sectional representation allows the more dynamic understanding of the design in terms of horizons, the point of view of the observer, and the three dimensional orientation of the surface. In addition, the time-based would be the more appropriate methods for conveying the emergence of surface from time. The change of surface from time to time, as well as the movement of bodily experience throughout the surface of building and landscape, could only be captured through representation techniques that incorporate series of images/drawings/scenes – rather than single, projection images.

Concluding remarks

The exploration of possible surface materiality from nature, culture and time as demonstrated in *Svarga Resort* design project suggests an alternative way of defining materiality of architecture. Materiality is not confined or limited to the common use of modern building materials. The finding from this design research project highlights the emergence of materiality from various possibilities of sources and techniques, and thus the understanding of materiality could be extended beyond the types of material substance.

This process also suggests the significance of certain techniques of design, materiality and representation, which are required to enhance the performativity of surface. Intimate engagement with the existing natural context, inquiry on local potentials, as well as the direct experience of space through time become powerful techniques to explore the potential surface materiality. Various alternative modes of representation that could depict the surfaces of architecture from different perspectives and at different times become necessary.

The emergence of surface materiality could depend on what already exists – the natural site, the surrounding horizon, the day and night, and the local culture. The emergence of surface materiality could also be triggered by various possibilities of relationship between the perceivers and the perceived elements of architecture, interior and landscape. In this way, the process of materiality becomes very specifically attached to the context of the project.

This might result in the emergence of spatial arrangements, elements as well as experiences that are deeply rooted in the existing context.

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Exploring the relationship between material and textile structure in creating changing textile expressions

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Abstract

This paper explores the relationship between potentially dynamic materials and textile structures for designing textiles with inherent changing qualities. Textiles are usually designed to retain their appearance for as long as possible. Yet all textiles wear out and change over time, both physically and aesthetically. This means the life spans of textile object and the material it is made from will not necessarily be equal. The dynamic changeable qualities in textiles could instead be enhanced by using the potentially dynamic, changing qualities inherent to materials and combining them with textile structures. Through contextualisation and design examples, this paper discusses the possibilities of embedding these qualities into textiles, and presents a series of woven and knitted designs that combine these materials into different textile structures. Two materials with differing dynamic qualities were chosen for the experiments. These are polyvinyl alcohol (PVA) yarn—a material that melts in water and uncoated copper wire—which creates a patina when it reacts with air. These materials are combined into woven and knitted structures and then exposed to two types of stimuli to explore how different stimuli affect the way in which the materials change: passive exposure to weather, and an active workshop with fashion design students. The results are initial explorations into the basic principles of combining potentially dynamic materials into textile structures to create textiles that take advantage of how different materials change over their life span, and how this might look. Through embedding different time spans into textiles instead of designing static expressions, the life span of materials and textile objects could be better matched, enabling the designer to tailor a more appropriate life span for textiles.

Keywords

textile design; material; structure; weaving; dynamic

In traditional textile design, form, colour, and texture are expressed by combining different materials and treatments with textile structures. When designing textiles that have dynamic qualities – those with the ability to undergo changes in expression or structure in response to different stimuli, - time, must also be considered as a design variable. The textile can thus be designed according to a time span under which it changes. In this paper, “expression” refers not only to the artistic qualities given to a textile by its designer, but also to a material’s inherent visual and tactile characteristics.

Material and choice of technique are often the major variables in textile design. Choice of material gives a textile qualities making it suitable for certain applications and after treatments. Construction of the textile, such as being knitted or woven, and after treatments like printing, dyeing, or coating further shape the textile’s qualities. Materials have inherent qualities i.e. they exist in the material itself. In some materials these qualities could be seen as potentially dynamic possibilities to change, such as wool’s tendency to felt. Having knowledge about materials is thus of great importance to a textile designer, yet this knowledge is often non-verbal. Technical information about materials is available, but designers often use their intuitive knowledge when making decisions during a design process. This knowledge can be in part experiential, i.e. gathered by the designer by experience, requiring physical interaction with the materials.

Along with material, the yarn and textile structures form the other basic elements of a fabric. As early as 1927, Nisbet (1927, p. 3) described the role of structure in woven fabrics by stating that: "…it is equally if not more important that a textile designer should be conversant with the principles of fabric structure, as that he should be an artist and expert draughtsman." The tangible knowledge in the construction textiles is thus for a textile designer a fundamental variable in forming the expression of a textile. Also Nuno´s founder Reiko Sudo works with materials´ inherent qualities and combines them with woven structures. Sudo´s textiles often have a strong tangible presence and she has said that the first thing she considers when designing a textile is how it would feel to touch it (Millar, 2005). In this way she lifts the tangible experience of touching as a central quality in a textile.

Dynamic qualities in textiles can be divided into reversible and irreversible. A reversible pattern can go back and forth between one or several states. An irreversible pattern does not return to its original state. Instead its expression is built up over time (Worbin, 2010). Linda Worbin (2010) describes this as an inherent continual expression the textile gradually undergoes. These changes are thus inherently embedded in the textile due to its material and construction. This paper will focus on irreversible changes, since it addresses textile time spans. There is research on textiles with irreversible dynamic qualities that approaches them with various perspectives, such as interaction design (Landin, 2009; Persson, 2013; Worbin, 2010) and in relation to space design (Dumitrescu, 2013).

Several examples of this research embed change in potentially dynamic materials by using electronics and programming. Changes can be programmed to occur in response to certain stimuli, such as a textile that can for example break or shrink when it is touched (Dumitrescu, 2013; Persson, 2013). However, less information about irreversible changes is available about materials' inherent qualities when used with everyday stimuli. Tom Dixon's EcoWare presents one example of this type of change; tableware made out of biodegradable plastic that gradually wears out from use. Dixon argues that this character in fact makes the tableware more interesting and unique to the user who moulds them over time (Fairs, 2009). Hussein Chalayan has worked with aging and wearing out garments in two collections, ´The Tangent Flows` and `Cartesia`. He sprinkled iron filings on the garments and subsequently buried them for several weeks. For Chalayan treating garments by burying them was a method for storytelling, although he has stated that processes are for the designer and the result, the actual garments, is what is most important for the people (Golbin, 2011).

There seems to be an imbalance between material´s and object´s life spans. For example cotton is in itself a durable material, but it might be processed into a t-shirt that is made of thin single jersey that breaks easily, constructed with low quality sewing work. The life span of the object and the material it is made of do not meet. Research regarding textile life spans and the effect of material and aesthetic durability exists, for example Kate Fletcher (2008) proposes that garments could, depending on their use, have various life spans ranging from fast to slow. Defining these rhythms relates to recognising for which purposes garments are acquired. Fashionable clothes that are used for a short time could be made out of short-lived or recyclable materials. Less trend sensitive garments such as winter jackets could last for a long time and age beautifully becoming more personalised with use (Fletcher, 2008). This has been researched also by Jonathan Chapman (2013), who suggests that textiles and garments could be designed to improve with age, such as a pair of jeans that the user moulds their own through continuous use. Attaching personal memories to garments could be seen as a factor preventing early disposal of garments (Niinimäki, 2011; Chapman, 2005). Embedding fast or slow life spans directly into textiles could help to create a better balance between the material and the textile object's life span, where life spans for both could be considered already during the design process. How such textiles could actually be constructed has so far seen little research.

In this project, textile samples are designed and produced to explore the possibilities of combining potentially dynamic materials with textile structures as a method for creating textiles with inherent capabilities for irreversible change. Two materials with differing dynamic properties are experimented with. These materials react to different everyday stimuli by changing and together they offer a range of qualities. The materials are combined with both woven and knitted structures. The fabric samples are then exposed to the passive stimuli, nature as well as active stimuli, use in a workshop for fashion students.

Experiments

Method

The starting point for the experiments was an interest in how irreversible dynamic qualities could be embedded into textiles during the design process, and to what extent it is possible for the designer to control these changes and how they might look like.

Two materials that change under everyday conditions were chosen. The first was uncoated copper wire, which forms a patina from exposure to oxygen and carbon dioxide (i.e. air). The second was polyvinyl alcohol (PVA), which dissolves when in contact with water over 20ºC. The materials were chosen because of their ability to produce visible changes from different stimuli over various time-spans. Patina can form on uncoated copper slowly or quickly depending on the circumstances. PVA reacts to water instantly by shrinking and melting, but the process stops temporarily if the material is left to dry, turning hard and translucent.

Textiles were designed to explore the synergy of these materials and textile structures. Experiments A and B explored the role of material and structure in woven textiles exposed to passive changes by setting them outdoors. Experiment C compared active and passive methods of inflicting changes on a three layered woven fabric. Experiment D focused on exploring in what way the textile´s expression change and how these dynamic qualities affected the way they are manipulated. A set of knitted fabrics with a range of dynamic qualities was developed and an active method of causing changes in them was used - fashion design students worked with the fabrics in a workshop.

The role of material and textile structure in creating dynamic changes in textiles

The initial experiment A was conducted on knitted single jersey in uncoated copper. A piece of the material was buried in earth for one year. Other pieces underwent active changes, exposed to vinegar both by soaking and through evaporation by being left closed in a jar with the material for various lengths of time ranging from one day up to a year. Afterwards the pieces were compared and analysed (fig.1 top row).

Experiment B explored the relationship between inherently dynamic material qualities and woven textile structures by creating changes in its expression over different periods of time. All samples were woven to an unbleached cotton warp on an industrial Jacquard machine. In experiment B1 two woven pieces of same size and materials, but with different bindings were placed outdoors for one month to observe if the choice of binding affected the way the textiles changed (fig.1 second row from the top). Both fabrics combined a white cotton warp with uncoated copper weft of the same density. One piece was of a rep weave and the other a satin binding. Two more woven samples made on the same warp with differing weft materials were hung outdoors in experiment B2 (fig.1 third row from the top). One sample combined PVA with a copper weft in a rep weave, the other used sample had only PVA as weft in a satin binding. In this experiment nature was chosen as a passive stimuli to cause changes in the fabrics. The outdoors, with its unpredictable rain, wind, sun and temperature was judged to be suitable to help create changes that could be observed occurring in the materials. All samples were exposed to weather under similar conditions and time, freely hanging outside, attached to a support from the top. The experiment lasted for one month.

Exploring possibilities in how textiles could change

Experiment C compared active and passive methods. A woven material consisting of several layers was developed. The sample combined an outermost layer of PVA with a black cotton background and a hidden middle layer of stainless steel. For comparison a variation of the same construction was woven out in a variant where the PVA was replaced by non-dynamic casein-yarn. The fabric was then subjected to different treatments. One sample was placed outdoors for one month, one sample was sprayed with water and one sample was machine washed at 40ºC. Afterward the samples were compared and analysed (fig.1 bottom row).

In experiment D knitted fabrics were developed with the aim of leaving their dynamic qualities open for other designers to work further with. Three fabrics with qualities ranging from subtle to explicit in expression were designed and produced on industrial circular knitting machines, combining PVA with more stable materials such as stainless steel and wool (fig.2). As this experiment explored how other people could further work with the textiles, PVA was used because it causes more instant changes in the textiles, making it more accessible to work with. The fabrics were used during a one week workshop ´Crafting Wearables ´with BA fashion design students that was held at the Swedish School of Textiles on 28th October – 1st November 2013. The aim was to see how other designers could actively work with the dynamic qualities. At the beginning of the workshop, students were presented with the materials. After initial free experimenting the students could choose the materials they wanted to work with further. Their task for the workshop was to re-create an existing garment of theirs using the dynamic materials.

A

B1

B2

C

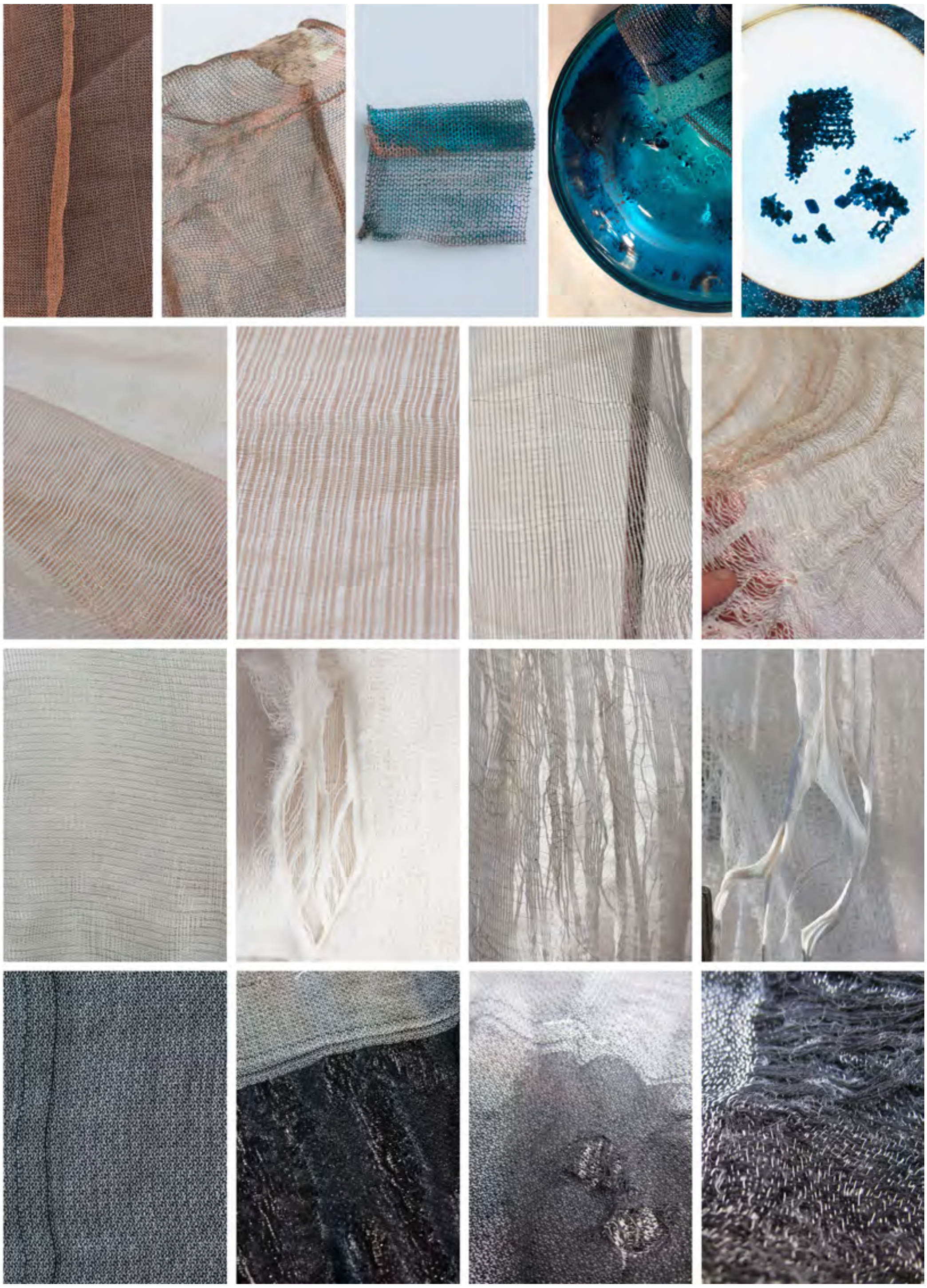

Fig. 1 Overview of experiments A to C. From top downwards: Uncoated copper jersey samples from experiment A. Treatments from left to right: untreated, buried for one year, exposed to vinegar for one day, soaking in vinegar for two months, soaking in vinegar for one year. Woven samples from experiment B1 exploring the role of two woven structures (left: rep weave and centre left: satin) and same samples after one month outdoors. The rep-weave had retained its flat structure (centre right); the satin (right) had developed a wavy structure. Experiment B2 exploring the choice of weft materials in creating changes in fabrics shown at a stage before changing (left: PVA and copper weft and centre left: only PVA in weft) and the same samples after one month outdoors. Different treatments of sample C. All samples show a comparison between changes that have occurred in PVA and areas with non-dynamic casein-yarn, where no changes have taken place. From left: fabric in its

original state, a sample after one month outdoors, a sample with water sprayed on and a washed sample.

Results and analysis

In experiment A subtle changes occurred in the buried copper knit, which developed a surface of brownish and greenish shades (fig.1 top row, centre left). Compared to the B samples that were hanging outdoors, the colours were deeper. In the sample exposed to vinegar changes in the material occurred after one day (fig.1 top row, middle). Bright turquoise powdery patina formed on them. When left in the vinegar for a longer time the copper knit began to dissolve. After two months most of the knit had dissolved into crumbles (fig. 1 top row, centre right). After one year, the crumbles had transformed into rectangular crystals. In some places the structure of the original knit was still visible, even though the material had transformed into something different (fig.1 top row, right).

