DRS 2018 | Design as a catalyst for change

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Edited by:
Cristiano Storni
Keelin Leahy
Muireann McMahon
Erik Bohemia
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Proceedings of DRS 2018

Catalyst

Volume 4

Editors
Cristiano Storni, Keelin Leahy, Muireann McMahon
Peter Lloyd and Erik Bohemia

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Editorial

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DRS2018, hosted by the University of Limerick and the Limerick Institute of Technology is the first international biennial conference of the Design Research Society since the 50th anniversary conference in Brighton. This represented both a challenge and an opportunity; a challenge to meet the high standards set in 2016, but an opportunity to contribute to a growing design research field. The balance between these has translated into the conference theme of *Catalyst*. A catalyst is something that precipitates events; it is the coming together of different entities to generate something new; it is the spark for wider change. Framed by the Catalyst theme, these proceedings explore existing and emergent areas at the intersections of design research, practice, education and policy.

The conference itself built further on innovations from the past two conferences; developing more interactive conversation and debate formats, and providing a forum for practice-based research through the increasingly popular workshops. A *PhD by Design* day, first initiated at DRS2016, provided a platform for PhD researchers to learn new skills, present their work, and network with other researchers. The design of the conference, however, was largely formed around the managed theme tracks which included themes relating to the Special Interest Groups of the DRS. In some cases theme tracks emerged from conversations held at previous conferences, representing a pleasing continuity.

From the initial calls for participation there was a great deal of interest in the conference. Once again we had a truly international range of work presented and published in these proceedings. The original call for theme tracks yielded 46 proposals from which 24 were selected. These formed the backbone of the conference and of these proceedings. The theme tracks represent an increasing engagement with new technologies and data but also reflect contemporary social and political concerns, and the need for different types of design research voices to be heard. In particular, the programme