When comparing B1 samples it could be seen that the sample with rep weave had changed colour from reddish to greyish, while remaining quite flat in structure (fig.1 second row from the top, centre right). Colour of the satin sample had turned from an even reddish to different hues ranging from brown to grey. The fabric had developed a wavy three dimensional structure (fig.1 second row from the top, right) due to the loose satin binding, with its irregular binding points, that allowed threads to bend in response to wind and rain. The more strictly organised rep weave was more stable, resulting in a flatter surface. The choice of binding combined with the material was thus an important design variable defining how the fabric will change.

In experiment B2 both weaves shrank over the duration of the experiment, and developed a matte, dense surface structure that felt like dry paper to the touch. Structure of the weave containing only PVA in weft was completely dissolved (fig.1 third row from top, right). The dried out weave could be torn in direction of the warp. The piece containing both PVA and uncoated copper in the weft held its shape better. The sample shrank also, but the copper wefts held the overall structure of the weave in place resulting in flatter structure (fig.1 third row from top, centre right). The shrinkage of PVA caused the copper wefts to form loops on top of the weave creating a new visual and tactile surface texture. Here it was the choice of material, combined with the binding that was the relevant variable defining the outcome.

At the beginning of experiment C all the samples had a similar, flat, neutral expression (fig.1 bottom row left). After one month the sample placed outdoors developed a different visual and tactile surface expression as the PVA top layer had repeatedly melted and dried (fig.1 bottom row, centre left). The surface was a combination of hard areas with dried, transparent PVA coating and soft areas where PVA had completely washed away. The middle layer of stainless steel had been revealed thus changing the light, neutral and sleek surface to dark and textured. Spraying with water caused more local changes revealing the stainless steel layer in specific places and causing the surrounding areas to shrink evenly (fig.1 bottom row centre, right). Washing removed the top PVA layer completely creating a soft, dark surface (fig.1 bottom row, right). No changes occurred in the sample containing casein-yarn instead of PVA. In this experiment the choice of material and binding in combination with how the textile was treated were the determining variables.

In experiment D working with a range of qualities from completely breaking down to stretching out enabled the creation of textiles that reacted in complementary ways. The fabrics developed included a single jersey in PVA that completely dissolves when in contact with water, a two-thread fleece combining PVA and stainless steel that changes its visual and tactile expression through partial breakdown of its structure, and finally a slipstitch pattern in wool, stainless steel, and PVA, which changes its visual and tactile expression by stretching without breaking apart (fig.2). During the workshop the students worked with a variety of different topics. They took the materials' dynamic qualities as part of their design process and developed a range of methods for working with them. These methods included among others painting with water, steaming, fusing, sculpting and moulding layers with water, painting with teabags, heating, spraying with water and stretching and sewing with PVA thread.

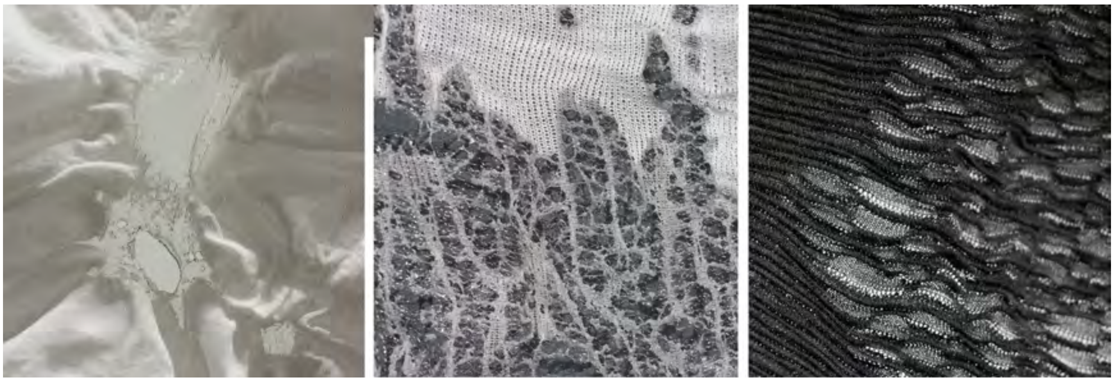

Fig. 2 Range of knits with dynamic qualities from experiment D used in the workshop. From left: a completely melting fabric that can turn from soft and white to hard and transparent, a fabric changing visual and tactile expression, and a fabric that can be stretched out without breaking.

The students effectively used and formed the fabrics' qualities, such as dissolving, shrinking, stretching, stiffness, and formability and transition from white to transparent and soft to hard to create a variety of forms. Some worked more with the dynamic qualities as a tool for expression, others wanted to enhance the textiles' expressive possibilities, and some used them as a functional part in their design. Students reported that in some cases the fabrics changed their way of working during the process. In one case a student redesigned a poncho. Instead of relying on creating volume in the poncho by adding fabric in the pattern, he cut out and sewed together pieces of the grey slipstitch fabric (fig.2 right). He then added volume to the garment through forming and stretching out the fabric in certain areas and leaving others untreated (fig.3). Another student created a dress combining three-dimensional structure and flat surface in the same fabric by shrinking parts of the two-thread fleece (fig.2 middle) with water (fig.4). Another created a white pleated top that could be transformed into a striped dress by using PVA as sewing thread and combining it with thermochromic print, creating a multifunctional garment with the help of dynamic materials (fig.5). In this experiment it was the combination of material and knitted structure that created a framework around how the textiles could change, but it was the action of forming them, which defined how the expression would change.

Fig. 3 A poncho by Lui Iarocheski, where volume and form were created by stretching out certain parts of the fabric.

Fig. 4 A dress by Sofie Larsson combining three-dimensional structured surface with sleek flat surfaces in same fabric.

Fig. 5 A multifunctional garment by John-Daniel Isacsson, which can be transformed from a white pleated top to a striped long dress with the help of warm and cold water.

Discussion

The first experiments, A and B, focused mainly on material qualities, their combination into textile structures, and observing how the structure of the textile contributed to how the material changed when subjected to the elements (fig.6). In experiment B2 copper darkened in contact with air, and humidity seemed to speed up the process. Samples kept indoors retained their original colour. How tightly the copper was woven with other materials affected the result. The copper could also be shaped for example by crumbling or folding, but the resulting expression will differ from sample B1's wavy surface which was formed by wind. Shaping PVA manually offers perhaps broader possibilities for creating different forms and surfaces, as was seen in the workshop with the fashion design students. This would suggest that materials and structures, as well as different stimuli, afford the textile certain qualities that suggest different uses. They also reveal evidence of the textiles experiencing different conditions.

type of experiment	experiment	passive	active
The role of material and and textile structure in creating dynamic changes in textiles	A	x	
	B1	x	
	B2	x	
Exploring possibilities in how textiles could change	C	x	x
	D		x

Fig. 6 A table over the experiments

The results of experiments C and D (fig.6) indicate that the way in which the textile is formed and changed is at least as important as its material and structure. In experiment C the sample exposed to weather showed the greatest potential for creating different expressions. In this case the overall effect of the weather created a change in the expression that proved difficult to achieve with other, more conscious methods. In experiment D the material and structure afforded certain types of changes, like shrinking, hardening, and breaking in the knitted fabrics, but how exactly the textiles were formed was decided by the fashion design students. This led to a variety of expressions in the resulting garments. The samples in fig.2 present one example of how the textiles could be formed, but exactly how they change depends on how they are formed and for what purpose. For example the two thread fleece in the middle of fig.2 is manipulated into a flat surface. The dress in fig.4 is made from the same material, but the student has formed a three-dimensional surface structure with the material.

Textiles are often experienced simultaneously with more than one sense. This is why their tactile qualities could perhaps be considered more in the design process. The experiments made during the project indicate that to be able to work with dynamic qualities in textiles, a textile designer needs extensive tangible knowledge about both materials and textile structures in order to be able to predict how the textiles will change. For example some of the experiments made during the project showed considerable change in their tactile qualities. Left out in the weather, PVA developed a dry paper like surface, while the same material sprayed with water turned hard and smooth. Such understanding is gained through physical interaction with material and technique—Nisbet (1927) describes this interaction as a conversation. Also for Reiko Sudo a textile´s tactile qualities are as at least as important as its visual expression (Miller, 2005), and her textiles often visually convey a sense of how it would feel to touch them. The students working with the knitted materials in the workshop reported that having the material melt against their skin felt repulsive and that the steel and PVA fabric changed from smooth to prickly when it half melted. The physical experience of interacting with the materials that dynamically and tangibly reacted to manipulation became quite central for the students. They needed to adjust the way they usually manipulated materials, which resulted in them developing new working methods.

In the project different types of changes were embedded into textiles depending on the planned method of testing. The samples tested in nature consisted of loose structures enabling them to be moulded by the weather. Subtle changes in texture and colouring occurred over longer periods of time through repeated exposure. This type of change could be described as passive. The knitted fabrics developed and used in the workshop for fashion design students had qualities that enabled them to be actively formed in different ways that would perhaps not translate as clearly when exposed to nature. Further research is needed to compare different types of change on similar textiles to acquire more comparable information about the effect of the type of stimuli and how textiles could change.

In traditional design processes with static textiles, chance is usually sought to be eliminated so the textile can retain its expression for as long as possible. Yet faded colours and worn out materials will always occur in textiles over time and use. Instead of aiming to remove all signs of ageing, wear could be taken as yet another quality of a textile. Kate Fletcher (2008) proposes that garments could have life spans ranging from fast to slow, and that one way to make this possible would be to make textiles from materials with different life spans. A pair of jeans often requires repetitive use over time to fit its wearer perfectly. This quality cannot be added to the garment at production state, but it requires the jeans to be made out of a material that wears out in a good way. Instead commitment from the user is needed, which also contributes to creating a meaningful relationship with the object (Niinimäki, 2011) and could encourage people to look after their garments for longer (Chapman, 2013).

Still the textile designer most likely cannot entirely control the exact changes the textiles might undergo. The changes will occur in interaction with other people or the environment and their precise nature is difficult to predict. There remains an element of chance in the nature of such textiles. Further research could explore what types of uses and contexts textiles with different types of dynamic qualities or life spans could afford or suggest. In the case of Tom Dixon's EcoWare it was the combination of the material and the form of the object that determined its intended use. This exposed it to certain stimuli, in this case water and detergent that become the variables defining the product's life span. In Delia Dumitrescu and Anna Persson's (2013) Knitted Heat project the textile's tangible response to touch by shrinking or breaking afforded or encouraged interaction with it and the space. The passive changes in the burying and weathering experiments were subtler. They could perhaps offer proof of the textiles' life span, in the same way that jewellery can be refined through patina, or Hussein Chalayan's buried dresses tell of not only his story behind the collection, but also what the actual garments have been through. Perhaps changeable qualities in textiles could invite users for more tangible interaction with their textiles, or even empower them through offering possibilities for engagement in changing the textiles.

Conclusion

The textiles developed during the project are initial explorations into how materials with potential for dynamic changes could be embedded into textiles by the designer. The results of the project suggest that the choice of material and textile structure both have effects on how the textile will change. Depending on the combination of materials, different life spans could be embedded into textiles. The inherent qualities of a material can give indications of how they might change. Wool's tendency to felt in contact with moisture and abrasion could for example indicate the ability to shrink and become denser in the wash. Likewise, polyvinyl alcohol's ability to dissolve in water could be used to create textiles that are able to break or change their structure when they come into contact with water—garments could thus change their form when washed at a high temperature. Depending on how the potentially dynamic material is combined with a textile construction, different expressions can be created.

However, the experiments reveal that the way in which the textiles are formed or changed is at least as important as their structure. This would suggest that already at the stage of making choices about material and construction, the designer should consider the context in which the textile will be used. Embedding life spans ranging from fast to slow into textiles could help create a better balance between textile and object, when appropriate life spans could be considered already during the design process. The textile designer does not just estimate how long a life span could be, but actively designs it. For example, a fast fashion garment could be given a very short life span, whereas a quality jacket meant for a long term use could be designed with qualities that make it age in a graceful way, becoming more personal to the wearer. Further research is however needed into how these textiles could look like under different stages of their life spans.

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Materials, Time and Emotion: how materials change in time?

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Abstract

During their lifecycle, objects shift from their initial state of perfection, in which they are conceived by designers and industrial production, and approach an imperfect status. This is shown by changes that impact shape, surface and material properties, due to usage and time. In this paper we focus on the passage of time and its consequences. For some materials ageing is negatively addressed as decaying, for other ones it may have a positive effect to be defined as evolution or maturation. What are the factors that lead to a positive or a negative perception of ageing objects? In other words, what parameters and emotions are ultimately bonded to the idea of evolution or decay? Our main intent is to move the first steps needed to answer these questions to support designers during the phase of material selection. Thanks to an experiment conducted on 25 persons, this paper validates a method to identify the properties subject to time and quantify their variations, which influence the varying user's perception. During the experiment it stood out that materials and their change in time play a crucial role.

Keywords:

properties of materials; time; material experience; selection of materials; expressive characteristics

Change is everywhere. Everyday objects are subject to evolution as they mutate and grow older. They move away from their initial state of perfection, in which they are conceived by designers and industrial production, and approach an imperfect status. This is shown by changes that impact the shape, the surface and material properties. The agents responsible for this are mainly time and usage.

Industrial design usually produces objects to be used in the future, but rarely investigates how these objects will change in time. Some interesting researches did take into account this important variable [1] but only on a theoretical level [2]. To get more practical we focused our attention on materials as they play a crucial role in the products ageing dynamics. Nowadays designers select materials based on various engineering parameters (for example: optical, mechanical and processing properties) and on, for example, the expressive and sensorial characteristics [3]. Several studies have evaluated the importance of material selection in the design process [4 - 8]. Time is here considered, but only as an expression of durability whereas it is really an important agent in the mutation of some properties that influence the user's perception.

The goal of this paper is to validate a method to identify the materials properties subject to time and quantify their variations, which are influencing the changed user's perception. In our opinion, in the future these properties variations should be included in the materials selection process. On one hand it has become more important, in an environmental sustainability perspective, to design consistently with the objects lifespan. On the other hand lifespan is often a function of the obsolescence, especially if psychologically driven. In literature there are many studies focused on the evaluation of aging-obsolescence relations.

Wooley [9] has already correlated life cycle phases with users' changes in satisfaction levels. In his study pleasure is closely linked to satisfaction. He found that it is extremely difficult to separate physical decline of products over time from growing dissatisfaction. Furthermore the emotional evaluation of products [10, 11] has been studied for the past 15 years, also in relation to materials [12]. These studies have had the merit of focusing on the user's emotional mechanisms and have brought significant results, including a catalogue of emotions that influence design and the addressing of specific tools able to qualitatively evaluate these emotions. In addition we can also find important examples in literature where ageing and durability have already been analysed together [13].

This is our studies' starting point, we will further focus our practical investigation on the specific aspects of materials' time ageing and its relation with user perceptions. The next two paragraphs present the theme of time in design and analyse the benefits of including it in the design process. Following that, we evaluate the links between materials, time and emotions with the purpose of conducting the first estimate of the chosen method and tool in our pilot study.

Time in design

One of the major challenges for designers today is to give the right consideration to time, especially in our fast-replacing goods society. It may be aimed to an enhancement of the product's life span or to maintain consistency between a material and the intended usage [14]. But it does not necessarily mean making objects more robust or easier to repair. By focusing only on the mechanical/constructive optimization of product design, the risk is having to deal with long-lasting junk rather than longer-lasting products [15]. To avoid product obsolescence, a possible approach is to allow products to evolve together with their owners, enabling them to reveal their beauty with time [16]. Many objects lose value in time because they lose newness, which is the attractive factor in the purchase phase. Newness is a complex mixture of different sensorial properties like odour, shiny colour and the integrity of surfaces.

Many objects are already designed this way. A copper dome for example will gain value in time by turning green exposed to air oxidation. It will not lose its importance or public appreciation for that. This is an example of *patina*. Patina shows the passage of time and is the balance between the functionality, the material choice and the meaning of the object. Despite these gross inconsistencies patina is, indeed, a necessary – if not imperative – design consideration to assist the extension of product lifespans in graceful and socially acceptable ways [13]. Designers should value such material ageing properties.

Value of time

For some materials ageing is negatively addressed as decaying, for other ones it may have a positive effect that can be defined as evolution or maturation. But speaking of materials and their relation with time, what is actually driving our judgment? What are the factors that lead to a positive or a negative perception of ageing objects? In other words, what parameters and emotions are ultimately bonded to the idea of evolution or decay?

Decay is intended as the passage from an optimal initial situation to an inferior condition. In this common understanding, time and usage leave traces or defects on the products considered. This is an association that generally involves artificial materials such as metals or polymers, which tend to deteriorate, losing their original mechanical and aesthetical properties. Among the negative consequences of ageing, decay includes spots, rust, scratches, turning yellow, losing brightness and so on [17]. On the other hand, *maturation* is usually associated to natural-based products, like those made of stone, paper, wood, leather, which in time gain new fragrances, colours and consistencies. These newly gained properties confer an added value, a sense of preciousness. An old leather purse, a painting on an aged frame or an oxidized bronze statue: these are all examples of tangibly aged objects that have not lost their beauty and keep on attracting us. Both artificial and natural materials are subject to a similar chemical and physical degradation in time (exposure to the atmosphere, UV rays, humidity). It would be wrong to associate a positive evaluation of a certain class of materials with their ability to be positively affected by time.

The negative aura of artificial materials being old is related to the idea of failure. They are materials created by us, meant to shine and saturated in colours. If they get old, their decay is our failure. In 2004 the Eternally Yours foundation launched a survey, Proud Plastics, in order to understand what was the common perception of plastics [1, 18]. "It is OK for wood to become old and dirty. You can't blame it; it is its nature. But plastics were invented. So when they become ugly, when they melt or crack, you blame the inventors. They should have done a better job."

The challenge for designers could be to handle not only natural-based materials but also artificial materials in a more conscious way, especially when it comes to time passage. This could also lead in the future to a less critical (if not positive) perspective on ageing compared to the present one described. We therefore decided to focus our research on polymeric materials. Plastics are the materials associated with design, thanks to their versatility, which opens fields to creativity. "Plastics technology strongly helped design to grow as a profession. On the other hand industrial design contributed to shape plastics into products, their end-form and also by promoting their image through the invention of new cultural codes" [19]. We've chosen polymers also because they perfectly represent this dilemma between ageing and artificiality. Moreover, from a sustainable and environmental perspective, it's important to remember how plastics account greatly among "dismissed" products every year [20]. Waste production represents an important loss of material and energy resources and for this reason it's essential to avoid or delay as much as possible the number of products that are sent to waste.

Finally our main focus is firstly on the qualitative understanding of the user-product relation with old products and materials, and secondly to develop an analysis able to inform and eventually inspire designers while starting a new design process. In this study our attempt is to validate a method (composed by a series of tools) useful to relate material parameters with users' perceptions and emotions in time. For our investigation we used the following polymeric materials: ABS, PC, PET, PMMA and PP.

Tools

It was necessary to identify the analytical tools for the sensorial properties evaluation (called S*ensorial level*). In order to identify the most suitable tools we proceed with a literature review, specifically focusing on the evaluation of the user's emotional variation towards new and aged products. Emotional variations bonded to the *Product experience* [21] were also analysed. Product experience is defined as the research area focused on individual experiences and the user-product relation.

We investigated the role of materials and their emotional impact, also known as *Material experience* [3], which is a part of the product experience and plays a fundamental role in how products are lived. Material experience is defined by the effects involved in the user-product bond – limited to a specific context. Today there exist many tools that allow an evaluation of product and material experiences. Desmet [10] offers a broad classification of those tools, grouping them into two categories. Firstly, there are verbal evaluating tools, where the user is asked to share his individual emotions through evaluation scales or written protocols, for example the Kansei Method [22], Self-Assessment Manikin [23] and the SEQUAM Method. Secondly, nonverbal tools determine affection bonds through the analysis of the physiological or expressive reactions the tester shows against different products. Examples of such tools are EMG (facial electro-myographic activity) and Face reader [24, 25]. The limit of these tools is that they do not allow consideration of contrasting emotions at the same time.

The tool we selected for our research is the software PrEmo developed by Pieter Desmet [26]. It allows us to combine the pros of both verbal and non-verbal methods, measuring emotions even if they are contrasting among each other and without requiring a verbal emotional analysis to the tester. This tool has been developed for *Product experience* evaluation but has also been validated for its use in *Material experience* by Gaia Crippa [12], who has used it for an emotional evaluation of different material samples.

Study

We carried out two different tests on a panel of 25 participants. The goal of the first test is evaluating the ageing effects on products (characterized by different shapes, colours and functions) made of different specific materials. The second test is focused on the same materials, but now taken as samples. The scope of the second test is to evaluate the ageing of the material itself more precisely. This is possible by changing the material variable but fixing shape, dimension, function and colour.

The main goal of these two tests is to verify the usefulness of the chosen tools, when used to check the influence of materials decay on emotional and sensorial perception.The tests are meant to set a first step in understanding the physical and emotional variables that influence the perception of being old (linked to a specific material). In this first step we set the base to understand which is the best method to identify all these variables. To design products more situated in time, this knowledge identification will be useful for designers by supporting the material selection process.

Method

Participants

Our panel is made up of 25 Italian subjects, aged between 20 and 60. Gender equality was taken into account, with 12 females and 13 males. The age distribution of the respondents was 72% people aged between 20 and 30, and 28% aged between 30 and 60. We also considered the cultural background, which turned out to be the most important variable [27].

We divided the subjects into 2 categories:

- *Naive* (12 persons) who don’t belong to the design field and without specific knowledge about materials.

- *Professionals* (13 persons) selected between students from the master in Design and Engineering in xxx University.

Stimuli

As mentioned before, 5 different polymeric materials were selected, two transparent and three opaque:

- PC (polycarbonate)
- PMMA (polymethyl methacrylate)
- ABS (acrylonitrile butadien styrene)
- PET (polyethylen terephthalate)
- PP (polypropylene)

These materials can worthily represent the designer's world of materials. They are also enough differentiated in terms of optical, structural and sensorial properties. Elvin Karana demonstrates in her study [28] that the shape of a product can influence its evaluation. In particular the perception varies considerably between round- and sharp-cornered objects. Also the context of use influences the product experience and perception. One material can create different emotions depending on the context of use (kitchen products or office products). Furthermore, dimensions are also important, for example small products stimulate more sensorial description than bigger objects because we interact more with them. [28].

Following requirements were taken into account while choosing products for the Test 0:

- Formal simplicity, little details, constant thicknesses and homogeneous geometry;
- Single-matter products, allowing evaluation of only one material per time;
- Small dimensions: to stimulate interaction and handling of the products;
- Uniformity on the context of use.

The artefacts we selected for the first test are kitchen products (see Fig. 1):

- a potato peeler in ABS;
- two glasses in PC and PMMA;
- two small containers in PC and PET.

Maximum dimensions are 130 x 130 millimetres and all products present round-cornered shapes and constant thicknesses.

For Test 1 we limited variables as chromatic aspect and geometry. The samples are all squares of 100 x 100 mm, with a constant thickness of 3 mm (see Fig. 2).

Fig 1. Artifacts used in Test 0

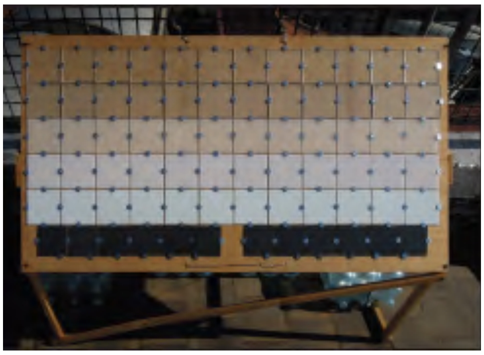


Fig 2. Aging set up of polymeric samples for 5 different materials, used in Test 1

Ageing process

The objects from Test 0 have been artificially aged via UV-rays exposure – Helios Italquartz high performance UV lamp with mercury vapours source [29], 500 W electric group, exposure duration of 120 minutes. All samples' surfaces were treated with fine "glass paper" (M622 type) to simulate the product's impact abrasion in a normal life cycle. This choice was made to focus on the material rather than the product. The objects have been aged in accordance to ASTM D1435 [30] and the *Natural Weathering* technique. The samples form Test 1 were exposed in Milan on a wooden frame inclined by an angle of 45° degrees facing south for hundred days (between June 24th 2012 and September 21st 2012). During the whole period of exposure, temperature was monitored daily (maximum and minimum recorded) along with humidity (maximum and minimum recorded), wetting and global irradiation. An example of the samples of the new and aged samples can be seen in figure 3 and 4.

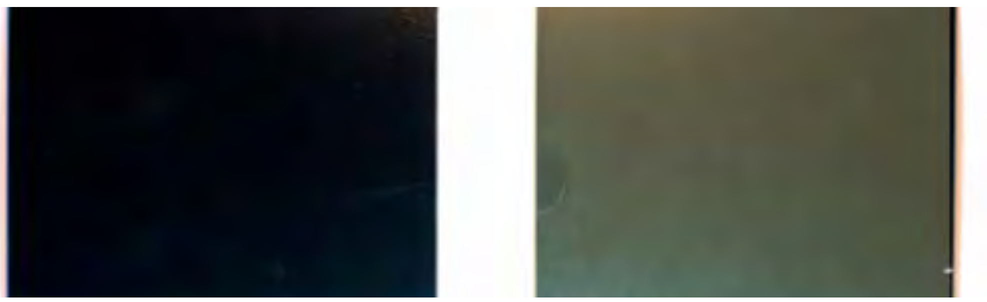


Fig. 3 Example of new (left) and aged (right) ABS

Fig. 4 Example of new (left) and aged (right) PP

Procedures

We then conducted Test 0 (on artefacts) and Test 1 (on samples) in two sequential phases:

- Phase 1: the emotion evaluation with PrEmo [31];.
- Phase 2: the sensorial evaluation with a 1 to 5 scaled questionnaire.

Phase 1

Participants had to evaluate five sample pairs. For each pair one material was aged and the other one was new. The test was conducted with PrEmo [10], a tool especially designed to evaluate product-generated emotions. PrEmo is aimed to comprehend and evaluate emotional responses to products. It evaluates twelve emotions – six positive (desire, satisfaction, pride, hope, joy, fascination) and six negative (disgust, dissatisfaction, shame, fear, sadness, boredom). Each emotion is pictured as an animated character and the emotional intensity level is graded on a five points scale. Each participant has evaluated the samples individually and in the following sequence: new ABS, aged ABS, new PC, aged PC, new PET, aged PET, new PMMA, aged PMMA, new PP and aged PP. All samples were lying on a table and participants were entitled to look and touch the samples during the evaluation. Instructions were shared verbally in Italian with the aid of a short tutorial video. An average evaluation time of 10-12 minutes per participant has been recorded even though no time limit was imposed.

Phase 2

Participants were asked to evaluate the sensorial properties of the materials based on a questionnaire developed by Elvin Karana in her study Meanings of materials. This was done through sensorial properties and manufacturing processes [32]. The questionnaire presents a list of 13 sensorial properties (hard/soft, smooth/rough, matte/glossy, reflective/non-reflective, cold/warm, non-elastic/elastic, opaque/transparent, tough/ductile, strong/weak, light/heavy, washed-out/colourful, pleasant-/unpleasant-sounding, scented/odourless) consisting one page per material. Each parameter is linked to a representative icon and a brief description of the relevant property. The participants were asked to evaluate the intensity of each property on a scale from -2 to +2.

Results

The collected data were analysed on three different levels:

- the correlation between emotions and aged products,
- the perception of aged materials;

- the correlation between perceptions and emotions.

The analysis was abstracted from the materials themselves. Consistently with the aim of this research, our analysis is based on mathematical methods rather than statistical ones. Our intention was to propose a method to obtain time-, perception- emotion- and material-related data and an analysis of the above. Not to obtain data directly usable by the designer. This is a topic that we intend to address in the future. Our results show clearly how emotions (and their variation) are strongly dependent on the link between the user and the differently aged products. This function, calculated for each emotion, reaches its maximum at 30% (fear – PMMA) and has a minimum at 1,25% (shame – ABS). This is shown in figure 5. The results are in accordance with previous studies' hypothesis [13, 33]. We therefore had a confirmation of the reliability of our tool with the hope that in the future it will return objective and quantitative data relevant to measure these perception-variations.

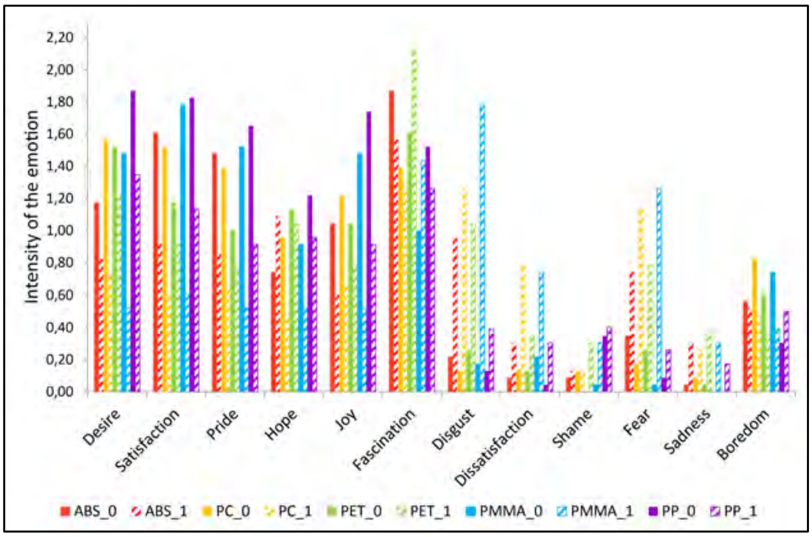


Fig 5. Results of Test 0

The two tests are comparable. From our data analysis it is clear how emotional and sensorial variations are proportionally related to the ageing shown by materials. More specifically, among the materials in both tests the emotional variations average is directly comparable to the sensorial variations' one. This comparison is 0,44 versus 0,48 in the products test (see Fig. 6) and 0,22 versus 0,22 in the samples test (see Fig. 7). An increase in the material decay directly implies a variation in the user's emotional reaction.

TEST 0	ABS	PC	PET	PMMA	PP	Average
Desire	0,35	0,83	0,3	0,96	0,52	0,59
Satisfaction	0,7	0,91	0,26	1,17	0,7	0,75
Pride	0,61	0,74	0,22	1	0,74	0,66
Hope	0,35	0,48	0,09	0,39	0,26	0,31
Joy	0,43	0,57	0,26	0,96	0,83	0,61
Fascination	0,3	0,13	0,52	0,43	0,26	0,33
Disgust	0,74	1,13	0,78	1,61	0,26	0,90
Dissatisfaction	0,22	0,65	0,22	0,52	0,26	0,37
Shame	0,04	0	0,3	0,26	0,05	0,13
Fear	0,39	0,96	0,52	1,22	0,17	0,65
Sadness	0,26	0,17	0,35	0,3	0,17	0,25
Boredom	0,04	0,35	0,26	0,35	0,2	0,24
Average	0,37	0,58	0,34	0,76	0,37	0,48

TEST 0	ABS	PC	PET	PMMA	PP	Average
Cold-warm	0,22	0,22	0,04	0,09	0,26	0,17
Hard-soft	0,17	0,17	0,26	0,17	0,04	0,17
Smooth-rough	0,56	1,39	1,09	1,35	0,14	0,91
Light-heavy	0,17	0,13	0	0,26	0	0,11
Tough-ductile	0,26	0,09	0,26	0,26	0,13	0,20
Not elastic-elastic	0,22	0,04	0,13	0,09	0,09	0,11
Strong-weak	0,09	0,17	0,17	0,04	0,16	0,13
Opaque-transparent	0,05	1,13	0,52	1,17	0,05	0,58
Matte-glossy	0,52	1,29	1,32	1,57	0,2	0,98
Not reflective-reflective	0,41	0,74	0,68	0,5	0,3	0,53
Faded-saturated	1,57	1,41	1,77	1,13	1,31	1,44
Nice sound -unpleasant sound	0,17	0,04	0,04	0	0,22	0,10
Odorless-odorous	0,64	0,41	0,32	0,05	0,05	0,29
Average	0,39	0,56	0,51	0,51	0,23	0,44

Fig 6. Results of Test 0

TEST 1	ABS	PC	PET	PMMA	PP	Average
Desire	0,32	0,27	0,55	0,18	0,23	0,31
Satisfaction	0,41	0,18	0,55	0,41	0,14	0,34
Pride	0,09	0,18	0,5	0,32	0,05	0,23
Hope	0,14	0,23	0,36	0,05	-0,5	0,05
Joy	0,36	0,41	0,23	0,55	0,41	0,39
Fascination	0,32	0	0,18	0,23	0,45	0,24
Disgust	0,32	0,36	0,32	0,14	0,82	0,39
Dissatisfaction	0,18	0,23	0,09	0,09	0,64	0,25
Shame	0,05	0,05	0,05	0,09	0	0,05
Fear	0,05	0,18	0,14	0,09	0,41	0,17
Sadness	0,05	0,18	0,09	0,05	0,23	0,12
Boredom	0	0,23	0,14	0	0,09	0,09
Average	0,19	0,21	0,27	0,18	0,25	0,22

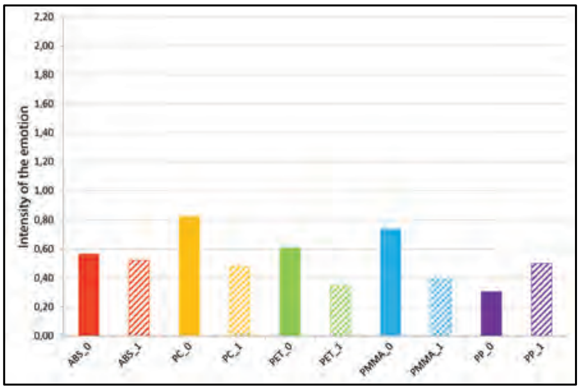
TEST 1	ABS	PC	PET	PMMA	PP	Average
Cold-warm	0,18	0,5	0,09	0,14	0,5	0,28
Hard-soft	0,64	0,05	0,18	0,05	0,09	0,20
Smooth-rough	0,18	0,14	0,27	0,14	0,27	0,20
Light-heavy	0,23	0	0,07	0	0	0,06
Tough-ductile	0,09	0,05	0,32	0,23	0,05	0,15
Not elastic-elastic	0,14	0,09	0,05	0,09	0	0,07
Strong-weak	0,18	0,23	0,14	0,14	0,14	0,16
Opaque-transparent	0,09	0,09	0,05	0,09	0,05	0,07
Matte-glossy	0,64	0,03	0,05	0,19	0,73	0,33
Not reflective-reflective	0,73	0,32	0,36	0,14	0,41	0,39
Faded-saturated	0,95	0,52	0,52	0,47	0,29	0,55
Nice sound -unpleasant sound	0,05	0,18	0,05	0,05	0,05	0,07
Odorless-odorous	0,18	0,05	0	0,05	1,05	0,26
Average	0.33	0,17	0,16	0,14	0,28	0,22

Fig 7. Results of Test 1

Following Russell's model 'circumflex of emotions' [34], where each emotion is defined based on the perception intensity (exciting - not exciting) and on its pleasure, we can note that disgust and satisfaction, which are each other's opposites, are more often related to new and old products. The emotional variation involves all levels of sensorial perception. Without generalizing the obtained data in an absolute way, it is significant to note how disgust grows passing from the new to the old product and satisfaction decreases in every sample pair. From the analysis on sensorial variation (Level 2) it is clear that with product ageing all four photometric properties also vary: transparency, brightness, reflectance and saturation. Six of the seven textile properties remained constant, like all sound properties of the objects.

The tests confirmed how sight is the most important of our sensorial perception abilities and it dominates the process of emotional evaluation of products with different ageing degree. These results are in accordance with the scientific community leading opinions and confirm how through sight we evaluate the universe around us [35]. A particular clear link is shown with the research of Shifferstein [36], relative to 45 industrial products where, through the development of a few tests, it is highlighted how products' sensorial evaluation happens first through sight, followed by touch, odour, hearing and taste. Sight is the dominating sensorial mode because it is the first step in our experiencing. Textile properties furthermore have the capability to maintain the emotional bond generated within the user in time, as opposed to sight properties, which are related to more formal and superficial aspects that tend to dissipate their importance in time.

The results obtained confirm tendencies already investigated by others. Only some cases are of more particular interest and may be somewhat astonishing (refer for example to boredom and fascination shown in figure 8 and 9).



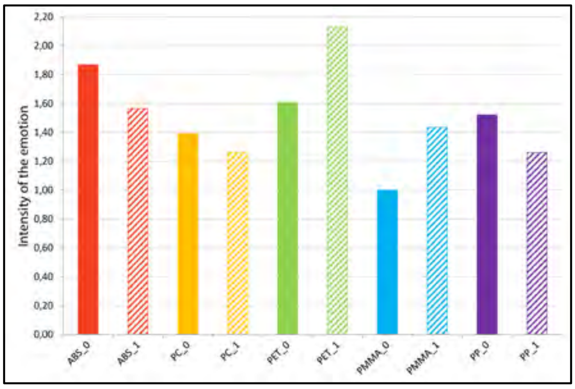


Fig 8. Results of Test 0: Boredom

Fig 9. Results of Test 0: Fascination

Firstly this means that it's important to consider the dependence on time as this has an actual impact. Secondly that the selected tools are consistent for obtaining a quantitative analysis of the phenomena related to product ageing. It is crucial to consider such parameters, their variation and their emotional impact in early design phases, especially for products that are intended for an extended life cycle.

Conclusion

The study shows how time acts on materials by changing their meaning and their expressive characteristics. Our goals have been in summary:

- Focus on materials to understand what role materials play in product's ageing and how they influence the user's perception by acting on his emotions;

- Extend this analysis (product and material experience) tying it to real products, used and aged – not new or abstract ones.

The intent was to comprehend, first in a qualitative way, if these ageing phenomena can cause a variation on the user-product emotional bond. The aim has been to highlight the relationship between materials, structural properties, perceptions, emotions and time. This done, our future intention is to deepen this issue to inspire future research. The experimental part of this paper aimed to identify and validate a method able to include time among the parameters useful in material choice, basing this choice on an expressive-sensorial base (qualitative analysis). Even if limited for their number, the data obtained through our testing show clearly how perception (emotional and sensorial) varies greatly between new and old products. This change depends on the type of emotion involved and the material ageing entity. This means that in time the user-product bond varies as a function of the material's specific properties. In our opinion this is an aspect of great interest also for future developments in the field of design. Thanks to the tests developed it has been confirmed how shape, function and colour of the product influence its ageing and the perception of it significantly [37]. A direct comparison among the different test results (test 0 and test 1) seems therefore irrelevant. Also, the participant's panel size is too small to extend generically the quantitative conclusions of our results. We also didn't want to focus on a statistical analysis before having validated a method thoroughly.

The tools used, PrEmo [31] and the iconographic questionnaire [32], have proven to be adequate for evaluating the material experience on objects exposed to different ageing stages. In the future we intend to obtain quantitative data through the execution of the tests presented in this paper to an extended number of participants, adding a statistical evaluation to our analysis. We also want to reorganize the results in order to define them better as a tool for designers and companies, a tool useful in a long-term perspective of product design.

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Processes of Artefact Creation in the Hybrid-Reality Engaging with Materials through Material Oxymorons

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Abstract

Yet the nature of all these things must of course be physical
since otherwise they could not impress our senses
—for impression means touch, and touch means the touch of bodies.
Lucrezio, "De Rerum Natura"

The materiality of things represents the connection between our bodies and the physical world. However, in recent years, with the overlay of a new digital reality onto the existing physical one, materiality has extended its domain of existence into the virtual world through haptic technologies. The sense of touch is no longer restricted to a physical contact with any kind of "thing" existing in our world, but accessed through perception of it. By means of neurocognitive processes, which reproduce the sense of touch by stimulating particular areas of our brain, touch lost its direct and instinctive connection with the physical world to rely more on mnemonic processes of virtual perception that construct hybrid knowledge based on digital rather than physical stimuli. This paper investigates what the human relationship with things is in the age of human sense simulation. Also, what kind of sensuous relationship is established with our surroundings when the main territory of material investigation has shifted to the virtual, understood as "real"?

This paper will attend to human-object/thing relationships via the concept of the "material oxymoron". An oxymoron is a figure of speech that juxtaposes elements that appear to be contradictory. The "material oxymoron" finds its hybrid materiality by means of the human's perception of, and engagement, with things. By embracing the hybrid context (between the digital and the physical) in which we dwell, we would like to define a new kind of relationship between humans and objects/things using Malafouris' theory of “material engagement”. We will articulate the process through which material oxymorons are constructed, and consider the role of material engagement theory in explaining it.

In the material oxymoron, the surface quality is no longer defined a priori in reference to information stored in the human brain, i.e. what we expect, but emerges from the process through which material oxymorons are created. We will therefore treat materials as mutable things, continually transformed by humans and material actants, rather than treating them as objects existing ad infinitum. By means of material oxymoron we aim to challenge a sensuous discovery of the physical whose outcome creates composite matter, i.e. a materiality that fosters human perception and engagement with the physical world.

Keywords

Artifact; process; oxymoron; hybrid; engagement

The University of Bristol recently published research that challenges the concept of touch by using “principles of acoustic radiation force, whereby the non-linear effects of sound produce forces on the skin which are strong enough to generate tactile sensations” (Long B., Ann S., Carter S.H., Subramanian S., 2014). Researchers Long, Ann, Carter and Subramanian looked at a system that simulates the feeling of touching an object without the presence of a physical object, and without any visual contact with it (2014). By employing the natural "acoustic" properties of human skin, University of Bristol researchers created a "tangible" sense where “dimensional phased arrays of ultrasound transducers enable tactile sensations to be produced in three dimensions in mid-air” (Long B., 2014 et al). In other words, frequencies and sound amplitudes are used as interchangeable data between the object and the human body. In order to allow our brain to "feel" the volume of the object, researchers extended the fields of points that generate the ultrasonic frequencies to maintain continuity among fields in time and space (Long B., 2014 et al). To increase accuracy and details of the actual object they modulate the different amplitudes’ contrasts. From the human point of view, the actual geometry is then understood by converting the cloud of points generated by the acoustic field into meshes that reconstruct the object and the hand in virtual space. The mutual physicality of both parts, object and hand, is described by parametric coordinates ruled under the “limit to zero” equation that describes the behaviour of the curvature representing the density of points, hence the physical proximity of the two entities. This research is one of the most sophisticated in the field and aims to extend digital reality to the physical one and vice versa through different applications. The domain of hybrid-real is currently the territory of exploration of different agents, from engineering to design. The common aim is to blur boundaries and improve continuity so that reality can be understood equally, as much digital as physical; i.e. hybrid. For this specific reason there is a common urgency to find direct connections between the two parts, so that they are felt as a continuous field with no division.

The challenge that the digital has introduced to reality is the process of thinking how to make, which doesn't stop with the rapid prototyping revolution, but extends to the heart of how things, from the macro to the micro, are understood.

According to Andrew Benjamin (2006), the digital augments human sensitivity of the physical by means of its relation to representation. The ontological mimetic process by which we reify reality through images (Kant, 1781) matches the machinic process of the virtual, which relies mainly on representation; building make-believe worlds from synthetic visual representations of reality. However, since digital reality entered our "physical" space, visual engagement appears obsolete, as it constrains the other senses we human employ to experience reality. Memories are triggered by images as much as smells that in our brain stage the situation we experienced in the past. However materiality is quite an important element for humanity, as it defines the bridge between our body and the physical environment we inhabit. Nevertheless, in the hybrid-real materials implement their physical properties, through technological innovations such as 3D voxel printers that combine multiple materials to give shape to a composite. In other words, with the emergence of composite materials in our everyday scenario, and haptic technologies, which challenge the perception of physical materiality by joining touch and memories, we are reshaping a new framework based on the engagement we establish with materiality. Within this specific area the material oxymoron concept takes shapes. It looks directly at human engagement with materials by means of process. In the material oxymoron theory, materials are experienced as composite entities whose sensuous perception define the surface quality. Material oxymoron intends to trigger a physical/digital experience of the real based on the unexpected perception of it.

A matter of things and objects

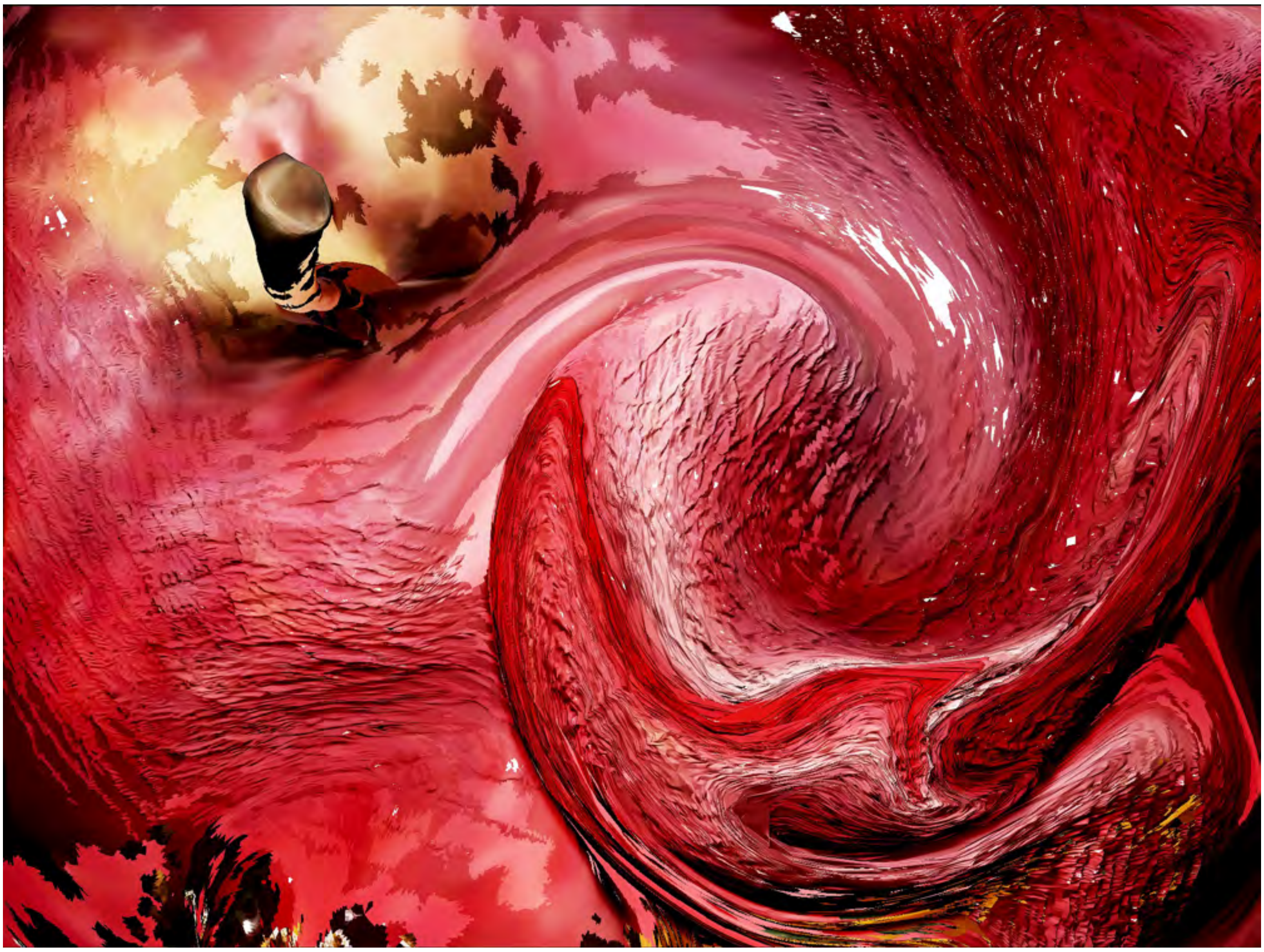

Fig 1. Painting materials and sculpting surface with ZBrush on a 3D scanned apple.

Physicality of the real touches metaphysical territories, if related to ontological open queries that investigate the understanding of the self, as entity belonging to the physical world. According to Lambros Malafouris, since childhood “we constantly think through things, as material culture shapes the manner in which people act, perceive and think” (2013); indeed within the human/object relationship, matter concerns metaphysics rather than physics. Such an intricate relationship is illustrated with the concept of the “cognitive life of things” where objects are “reduced to their ability to act as semiotic mediums of representation to amplify cognition” (Malafouris, 2103). According to the anthropologist Daniel Miller, who finds seeds of the materialist culture in Simmel and Marx, materiality, as a concept, “exists not through our consciousness or body, but as an external environment that habitates and prompts us” (as cited in Boscagli M, 2014). The resemblance of things, indeed, is quite a fundamental aspect in the hybrid reality we dwell everyday, as pointed out by Andrew Benjamin when he describes the representational value of the real in the digital world. Indeed, virtual reality adds to physicality an extra layer of complexity in the ontological system where our physical existence takes form. Within the physical realm we acknowledge our bodies as other matter of the real among objects or artefacts. Malafouris’ cognitive life of things makes us rethink the role of humans in their mutual technosocial transformation (2013). Since the beginning of civilised society, the human being dwells the twofold fascination of learning how matter continuously transforms its physical properties against the possibility of changing them. For such a reason, things are matter that resemble social relationships between people. “Mind and things are in fact continuous and inter-definable processes rather than isolated and independent entities. By knowing what things are, and how they become what they are, you gain an understanding about what minds are and how they become what they are - and vice versa" (Malafouris, 2013)

The physical world is made of things whose matter is in perpetual transformation (including ourselves). Philosopher Manuel De Landa describes how French philosophers Gilles Deleuze and Félix Guattari shifted the obsolete understanding of matter as obedient entity, which obeys the physical laws, to a fluid active entity with its own physical characteristics (2012). When such a thing enters into contact with a human it becomes an artefact, which is a product of a human's modification of physical matter. For instance, a clay pot is the result of a direct, tactile interaction with matter.

It is important to notice how an object differs to a thing. Objects are our interpretation of things, through a system of categories that we apply to acknowledge their existence. Indeed, objects are the ephemeral formal constraints that represent things in our mind. According to such definition, the virtual world(/mind) is characterised by objects, as they are artificial entities that human minds have created and categorised. It then follows that design is an act of classification of 'objects' into the world. What happens when design is processed through the virtual world?

Social change introduced by the overlap of digital over physical reality has opened up the possibility of creating, establishing and challenging networks of people connected by enthropic relationships. The possibility of a global and fluid exchange of information, transmitted via the digital world, redefined the relationship between things and objects from not only a physical point of view. Thing/object understanding has been influenced by the fluidity of shared information, which engages different agents, human and non-human, in the manufacture of things/objects. For this specific aspect, things/objects cannot be analysed as isolated entities, but as components of a larger system where the human and non-human coexist. "By knowing what things are, and how they become what they are, you gain an understanding about what minds are and how they become what they are - and vice versa" (Malafouris, 2013). Hence, the cognitive life approach emerges, as acknowledgement of a material life that challenges a "methodological fetishism, essential in undertaking this key task of recasting boundaries of mind". (Malafouris, 2013)

Material engagement

According to Manuel De Landa "the state in which we are born is a state of delirium, in which all the different intensities that have the capacity to affect senses - intensities of colour and sound, of flavour and aroma - exist in an unstructured field". However, when we grow, we stabilise such intensities by conforming to social rules. Gilles Deleuze draws possibilities of destabilising such social constraints to free our perception of the physical by means of sensorial chambers (2012).

New engagement between human and non-human, via the new relationship between thing and object have created a new route in the cognition of the physical. According to Malafouris, "the extended mind is a new, radical and much contested thesis over the mind's location" (2013). The dichotomy in discussions of cognition of internal "in the brain" and external "in the world" processes is collapsed by focussing on the in-between. (Wilson 2004; Wheeler 2005; Clark 1997; 2007; 2008; Clark, Chalmers 1998; Adams, Aizawa 2007 as cited in Malafouris, 2013). The internal understands mind without any external and 'non-biological' conditions, so that cognition is limited to the internal world without taking in consideration the external environment, i.e. body and matter. Externalism creates the syllogistic paradox by drawing the connection of mind with the external world - environment, body and matter - thus recognising the importance of external elements in the process of cognition. (Malafouris,2013). It then follows that the extended mind intertwines mind, body and things to shape cognitive processes. Human brain is part of a body integrated in a physical environment so that the human acts on his environment and the environment acts or feeds back. The extended mind draws a continuous process of engagement that describes how humans interact with the world and the other entities in it. For instance, the creation of an artefact such as a pot establishes a relationship between potter and clay, which both exist in a physical environment. The human acts on the clay and the clay acts back on the potter and the muscles in his hands. This process is tacit and ignores linguistic processes. Here we are not bothered with discussions of semantics, but an embodied experience of the world (touching the world) that humans draw on to form knowledge about the environment around them. The human species has always done this as do all other animals.

In relation to the extended mind theory, boundaries hinder a proper understanding of the world. It is useful to consider the world as a complex of things in continual transformation rather than as a collection of objects that exist ad infinitum. However, in human perception, out of necessity, we objectify things generating meaning about them. Mentioned already, an artefact is a thing created by a human. It is evidence of an act of human modification or transformation of matter. When we create an artefact the human imposes an idea onto the world. This can be seen as a hylomorphic process and an anthropocentric one. The artefact becomes an ontological act that relates the human mind to its environment, in relation to the cognitive process described by the extended mind.

Fig 2. Toy plastic-like material is painted on the 3d scanned apple. Then the surface is treated as mouldable like a toy would be. An extra pattern is added to enhance the oxymoron effect.

The material oxymoron process in design

According to Mark Titmarsh "ontology as a mode of enquiry asks what kind of things, including abstract things, can be said to 'be'". (2006). In the design process, ideas are transformed into tangible objects. To some extent, the act of design is capable of creating new worlds by embedding in its poiesis a multiplicity of possibilities given by the continuous flux of fields, which are our physical and virtual reality. The design process does not involve an interaction with the physical world as does making a pot per se. However, in relation to the extended mind process, there is an embodied engagement with the physical world.

Contemporary design, in general terms, mainly takes place in the digital world. 3D modelling is a virtual act that gives form, and matter, to virtual entities that 3D printers bring back to physical reality. This process can be described under a looping process overseen by the extended mind. What are the artefacts of hybrid realities?

According to Titmarsh, the act of making requires a "physical and conceptual behaviour, involving intentional activity, pre-reflecting know-how, and a dialogue with the specific material qualities of a medium" (2006). Materials are not passive, as argued by Deleuze, hence making is a kind of dialogue of events between the material and the maker informed by the resistance of the material, which shapes the form of the outcome. The process of making in the hybrid-real intertwines new layers of complexities at different levels. In the original contrast between objects and things, we cannot limit the space of objects to our mind, as the virtual itself can be considered as an extension of our mind. Objects are not only the formal subjective categories through which we understand things, they become matter of the digital reality, which is constructed under our own 'subjective' understanding of the physical world (objects). When digital interfaces become our tool to create new things, as it happens by 3D printing objects into things, artefacts become products of human action on hybrid matter. As we understand the physical through our body and matter, we replicate the same process when creating new things in the digital world. Design becomes a hybrid loop between the digital and the physical, which gives shape to a hybrid artefact. We call such a looping process the material oxymoron.

However, in the looping process between the digital and the real, something unexpected happens. The hybrid of body and mind are integral to our ontological existence, so it follows that a second level of hybridisation occurs in the material oxymoron, which is the effect of physical and digital when approaching artefacts. This condition is enhanced by the fact that digital materiality has no resistance. "The distance between the conceptualisation of a virtual thing and its appearance on the screen is not readily understood in terms of physical energy or material resistance."(Titmarsh, 2006). As no resistance is opposed, design offers multiple possibilities based on concepts rather than feedback constraints. The increased degree of freedom channels the process of designing towards human sensation of matter. When 3D printing digital artefacts we produce matter based on sensations formed from our expectation of physical matter, constraints that physically do not exist in the digital world. 3D printed artefacts are in-between digital and real; hybrid (oxymoron) artefacts. Under this light, 3D printing becomes an indirect interaction with matter that is capable of generating an uncanny, unexpected and unfamiliar sensuous perception which is the material oxymoron.

A material oxymoron is a hybrid between the virtual(/mental) and the physical, that uses digital languages to mediate the physical process of traditional artefacts to define a hybrid version. The hybrid artefact institutes a new form of interaction with materiality that enhances the perception of the physical world. Material oxymoron establishes and enhances sensuous relationships with machines by means of matter. A material oxymoron is the result of a new kind of design process.

Even if occupying a virtual environment, design creates new physical artefacts using 3D modelling software. This virtual realm is similar to the mind, as it draws on the existing knowledge of the physical world. This knowledge has been established through physical experience, from probing it with senses (especially touch which we immediately implement from birth). Just as the software is an extension of human mind, manufacturing machines extend human physical capabilities to realise 3D models as an artefact in the physical world. As objects are born into the physical world the designer can engage with this new thing through his senses, including touch, via hybrid reality. Synthetic materials are applied to this new thing using a software such as ZBrush, which allows to 'paint' materials on the 3D model. Because of the artificial quality of digital materials, human senses enhance the traditional understanding of matter because of the freedom afforded by digital modelling softwares.

This process of creation is juxtaposed with the traditional formation of an artefact. Consider again the example of the potter at his wheel. His body engages with the material directly. The clay and his hands have a haptic relationship and a feedback loop is established where the muscles in the potter's hands react to the transformation of the clay. Although this kind of material engagement is lost in the process that produces material oxymorons, there is an enhanced perception, given by the unexpected results. The whole process of making is defined by a continuous engagement with matter, but at a different level, which concerns the extended mind theory. Although a physical relationship with the thing emerges at the very last step, a relationship with the artefact is continuous throughout the whole process. As by definition an artefact is the result of a human's transformation or manipulation of matter, matter in the material oxymoron is always present in different kinds of hybrid states. The human still creates the outcome but his/her intention is mediated through technology. This is not new. A plane may be used to smooth a surface of wood, this is a tool between human and material. However, in the case of this new process, the idea passes into the virtual world before returning to the physical world. The human knowledge of materials is applied in a 'traditional way', to the virtual world; because the process is hybrid, the material is hybrid too.

Fig 3. 3d scanned apple sculpted in ZBrush. Materials and colouration are painted on the original pattern. Through ZBrush the apple transforms its own materiality.

New artefacts

Despite our ability to occupy a virtual space, human sensory experience always exists within a physical world. According to Maurizia Boscagli, "when materiality is separated from its use for humans, it can emerge in all its sensuousness and metaphysical presence" (Boscagli M., 2014). We know the world through our sense of touch, which helps to form in our mind the concept of material. Touch indeed is the sense we use from the moment we are born to navigate and learn about the physical world. It is the bridge between our body and the physical environment we inhabit. Nevertheless, new design has tended toward a translation of physical material into virtual representation; skeumorphisms of Apple and other companies being a key example. Touch is lost in place of its simulation, which evokes the perception of it, rather than the physical interaction. The material oxymoron describes a new design process where the physical enters the virtual environment (through the designer's tacit experience of it), but returns to the physical. The virtual is used as a space to facilitate the creation of new artefact rather than being the final destination of a (pre)rehearsed process. Here we establish a design ecosystem where the physical (body) flows to the virtual (mind) and back again in a cycle of production (not necessarily hylomorphic), which evokes materiality as continuous, sensuous thread. This is parallel with the material engagement mentioned by Lambros Malafouris; the mind has been extended with virtual software and the body extended through manufacturing machines.

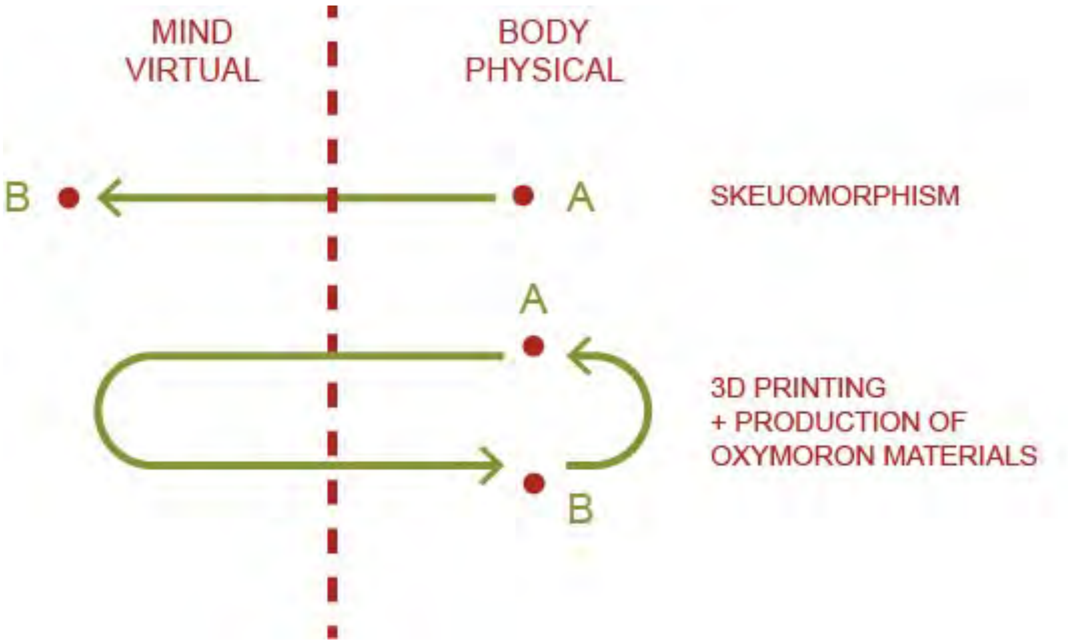

Fig 4. A linear process of transformation from the physical to virtual; a cyclical process of transformation from physical to virtual and back again.

If looking at the possibilities that voxel 3D printers afford, i.e. 3D printers that read 3D pixels (voxels) as physical materials, the material oxymoron becomes process of producing artefacts, which challenge the subject of materiality in its general terms. Through the material oxymoron process, we have the capability of imaging new kinds of things, voxel 3D printers offer us the possibility to combine different kinds of material and colours in the same print. We entered the composite thinking age, where complexity is the continuous thread that constitutes the entropic order of hybrid society. New artefacts may be material sensations generated in the hybrid world. This has ramifications for what it means to be a thing and how they are understood.

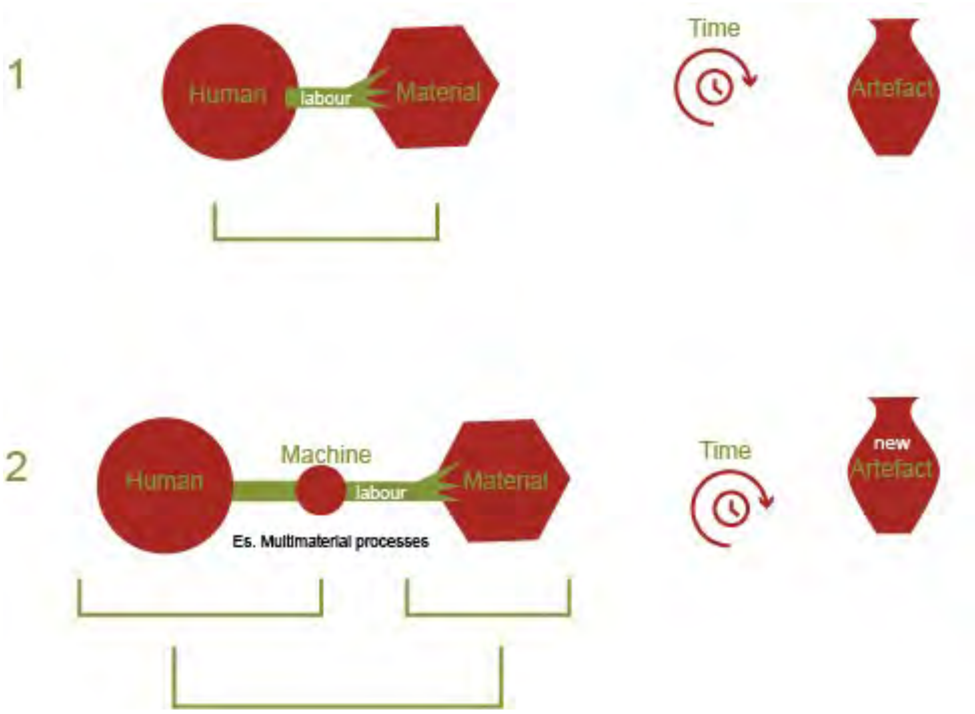

Fig 5. 1. The process of traditional artefact creation; 2. The process of new artefact creation employing extended mind and body in hybrid-reality.

Sensation world

Fig 6. 3D scanned apple sculpted in ZBrush. Materials and colouration are painted on the original pattern. Through ZBrush the apple transforms its own materiality.

Since the origin of civilised society, the intricacy of matter represents the ontological meaning, and substance, of the physical world. Recent studies, like the acoustic perception of touch explored by the University of Bristol, or the whole studies on robotics that look at haptic technologies as a link between the virtual and the physical world, offer pictures of the current direction that seeks an equal ontological approach for the virtual world. Virtual reality is no longer an external part of the self. It belongs to our vision of the real, the physical and the digital, as part of human experience.

This paper described how the poiesis of new things, or artefacts, can extend the "physicality" of real world, rather than projecting its perceived simulated quality in the digital realm. The material oxymoron is a process that aims to extend human sensorial perception of the surrounding via materials in the act of design. It wants to move from ephemerality in virtual space, to become real once 3D printed. The material oxymoron process transforms materiality from the physical to the digital and back to the physical. By targeting human relations with things, by means of the hybrid artefact, we intend to challenge the macro structure of materials via physical components, and the human sensorial act of modelling. Because we are capable of imaging materials that resemble physical properties with synthetic qualities, the human tangible experience becomes the looping engagement with things. Contemporary society is a permanent flux of events, which assembles and disassembles its components in real time. With the material oxymoron, we provide society of its own matter, which is capable of performing in hybrid reality the act of transformation, for creating, new substance via human senses.

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Service prototyping and organizational transformation: playing with the potential problems and solutions

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Abstract

The purpose of this paper is to explore small-scale service prototyping as a tool and a process for developing and implementing service concepts and initiating transformation in the involved public service organization(s) simultaneously. The paper describes a municipality initiated service design case and reflects on the prototyping process and findings. The paper focuses on the use of service prototyping in developing 'social emergency' services for families with children. The case illustrates how service prototyping and tangible prototype may establish a connection between front-stage and back-stage transformation both at operational and strategic levels. The findings explicate how the collaborative service prototyping joined various stakeholders to the process of problem-solution co-evolution by providing a shared tangible objective for their collaboration.

Keywords

service design; prototyping; organizational change

Service design is increasingly in the core of today's public service development, as the citizen-driven co-creation has become essential ability in public organizations. However, citizen-centric co-creation is not only about developing solutions, but also about helping to frame design problems. Enabling the co-evolution of design problem and solution is also important in order to enhance organizational transformation. Design tools such as prototyping make intangible future possibilities more tangible and concrete. The idea of prototyping as an activity for incrementally implementing a solution while developing is not new as such. However, service design research has focused on studying prototyping in the context of service development rather than as a means for organizational transformation and service implementation. The problem and solution space has been understood as intertwined and co-evolving during the design process (e.g. Dorst & Cross, 2001; Holmlid, Mattelmäki, Sleeswijk Visser, & Vaajakallio, 2015; Wiltschnig, Christensen, & Ball, 2013). This understanding is closely linked with the notion of concretizing abstract ideas not only in forms of visualizations but with tangible service prototypes. However, although exceptions exist (e.g. Coughlan et al, 2007) design research has focused mainly on co-evolving design problem solution space in the work of distinct designer before the implementation and organizational transformation phase. Without broadening this this view to address a collaborative perspective, the majority of collaborative prototyping activities and their influences on the involved organizations would remain hidden (Wiltschnig et al., 2013).

Service development is not usually done by one designer, but by a group of stakeholders in projects in which co-design gatherings and prototyping are typical. However, these co-design efforts and prototyping processes may gradually lead to changes in the organizations, which underline recognizing their importance. The studies on co-design and co-creation have pointed out that the collaboration during the co-creation practices may be as important as the actual end results of the gatherings (e.g. Holmlid et al., 2015; Mattelmäki

& Sleeswjik Visser, 2011). While the co-design approach to service development has enabled the involvement of different stakeholders within and between organizations, the impact of the involvement to organizational transformation needs more attention. An example of this is the notion that even though the systemic perspective in the service concept implementation is discussed in the context of service design, the development of the front-stage still dominates both service design studies and practical efforts. In this paper the front-stage implies the part of the service that is visible to a customer (e.g. website) and the backstage denotes the activities behind the scenes that enable front-stage activities to take place (e.g. systems and processes). Furthermore, the interest in the phases after the service concept ideation has increased, but research on the implementation phase and, in particular, the required organizational transformation in the context of public services there has been only few service design researchers that have paid attention to (see e.g. Lin et al, 2011).

This perception has encouraged research into the co-evolving public services and organizations, not only citizen-centric front-stage processes. The emergence of the interest in organizational transformation does not mean devaluing the need for citizen-centricity. On the contrary, the objective is to merge the citizen-centred service design activities with the organizational transformation. This paper focuses on the prototyping as a way to combine these two points of views. Prototyping as part of service design is an exploration through design doing, and contrasts the currently dominant design thinking approach (e.g. Deserti & Rizzo, 2014b). However, the supporters of design doing and prototyping (e.g. Blomkvist & Holmlid, 2011) have focused more on the customer-interface development than on organizational transformation.

This paper aims to explore the problem-solution co-evolution by examining a collaborative small-scale service prototyping process and its implications in a large public organization. By small scale we mean situated experiment within specific context and focusing on prototyping a minimum viable service. The study examines a real-world design project and data that was created and collected during collaborative service design and prototyping occasions. The aim of the study is to identify and understand the co-evolution episodes that arise while prototyping service and transforming the organization that provides the service simultaneously. A particular objective of this study is to understand the possibilities and challenges of using tangible prototypes in design process as a means for transforming the operational and strategic levels of the organization(s) involved in the prototyping processes. It also aims to track in more detail the aspects of the co-evolution process in the public-organization based service design context, by looking at the prototype as the shared objective of various stakeholders. The paper is structured as follows: It starts by reviewing the present discussions of the relationships between public services and organization(s) providing them, and summarizes the ways in which design process and techniques, especially prototyping may influence the organization(s). It then demonstrates these with an example case and finally, discusses the contribution of the findings to theory and practice of service design and tangible service prototyping.

Design for public services, organizations and the role of service prototyping

Design for public services have gained attention in recent years (e.g. Bason, 2010; Deserti & Rizzo, 2014a). However, the focus of design efforts is often on ideating service offering and not so much on the implementation and the required organizational change in close connection with the practical design activities such as prototyping. Thus there is a need for approaches that bridge up the front-stage service ideation to back-stage change processes. Service prototyping can be seen as one of such potential approaches. The perspectives on the relationships between public services, organizational change and prototyping are summarized next.

Transforming public services and organisations through service prototyping

Several authors have recently indicated the importance of seeking for new approaches to develop more citizen-centred, efficient, effective, accessible and cost-effective public services (e.g. Bason, 2010; Deserti & Rizzo, 2014a). Many of these service design efforts concentrate on developing the customer interface and service offering more than on the change in the organizations providing the services. The downside is that f the change management and the internalization and integration of new development practices is neglected, service design might result to have only decorative role (e.g. Deserti & Rizzo, 2014a; Junginger, 2013). Without effective development approaches service development may remain at abstract level of discussing and planning, gathering and analyzing information and trying to express and accommodate different stakeholders' conflicting points of view and making unsatisfyingly subtle progress (Coughlan, Fulton Suri, & Canales, 2007). Hence, more tangible and future oriented approaches are needed to support the development.

Junginger and Sangiorgi (2009) reflect on the potential of service design to generate and implement internal changes within an organization. They suggest that successful and sustainable new services, that aim for lasting transformations, require reflective inquiries into organizational systems (Junginger & Sangiorgi, 2009). However, design efforts typically create conflicts between the new and the established way of operating. Deserti and Rizzo (2014b) see the contradictions created by design as the sources of change in all situations in which innovation overcomes the constraints to its own development by generating new artefacts, knowledge, beliefs, processes, structures and technologies that become part of the organisation by modifying it. According to them the constant tension between the development of new products and the organizational attitudes of preservation and resistance to change builds a significant link between design and the problem of managing organizational change (Deserti & Rizzo, 2014b).

Prototyping has been considered fundamental in the design literature. Prototyping involves moving from the abstract ideas, analysis, theories, plans, and specifications to the concrete tangible, and experiential things and thus it is in core how designers work (Coughlan et al., 2007, p. 3). The creation of tangible expressions of ideas enable organizational thinking to develop in a concrete way through actions; making things tangible allows small, low-impact failures to occur early, resulting in faster organizational learning (Coughlan et al., 2007, p. 6). The prototype encourages new behaviours, relieving individuals of the responsibility to consciously change what they do. Service prototyping can have different objectives. In service design prototype may refer to different kinds of re-presentations of the imagined end results created during different phases of the design process (e.g. Blomkvist & Holmlid, 2011). Prototypes, and prototyping are vehicles for learning about and sorting out details of a service concept, process or system (Holmlid et al., 2015, p. 563; Säde, 2001) and different level prototypes can be used at any stage in the design process to explore, evolve, and/or communicate ideas (Coughlan et al., 2007, p. 3).

Collaborative service prototyping - co-evolving service and organization

Prototyping and tangible prototypes are tools for collaboratively exploring and communicating the design problems and solutions. Identifying the design problem and finding the solution are often described to 'co-evolve' in a mutually adaptive manner during collaborative design explorations (e.g. Dorst & Cross, 2001; Wiltschnig et al., 2013, p. 515). These explorations include making sense of the current systems, experiences, solutions and practices and at the same time seeking insights for future ideas (Holmlid et al., 2015, p. 546). Furthermore, the findings of Wiltschnig et al. (2013) support the view of co-evolution as the 'engine' of creativity in collaborative design.

The prototyping process also aims to help the stakeholders to express themselves. Co-designed prototypes create a shared understanding as the process of prototyping help the stakeholders to move beyond talking and thinking about problems to actually making progress toward solutions. Prototyping as a design synthesis tool represents commitment to a new future in contrast to often seen prolonged analysis of existing or historical practices (Coughlan et al., 2007, p. 11). Thus, prototype can be seen as a tool for starting conversation and creating mutual vision. Eck (2015, p. 2) argues “that design models or representations are first and foremost ‘vehicles’ to procure (counterfactual) understanding of to-be-build artefacts in terms of offering answers to what-if-things-had-been-different questions, and means for knowledge generalization and unification”. According to him prototypes generate design knowledge by using abstraction, and by invoking idealizations or deliberate distortions. Prototyping enable involved actors to create hypothesis of what happens if the prototyped idea is implemented and explore what the solution imply for them and their way of doing things.

Prototyping can be used for collaboratively exploring and communicating the design problems and solutions. The prototyping process and the activities of creating, testing and refining the prototype are as important as the prototype itself (Coughlan et al., 2007, p. 11). According to Deserti and Rizzo (2014a, p. 93) introducing the participatory construction and the prototyping of new services at a small scale trigger a process of change in the public institutions. In addition they give following three examples of the effects of small-scale experimentation: 1) change is connected to the competences of the organization by situating experiments within specific context and culture, 2) employees are engaged to change by involving them in the development of the new solutions, 3) change strategies become more dynamic and adaptive by constantly informing and assessing them through the results of the ongoing experimentation (Deserti & Rizzo, 2014a, p. 93). Prototyping synthesises problems and solutions and can help stakeholders to move forward collaboratively creating the future. It is activity for indicating progress, overcoming the fear of making mistakes, changing way of doing things not just conversation. However, prototyping requires time and resources and sometimes it is difficult to involve needed stakeholders.

Transformative service development projects may utilize prototyping in many ways throughout the process. It can be used for example for understanding existing experiences, exploring design ideas and in communicating design concepts (Buchenau & Fulton Suri, 2000). Prototyping process and tangible prototypes help to share the service idea across and between organizations. Furthermore, employing prototyping enables different levels of the organizational hierarchy to collaborate equally regardless the backgrounds of different stakeholders involved. As the previous section illustrates, the design and prototyping processes can be seen as inquiries to organizations and as an instruments for organizational change (Deserti & Rizzo, 2014b; Junginger, 2008). Through small scale prototypes organizations may evaluate the transformation before large-scale implementation. In the next section ee will introduce a case example of a small-scale service prototyping process and its implications in a large-scale public organization.

Prototyping transformation in practice

This section describes a design case from the Finnish public sector to illustrate the role of prototyping in co-evolving service development and organizational transformation process. The case comes from a large city in the metropolitan area of Finland. In the following we will first investigate the themes presented above and highlight the roles of prototyping and the prototype in co-evolution of the problem and solution. Second, we present the case and the preliminary findings. Finally, we summarize the outcomes as ways how service prototyping helped to explore and communicate the problem and solution spaces and enabled them to co-evolve.

Invisibility of the co-evolution of the problem and solution as an analytical challenge

Public organizations tend to be slow to transform because of their hierarchic and bureaucratic structures and processes. In the development processes more attention is directed to development of front-stage processes that are easier to approach, although the problems and solutions are strongly embedded in the organizational structures. Even during the development process itself the back-stage changes are often neglected. The process may lack concrete and tangible ways to explore and communicate the necessary changes in the organization and the resources needed to implement them. In order to study the role of prototyping in exploring and communicating these challenges, we will in the following introduce an example of a design prototyping case. In the case description the review on literature serve as analytical means to illustrate the potentials of service prototyping and the tangible prototypes in developing services and simultaneously changing the involved organizations.

Data and the research process

The example design case took place in a municipal service organization that provides services for families with children. The aim of the design process was to develop a service for a low barrier, easy access support in case of social emergency. Especially communication and information sharing were defined as problem areas during the inquiry and concept design phases of the design process. Therefore, the preliminary focus of the prototyping was in developing way for the families to easily find relevant and easy to understand information about the service and contact and communicate with the frontlines providing the service. The role of the first author of this paper was twofold during the design process: she acted both as a designer and a researcher. The data was collected during and after the actual prototyping process from 2012 to 2015. The data consist of documents (e.g. design illustrations such as service journey visualizations, stakeholder maps and prototype sketches) produced during the design process as well as documents related to the communication between different stakeholders (e.g. meeting memos, photos and other written documents). Also, the other related documents, such as project reports, strategy papers and media texts, were collected during and after the prototyping process. These were mainly used as background materials for the design process and also for understanding the influences of the prototype after the actual prototyping process.

The design case included both the exploration and communication point of view of prototyping, i.e., what had been done in the particular phase of prototyping, and what kind of role these actions had in the exploration and communication of the design problem and/or solution. However, it is important to note that in this design case the prototype was also used for other purpose than developing the services for families with children per se. It was also used as a tool for communicating more general problem and solution spaces in operational and strategic levels of the organization and the city. Accordingly, we aimed at examining and interpreting the service prototyping in public organization as way to explore and communicate the problem and solutions spaces at these levels and enable them to co-evolve.

The reflection and analysis process consisted of three iterative rounds. First, as one of the authors acted in the case both as the designer and the researcher, she reconstructed the design process into a descriptive narrative. Then, we divided the process into three phases, namely inquiry and concept design, prototyping and follow-up (Figure 1).

2012	11/2012-1/2013	2013-2015
Inquiry and concept design	Prototyping	Follow-up
Background study Collecting user insight Analyzing and visualizing the insights (design drivers, customer journeys, stakeholder maps, scenarios) Concept design Choosing the concept for prototyping and suggesting prototyping as way to proceed	Decision to do the prototype Finding an external design agency to help with the prototyping Iterative prototyping process (sketches, paper prototypes, wireframes, interactive mock-up, provocative minimum viable web service) Evaluating and developing the prototypes with customers and employees between iterations	Project planning to continue prototyping Presenting the prototype for different stakeholders and audiences and using it for educational purposes
	Prototyping as an **exploration process** Prototype as a **communication tool**	Prototype as **communication tool** and **enabler for further exploration** and contextualization of the problem/solution areas
	Changes inside the involved units and mindsets of the people	**Using the prototype in different contexts as way to communicate the more general problem areas and potential solutions**
	Operational level in the context of units involved **Strategic level implications**	**Strategic level implications** **Operational level implication in different contexts**

Figure 1. Design and prototyping process

The implications in service and organization in prototyping and follow-up phases were investigated and considered in more detail (as shown in the Figure 2). This was done by going through and analyzing the design documents created during the prototyping and documents related to the further use of the prototype. The aim was to reconstruct and reflect the prototyping process and explore how (and if) different phases of the process influenced the elements of the involved organization(s). However, as this paper is our first attempt to reconstruct and reflect the collective impact of the prototyping and the prototype, more detailed follow-up data and analysis is still needed to track the long-term transformative implication to the involved units and organization(s). Furthermore, most of the documents used for this study were collected and analyzed in order to serve insights necessary to design a minimum viable service, thus for example, interviews and observations during the design process were not documented for the research purpose.

Remarks on the design and prototyping process

In this section we present the preliminary findings of the analysis by demonstrating how the prototyping process and the prototype unveiled challenges and solutions. In the analysis two ways of prototyping to influence the service and organization were identified:

1. Communicating the design problem and solution at strategic level
2. Exploring the design problem and solution at operational level

Both of these perspectives are depicted below in the Figure 2.and later in this paper in the Figure 3. The findings suggest that the co-evolution of these was critical especially from the organizational transformation point of view. Insights listed in the figures 2 and 3 were mostly well known within the organization. However, the prototype and prototyping unveiled the connections between them and furthermore shifted the orientation from the reactive problem space to the proactive solution space.

Communicate	Problem		Solution
Strategic	Organization driven way of developing and providing services		More citizen-centric perspective Low barrier, accessible
	Prejudices, image of the service, accessibility, price		Prototype as a way to share user-insights and make abstract service ideas tangible
	Resource intensive corrective service	Co-evolve	Preventive service
	Co-evolve		Co-evolve
Operational	User-study reports, general and abstract insights		User-insights, internalizing and integrating
	Focus on corrective services		Shift to preventative focus
	Inefficient use of resources, coordinating, reporting etc.		More time for serving the customer
	Out-dated tools and processes	Co-evolve	Tools for supporting mobile work

Explore	Problem		Solution
Strategic	Relationship between the strategic and operational levels		Tools for supporting the co-evolution of the strategic and operational levels, questioning the strategy, using design as inquiry to the organization
			New practices, questioning assumptions, beliefs
	Established practices, assumptions, beliefs, self-created rules		
	Focus on front-stage		Back-stage, reconfiguring the processes to enable the front stage changes
	Focus on the change of the offering		Change of the offering requires changes in the organization
			Involve people, motivation to change
	Resistance to change		Learning and doing, involving and expressing
	Discussing and thinking		Implementing, small scale experiments
	Planning what to implement		Shared understanding
	Fragmented discussions		Activities and attitudes involved to the process of creating
	Focus on the end result		
			Effective and constructive commitment to future opportunities
	Analysing existing tensions and problems		Collaboratively creating the future, progressing
			Small scale errors and learning
	Repeating the problems		
	Ready plan and implementing	Co-evolve	
	Co-evolve		Co-evolve
Operational	User-insights		Engage people to transforming their own practices and tools, developing new tools and processes
	Exiting tools and processes		
			What kind of tools & processes are needed?
	What is wrong with the current tools & processes?	Co-evolve	

Figure 2. Prototype was used as a learning tool for exploring and communicating the strategic and operational problem and solution spaces and tensions between them

Emergency service for families with children: problem and solution co-evolution through prototyping

The focus of the prototyping was in information sharing and communication. Thus, the prototype took a shape of a website supporting multichannel customer journey of a parent starting from recognizing the need for help, to self-evaluating the need, and finally contacting the service provider. The prototyping process consisted of iterative rounds of first sketching the potential functionalities based on collected customer and employee insights and co-creation workshop, then creating a paper prototype, more detailed wireframes and initially an interactive prototype and a single web site providing emergency contact information. The Figure 2 shows how the prototype was used collaboratively for communicating and exploring the design problem(s) and solution(s).

The prototyping process included paper prototypes and simulations. When reflecting on the prototype different problems and solutions were highlighted by different stakeholders. For example, by materializing a simple idea of providing an online distress tests for parents explored the following problems and solutions: 1) from the child clinic nurse's perspective the test provided more holistic multichannel customer journey by using an electronic form for collecting information that is usually asked at the child clinic. This saves nurse’s time for more value added face-to-face discussion with the parent, 2) from the parent's perspective the results of the test enable parents to see their own position in the context of other people in the similar situation, 3) from the management perspective getting timely information about citizens’ service needs enhance efficient resource allocation, 4) from the childcare perspective by supporting parents to easily acknowledge the need for help as early as possible prevents problems to escalate. Based on the communications, the tangible prototype seemed to shed light into these perspectives.

Based on these comments it seems that the materialization of an intangible service idea was critical when the aim was to enhance the organizational transformation across expertise and functional units. Already from the first paper prototypes to more developed versions of the interactive prototype served as a tool for sharing narratives of different situations encountered by frontline employees and customers. In addition, the prototype provided a trigger to reflect the vision and strategy of the service organization and the city.

The already existing web site was structured to follow organizational structures and hierarchies, and citizens complained that it was really difficult to find the employees’ contact information and if they were able to find the information there were limited office hours for receiving calls. The prototype, in contrast, questioned this as a manifestation of the organization-centred way of thinking and providing the service. One particular element of the prototype offered direct contact information of local employees in charge of providing the emergency service. In addition, it provoked different levels of organization to think how the background processes ought to change in a way that the organization would be able to provide the emergency help 24/7. As such the prototype questioned also the existing strategy of the organization. Furthermore, by questioning the back stage processes it also pointed out the need for new ways of using the resources.

The prototyping process illustrated that it is not possible to do even small scale changes to the front stage operations without re-arranging the back stage processes and resources. The shared learning that took place in the prototyping meetings and later in different meetings where the prototyping process and the prototype were used as examples of successful service design experiments done in the city, invited the frontline employees and managers to re-think the purpose, processes and resources related to the service. Collaborative prototyping process was not only about communicating the service idea but step towards facilitating collaboration and change. In many ways the prototype acted as resource for reflection and action. For example, the process resulted in discussions of the tools that the employees were using and the processes and how the work was coordinated. It was highlighted by designers that as the coordination was based on traditional paper calendars it was difficult for the team leaders to handle where the employees were during the day and who was able to respond in the case of emergency. In addition without proper tools for supporting the mobile work the employees had to report each customer visit at the teams office. Because of this, some of the employees’ time was wasted for travelling between office and customers. These kinds of insights about the back stage processes were also made visible through the prototype that forced the management to examine the processes that hindered the 24/7 service provision.

Summary of the co-evolving service and organization in the phase of prototyping

Collaborative service prototyping as such has not been addressed much in the context of public sector services and organizational transformation. Figure 3 illustrates the small-scale service prototyping as a tool and a process for exploring and implementing service concept and organizational transformation.

The experiences of the example above illustrate first, that prototyping establishes a connection between front-stage and back-stage transformation. This connection is crucial when aiming at sustainable implementation of the service design outcomes.

	Operational		Strategic
Front stage	Need for easy access, low barrier 24/7 emergency help to prevent problems to escalate	Co-evolve	Shift from corrective to preventive service stated in the strategy
	Co-evolve		Co-evolve
Back stage	Processes and resources for providing 24/7 service	Co-evolve	Local interpretation of the strategy and distribution of the resources

Figure 3. Example of co-evolution perspective in case of social emergency service prototype

Second, the prototype connects the co-evolving design problem and solution both at operational and strategic levels. At operational level the design problem and the solution are contextualized through re-presentations of different elements of the service. Furthermore these tangible re-presentations act as concrete examples of the more abstract strategies.

Third, collaborative service prototyping combines various stakeholders to this process of co-evolution by giving a common tangible objective for their collaboration. The small-scale experimentation enables stakeholders that are usually not taking part in the development efforts, to share their insights and explore problem and solution spaces in their own context.

Conclusion

The motivation for the study originated from an observation that even though the systemic perspective in the service concept implementation is discussed in the context of service design, front-stage and customer-centric part of the development still dominate both service design studies and practical efforts. Although the interest in the phases after the service concept development has increased, research on the implementation phase and, in particular, the required organizational transformation has not yet attracted much attention among service design researchers.

In this paper, we introduced and analyzed the small-scale service prototyping case as an enabler of organizational transformation by reviewing existing literature and reflecting on the experiences and collected data in design case. This study suggests that small-scale service prototyping may be a tool and a process for exploring and implementing service concept and organizational transformation.

The benefits of the collaborative prototyping approach as illustrated can be summed as follows: the prototyping process is a platform for collaborative exploration of the problem and solution spaces. The example shows that materializing the intangible idea was critical in enabling the reflection and initiative of potential organizational transformation. In the example it was found that prototyping process and even a small-scale prototype itself have implications to all levels (from operational to strategic) of the organization(s) involved in the prototyping. Furthermore, the example indicates that the successful implementation of the results of development projects require that the organizational transformation is facilitated simultaneously with the service development. This transformation should take into account all organizational levels from operational to strategic.

This approach can offer several contributions. First, prototyping establishes a connection between front-stage and back-stage transformation, both of which can be placed at the centre of service design debates addressing the implementation of the service design outcomes. Second, the prototype links collaboratively the co-evolving of design problem and solution. Third, we applied service prototyping in context of public sector services and organizations, which is also a little studied context in organizational transformation.

Earlier research addressing service design processes have typically either focused on front-stage service development or early phases of the service development (Deserti & Rizzo, 2014a). Our study implicated, on the contrary, the significance of design doing throughout the process. Prototyping is foremost doing intangible ideas concrete and tangible. From practice point of view, prototyping can be considered as an alternative for intangible concept design. Our case indicates that prototyping does initiate organizational changes. The prototyping process enables testing the future opportunities by providing the participants not only an idea of service but tangible shared object. The prototype supports different stakeholders to explore and interpret the future in shared way.

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Illuminativa – The Resonance of the Unseen

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Abstract

This paper outlines some key considerations of my current creative arts doctoral thesis. The practice-led research investigates the metaphysical notion of light as an activating principle and how this is subjectively experienced. It re-contextualizes the illuminative process within creative arts, synthesizing its sensate implications with contemporary expression. Philosophically, the research is founded upon the medieval concept that illumination is a key transformational element of our cognitive journey – a process that begins with a sensory experience and leads through philosophical thought to wisdom.

Making and perceiving are both the essence and the framework of the research experiments. Light is explored as material; a form that is interactive yet ephemeral, providing disclosure and stimulus. It is also the research tool; the currency to capture, develop and articulate the subjective discoveries. Protean conjunctions of texture and light are arranged and evaluated as attempts to apprehend the vestiges of the unseen.

Beyond generating and documenting immersive material arrangements, practice is also employed to communicate insights. Transient installations are orchestrated as a non-verbal narrative and seek to embody the viewer within the works themselves. In doing so, my intent is to share a tacit understanding for the deliquescent relationship between embodied light and the conscious self.

The resulting discussion raises questions in relation to our appreciation of light and its agency, transcending a strictly utilitarian dimension. The broader aim of this paper is to expand the denotation of illumination and encourage a reconsideration of creative consciousness in contemporary design practice.

Keywords

light, cognition; embodiment; experience; illumination; research; creative arts

As digitized media continues to replace print, light has arguably become a vehicle of significance. Light is accepted as a common adjunct to our large and small screens; thus mediating the communication and dissemination of our design outputs in this “era of audio-visual dominance” (Groth, Mäkelä and Seitamaa-Hakkarainen, 2013, p. 2). Yet, I argue, the agency of light may be of much more value than that of a technical requisite, particularly in aspects of experienced cognition.

Universally, light seems dependable. It informs sight, which informs understanding. A distinct and common validation of our reality is what we can see. Through light we are engaged in a continuous exchange with our surroundings, immediate or (as in the case of digital devices) remote. Generally unquestioned, light holds the ability to facilitate, enable and influence our perception. As the light artist James Turrell indicates: “we live within this reality we create, and we are quite unaware of how we create the reality” (Govin, n.d., para 6). Light can illuminate or obscure, and is by its very nature intangible and ephemeral (Pleij, 2002). It is capricious, yet we trust it.

Historically, light has been understood as a force that bridges the visible and the abstract, with properties extending beyond radiance. Interpreted as the origin of wisdom and ontological truth, light in medieval traditions was associated with clarity through divine providence and the illumination of the human mind. The concept of light as a fount of knowledge was passed down from Babylonian through early Greek to Christian philosophers. It was continually adapted to become an essential axiom in spirituality, reflecting the human–divine nexus (McAdams, 1991). In the 5th Century, Augustine of Hippo described an explicit metaphorical journey as a form of spiritual redemption. Light, he suggested, radiates from the Divine as a life force and produces a path that can be followed. This affective movement would take humans from the exterior world to the interior mind and from there deliver them to the superior mind of the Divine (McAdams, 1991; Noone & Houser, 2005).

Of particular interest here is the work of Saint Bonaventure, an influential 13th Century Franciscan and scholarly philosopher. He was known as the Seraphic Doctor, possessing the insightful ability to balance the intellectual and affective life (Ozment, 1981). Bonaventure expanded the Augustinian concept of enlightenment and integrated his own cognitive theories (Stewart, 1987; Hayes, 1996; Schumacher, 2009). In his treatise *De Reductione Artium ad Theologiam* (On the Reduction of Arts to Theology), Bonaventure drew a distinct connection between manual craft and divine truth through light. He established an ascending hierarchy between the four realms of mechanical skill, sense perception, philosophical capacity and divine wisdom, proposing that guiding light falls through these realms. As this happens, a path is disclosed from each realm to the next higher one (Hayes, 1996; Miccoli, 2001). Thus, in Bonaventure's thinking, as we make and improve our practical understanding of the material world, we are illuminated through a sensory experience, which in turn may lead us to new thinking, generating fresh ideas and knowledge.

Although presented nearly 800 years ago with a clear theological telos, Bonaventure's writings have contemporary relevance. I remain, as De Botton writes, "…curious about the possibilities of importing certain of these ideas and practices into the secular realm" (2012, p. 12). If we can look beyond the theological barriers, we may discover plausible parallels to *De Reductione* in creative arts research.

Indeed, Bonaventure's theory of light is largely congruent with contemporary design writing. A number of authors suggest similarly that higher-order thinking and knowledge are gained through the process of making and sensing (Middleton, 2005; Sennett, 2008; Marzotto, 2009; Ings, 2013). These agencies form the basis of craft and creative practice, which play an ever-increasing role in visual arts research (Arnold, 2012; Ings, 2013; Nimkulrat, 2012). The iterative process of working through and with materiality, the deep engagement in the act of unconscious thinking through making, the integration of play and experimentation – these sedulous dynamics facilitate ideation, learning and understanding (Adamson, 2007; Crow, 2008; Pallasmaa, 2009; Schön, 1985). Although not uncontested, contemporary scholars recognize the validity of articulating practice as a developing dimension of knowledge (Arnold, 2012; Mäkelä, 2007; Niedderer, 2007; Scrivener, 2000).

Therefore, if the agencies of making, sensing and thinking are tenable research practices, it is worth exploring light as a capacity of their interconnectivity, as Bonaventure outlines. Regarding light beyond its metaphorical aspect, Bonaventure also delineates a seminal conjugation that connects the abstract with reality. He offers three metaphysical terms of perspective: "considered in itself the first form of all bodies, light is called *lux*. It emanates and thus informs corporeal beings. As it radiates back from these beings, it is called *lumen*. When this light is viewed as it becomes perceptible, it is called *color*" (Hayes, paraphrasing Bonaventure, 1996, p. 5). Thus, if there is a defined association between the metaphysical and the physical, might we investigate the tangible outcome to learn more about its genesis? Moreover, can we creatively explore the seen to discover more about the unseen?

Aim

Conceptually, light may be understood as a connective agent and a force, providing stimulus and purpose to cognitive potential (McAdams, 1991; Noone and Houser, 2005). If, as Bonaventure argues, lux is affective and stirs and informs me as I work, how might I experience this? It is around this notion that this project focuses its creative concerns and seeks to find a means of visual articulation.

Approach

Methodology

This practice-led enquiry represents “an effort to know the essence of some aspect of life through the internal pathways of the self” (Douglass & Moustakas, 1985, p. 39). As I work from the exterior inwards, the outcome of the enquiry is neither pre-determined nor certain. In this context of discovery, each new step is guided by past experience rather than an expectation of an end. Inescapably centered within the work is my conscious and sentient self, as both the participant and the researcher. Broad conceptual parameters are negotiated through a process of existential and reflective exploration, whereby I connect “knowledge, morality, beauty and everyday life” (Borgdorff, 2006, p. 21) to construct my own meaning (Ings, 2011; Griffiths, 2010; Pallasmaa, 2009; Peer, 2011).

The methodology most suitable for this form of subjective enquiry is heuristics; described as a journey guided by metacognitive knowing, self-learning and self-discovery (Schön, 1983). It requires a process of reflecting, exploring, sifting and elucidating the nature of the phenomena under investigation (Moustakas, 1990). Inherently iterative, diverse materials are brought together in anticipation of what might emerge (Ingolds, 2010). The findings may lead to reconsiderations of materials and/or direction, thus generating further findings (Douglass & Moustakas, 1985). In my research, the process was similar: I frequently exchanged and reorganised materials as a response to my reflection on previous arrangements. Thus I forged my own path, based on largely subjective factors. The inherent risk of this heuristic methodology is that my explorations or deductions might be superficial, incoherent, or self-referencing. Continuous exchange with supervisors and peers, however, ensures that the emphasis can be adjusted and the exploration rigorously and conscientiously managed. When applied prudently, the methodology of heuristics is most valuable because it allows me to engineer, orchestrate and modify my own approaches along a non-linear path of discovery.

Beyond all non-linear exploration, however, sits a strategic intent. One of my thesis’ main goals is to visually convey the findings to an audience, once a convincing personal mode of expression has been established. The practice thus becomes progressional: at its basis lies the experimentation with material arrangements of varying complexity. These experienced arrangements are documented through photography. Selected resulting images are then composed as a sequence, which in turn becomes the basis for an exhibition. This exhibition represents another form of material arrangement with further spatio-temporal implications that require the same depth of consideration as the original experiments. All stages of the practice are linked, yet without being predetermined.

Materials and Processes

An ongoing succession of studio-based experiments was conceived as a means of considering light’s dynamic properties. Because these properties reveal themselves through secondary materials, these mediators were investigated in a process of defining and refining arrangements. Through a diverse array of lighting and projection I studied how the agency of light interacts with material and texture through immersion, reflection, refraction, radiance and translucence.

To test texture, I employed medieval manual processes, such as gold-leaf and silver-leaf gilding, mirroring, sheet metal work and calligraphy. Experimenting and hybridizing, I combined and arranged these with a number of transparent, semi-transparent, glossy or smooth materials such as acrylic sheets, glass, mylar, sequins, lacquer and glaze. Finally, I integrated a variety of light sources. Candlelight, incandescent light bulbs, overhead projectors, strobes and light emitting diodes were utilized, sometimes indirectly or simultaneously, to dynamically influence and vary colour, intensity or reflective angle.

These combined arrangements were then explored photographically, in a process where I deliberately placed myself within the work, continuously shifting my position. My intent was to dialogue spontaneously and physically with and within these transitional concepts. I sought to negotiate the instability of the moment in order to facilitate a tacit experience. As I moved, my visual perception changed, and the emotive resonance with it. In doing so, a volume of documented ‘Momentaufnahmen’ (photographs of distinct spatio-temporal moments) was produced (Figure 1).

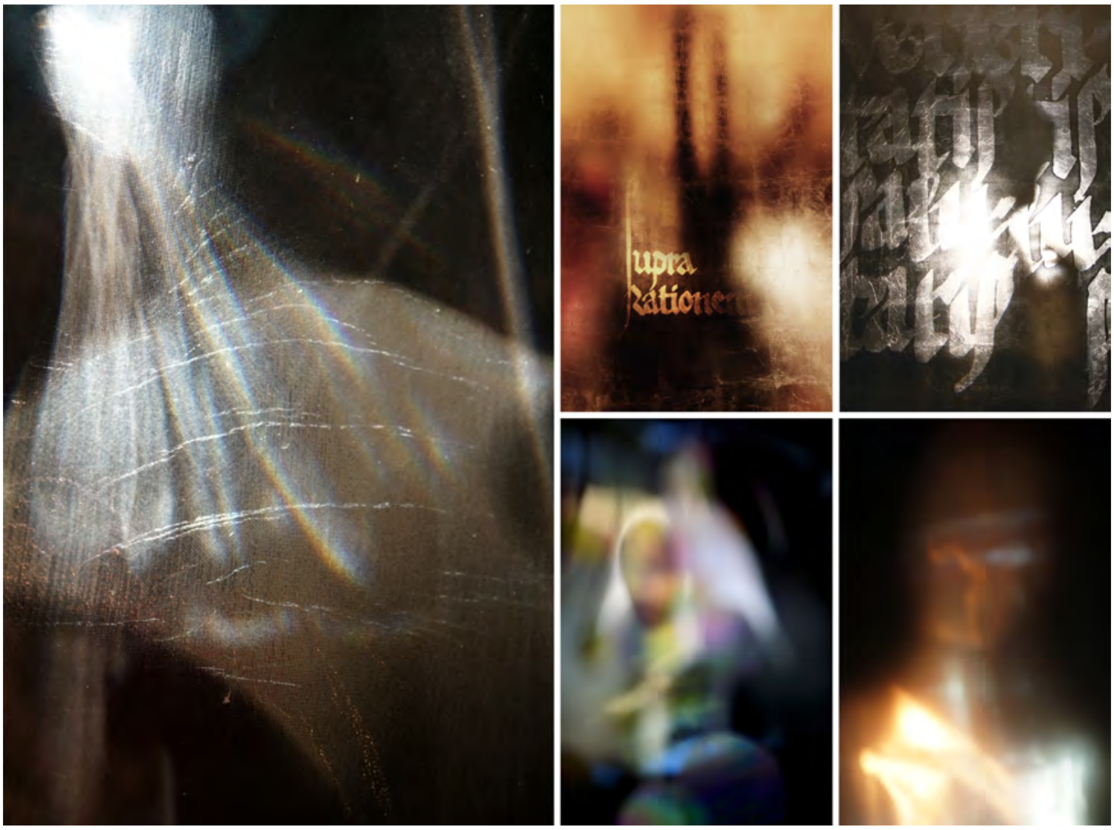

Figure 1. Five examples of ‘Momentaufnahmen’ (June 2013 through February 2015).

Images were reviewed on a computer and a selection made based on their evocative quality. (It must be noted that the images were not digitally manipulated in any way, so their expression remained authentic, and faithful to what I had actually perceived.) This selection was then carefully ordered as a gradually unfolding sequence in video editing software and output as a Quicktime file for projection. Slow crossfades were applied between images, causing the tones to grow and retract in an ebb and flow of intensity, heightening the sense of impermanence.

Exhibitions

Exhibitions, although temporary, represent the opportunity to relate knowledge. As such they might be considered my actual artefacts (Scrivener, 2000). In the context of this thesis, the exhibitions are specifically designed vehicles that allow an audience to access and explore my research findings on a non-verbal level. My goal was to create an installation that exists with and through light, emphasizing its protean properties. In doing so, I also aimed to compile a narrative that would engage the audience viscerally, so they might understand my thinking through their own experience. To date, two preliminary test exhibitions have been staged, each different in tone. Audience reaction and subsequent feedback helped refine both the research question as well as the communicative focus of the work. A third exhibition is scheduled as the culmination of the thesis.

The intent of the first exhibition was to demonstrate the ephemeral nature of light, in its metaphysical definition as a catalyst of potential within the self. I sought to evoke a contemplative and introspective atmosphere that connected emotionally to the medieval Bonaventure. Three spatially discrete vertical cloth screens (1500 x 2400mm) were hung in an otherwise empty and windowless room, lit only by a single candle. Chorale music was softly played in the background, adding a sense of medieval serenity to the darkened space. Ten images were projected in succession at large scale onto the three screens. For this I used three projectors situated across the room inside a low-level housing. In seemingly arbitrary order the images slowly faded in and back out to black. The audience was invited to move around this installation, physically interacting with the projections and the space, casting shadows onto the screens, and becoming part of the fleeting imagery (Figure 2).

Figure 2. First exhibition (April, 2014)

Some key insights were gained from the first exhibition (and these helped shape the second). The sequencing and fading in and out gave the originally static imagery an evanescent quality. The overall sense of impermanence and fragility was emphasized, highlighting the mutable agency of light itself. The slow pace added an experienced rhythm akin to breathing, obliging the viewers to dwell in the space and contemplate without haste. In feedback, viewers stated that their physical experience was heightened by allowing them to move between and actively engage with the projections. Although most of the audience spoke of a common feeling of transcendent nature, I felt their material interaction could be improved.

Building on these insights, the intent of the second exhibition was to create a personal experience of light as lumen, informing and radiating through the self. A small room was erected (measuring approximately 2400mm square), which allowed only a singular visitor access at any given time. From the outside a sequence of 'Momentaufnahmen' was projected onto one entire wall, built from cloth as a translucent screen. The other walls and the floor of this cubicle were fastidiously covered in silver leaf, subtly reflecting the projected image sequence filtering into the cubicle, as well as the visitor in its midst. A latin quote from Bonaventure was also projected across one wall. Because of the direction of this projection, the words were barely visible as the viewer approached, but became increasingly brighter when viewed from the front of the room. Although the projection was constant and stationary, it urged the viewer to move within the space and explore how the relationship with light changed. Specially composed background music was played to enhance the meditative atmosphere. The resplendent space asked the viewers to dwell a while and consider their being within the light. (Figures 3 and 4).

A focus group was organized to provide more careful and focused deliberation than the more generalized feedback from exhibition one. This group was comprised of professional visual artists, theologian philosophers and experienced designers. The post-viewing discussion offered an intensive unpacking of strengths and weaknesses in the work, strategic questioning and reflections on potentials within this iteration of the research. The viewers acknowledged the immersive and intense emotive quality of the installation. They understood the experience as a means to be present in the moment and ponder the nature of light, yet wished it was altogether more concentrated. Some suggested removing the additional elements such as the projected type and the music to an antechamber. By simply letting the images flood the space without didactic support, they felt the experience could unfold in a more individual, embodied manner. All viewers felt different within the confines of the space, depending upon, as one viewer suggested, "what personal experiences we bring with us".

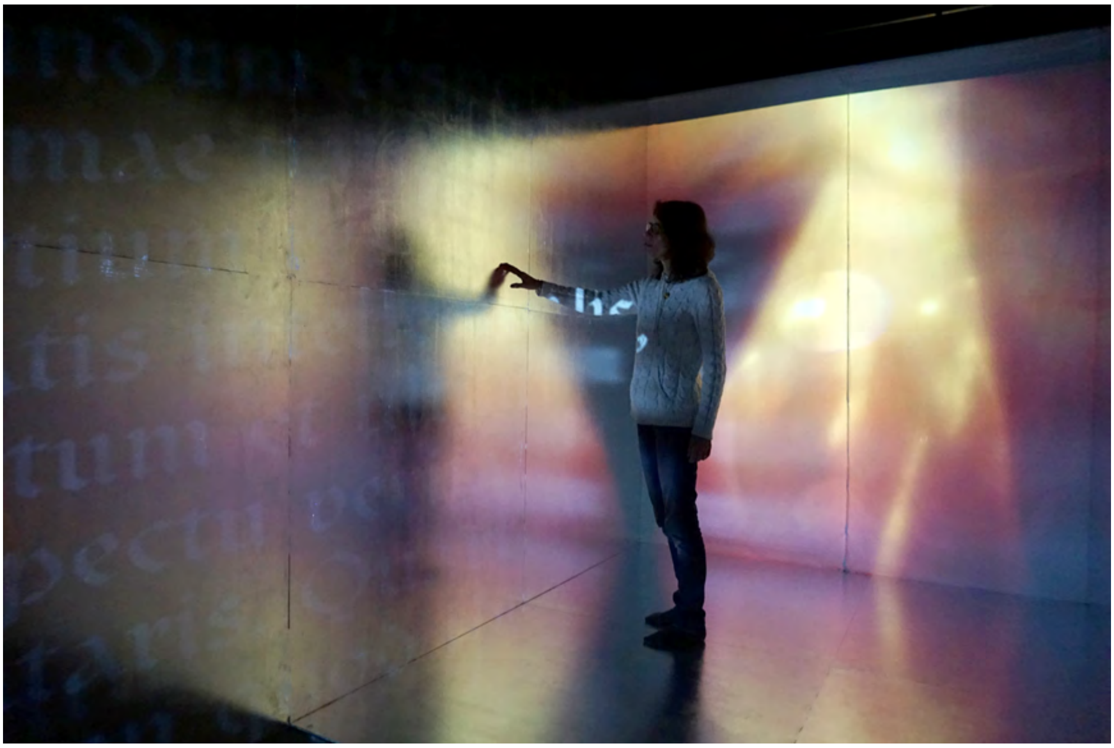

Figure 3. Second exhibition (October, 2015)

Figure 4. Second exhibition (October, 2015)

Concepts

Illumination

In contemporary writing, illumination is equaled to inspiration, and considered part of the creative process that gives rise to new ideas (Pallasmaa, 2009). Although commonly acknowledged in contemporary creative arts, descriptions of illumination remain indirect and obscure, without references to light as its basis. Sela-Smith (2007) summarises illumination as “that moment when there is a breakthrough in conscious awareness of wholes and clustered wholes that form into themes inherent in the question” (p. 67). “We make sense of the noise of the ‘infinite’ (Serres, 1995, p. 34) in what constitutes “the surprise of what is not yet possible in the history of the spaces in which we find ourselves” (Rajchman, 2000, p. 163). Accordingly, it is not the aim of this study to define the illuminative process, but rather to consider the experience through practice. The focus remains on the bearing of the self within this sensate and fragile aggregation.

During my experiments, breakthoughs in awareness occurred at various stages of working within the practice, precipitating new connections. Generally, these were not ideas or concepts but the not-yet-known: hunches and feelings that could not be articulated. However, some of these small shifts of disposition invariably rose to influence my thinking. For example, I had always assumed the agency of light to be a rigid force, intangible and therefore unaccommodating. However, similar to working with other materials, I realized I needed to consciously incorporate my own agency to shape and determine the experiments. Through my physical presence within the light, or manipulation of secondary materials, I could create arrangements with much greater authentic resonance. As the experiments progressed, I became more aware and attuned to my own emotive state, and was able to utilize this to create photographic artefacts that corresponded in their expression.

This process correlates to Bonaventure’s theory of illumination, in which he determines a cognitive journey from making (= mechanical skill) through sensing (= sense perception) and thinking (= philosophical capacity) to authoritative clarity (= divine wisdom) (Hayes, 1996; Miccoli, 2001; Stewart, 1987). As I reflected on the practice and these luminous moments, they indeed felt as if my consciousness was briefly expanding. In contrast to Bonaventure, however, I deduct that the relationship between making, sensing and thinking is not linear and causal, but interdependent. Each of these capabilities reaches into the other two, suggesting these junctures are fluid rather than discrete. Furthermore, each seemingly bears equal weight, thus it is their combined activity that establishes the process of insightful discovery. I contend that new insights occur in the intersection of this triangulation, rather than in a progression from one to the next.

Embodiment

Embodiment is of significance to this work because it describes the deep tacit engagement with sensory experiences. According to Pallasmaa, the body is “undervalued and neglected in its role as the very ground of embodied existence” (2009, p. 11). Since our bodies are permanently located and invested in the world, physical environments actively shape our experience and interactions (Merleau-Ponty, 2004; Nimkulrat, 2012). Conversely, we shape the attributes of our physical environments, because “all we see is seen in the perspective of our body and the history it embodies”(Tin, 2011, p. 224). In other words, we apprehend our world subjectively through our bodies, and this process is governed by our life experiences and memories.

This reciprocity of affect between the materiality of light and my embodied self plays a pivotal role in this thesis. Bonaventure asserts that light mediates between the soul and the body, or between spiritual and physical forms (Noone & Houser, 2005). Thus, searching for light inversely becomes a journey towards the inner self. As I work through my light arrangements in practice, the tacit and physical realms interact, stirring within me, provoking precepts and awakening memories. Fragments of embodied recollections and impressions well up to stimulate my thinking and shape my articulations.

Knowledge

Merleau-Ponty claims that some materials and their properties can only be understood in the context of our experience of them (Cerbone, 2002), and in this thesis I explore light as one of these materials. Thus, its affective meaning is established through an embodied experience. Consequently, the acquisition of knowledge is primarily sensate rather than intellectual. Similarly, Bonaventure asserts that knowledge originates from instinctive sensation (Miccoli, 2001), an apprehension that initially resonates with our instinctive, subconscious self. It is this approach that I take in this research, with the increasing tacit understanding leading the practice.

Experiential knowledge was obtained in two related areas. First, I sought an understanding of light's properties through a sensate experience. This might be comparable to acquiring a tacit language that I could later employ to express my considerations at an exhibition. Second, I sought to appreciate the bodily rather than mental apprehension of light, and the subsequent cognitive precipitation. A greater mindfulness of this connection and generative process might heighten my predisposition for illuminative resonance.

Over the course of this research, material experiments and arrangements changed and became increasingly complex. My experiential knowledge of light's properties (and of procedures to elicit and capture these) grew. I was able to reference the previously gained experience, and combine this with tacit knowledge to generate fresh paths of discovery. My repertoire expanded with my embodied understanding, and because of this, the resulting imagery became more meaningful.

As the research progressed, the ability to relevantly share my acquired tacit knowledge became a pertinent issue. Candy (n.d.) describes practice-led research as "research where some of the resulting knowledge is embodied in an artefact. Whilst the significance and content of that knowledge is described in words, a full understanding of it can only be obtained with reference to the artefact itself" (para 2). For an audience to understand my practice, an immersive exhibition was required that would also embody them in an experience with light. A transfer of knowledge to the audience could then occur through their sensate, not intellectual, perception. Yet this obliged me to acquire and apply a tacit understanding of the association between perception and the self. This understanding would be the key to developing an artefactual exhibition that would successfully engage the audience.

Discussion

Light is a resplendent yet fragile force that integrates our bodies into the world. As I have argued, it represents a unique material, one that becomes tangible only through embodiment. Light is atmospheric, thereby stirring me by its connection to my emotions. Perpetually active yet unpredictable, it continuously engages. Light works at me and through me, it involves and envelopes me, and I cannot remain indifferent to it. I live by light.

Generally we make little discrimination between light and perception.
Contemporary artists such as Mark Rothko, Robert Irwin, Bruce Nauman, Anthony McCall, Doug Wheeler and James Turrell utilize light to draw this issue to our attention. Often their projections or immersive environments are deliberately unsettling, obliging us to reexamine our sense of space and being. Their use of light allows us "to be present in the moment and experience our own existential place in the world" (Zara, 2014). Reviewing the number of young artists now taking an interest in the light element, Momin summarises "I hesitate to use the word 'spirituality' because it sounds too religious. But I think using light now is linked to the desire for transformation" (quoted in Sheets, 2007, para 19).

I do not see the idea of illumination as an anachronism. Instead I consider it a means of contemplating the nature and mystery of ideation in creative arts. Surmising about thinking in art, Rajchmann (2013) reflects that “ideas come after unexpected encounters with things that cannot be recognized in habitual ways” (p. 196). As Bonaventure contends, light works within us, deepening our sense of understanding, revealing truths that transcend reason (Stewart, 1987). Thus we make, develop and learn as embodied light transforms within us from the unseen to the seen, finally radiating in the vanguard of creative force.

Arguably, light might be the stimulus that nourishes and catalyses our creative articulation. If it connects and invigorates an exchange between making, tacit understanding and thought, then illumination might be interpreted as a state of heightened awareness, providential and immediate. Although an inherently unpredictable process, it provides, according to Bonaventure, clarity and certainty (Stewart, 1987). Illumination remains a tenet that is delicate yet grand, traversing notions of potentiality, immanence and consciousness. In general, I believe increasing our perception of internal processes, and our and sensitivity towards these, represents a long-term endeavour. It is here that a yearning for spirituality and greater contextual clarity arises. Bonaventure thus provides us with an intriguing junction between philosophy and theology, and (as I have described throughout this paper) with a framework for thought of surprisingly contemporary resonance.

Bonaventure suggests that light is the first form of all bodies, and its influence extends throughout the entire material universe. The varying participation of light is what differentiates all bodies. I understand this conjugation to be more philosophical than material. Considering this concept, scholars conclude that light is the principle of perfection in all corporeal beings, responsible for [revealing the divine in] beauty, colour and activity (Hayes, 1996; Miccoli, 2001; Pleij, 2002). Thus the scope for further practice-led research is considerable, as a contribution to creative arts culture and human experience (Nelson, 2004; Scrivener, 2000).

I understand my research as original creation undertaken in order to generate novel apprehension (Scrivener, 2002). It constitutes an invitation for designers to see beyond the commonplace and consider their own tacit experiences with and through the agency of light. My thesis advocates a reassessment of our understanding of creativity, a critical examination of our perception of reality, and greater engagement with the illuminative process (Duncan, 2004; Hayes, 1996; Scrivener, 2002; Sela-Smith, 2010). In the words of artist James Turrell: “the truth is, I want people to treasure light as we treasure gold and silver…” (Govan, n.d., para 16).

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Derek Ventling is currently completing his Art & Design PhD at AUT University in Auckland. After 20 years of experience as graphic designer and creative director in Switzerland and New Zealand, he recently turned to education and is enjoying a position as a secondary school Art & Design teacher. Holding degrees in science and philosophy, Derek is interested in exploring the intersection of perception and philosophy within the creative process.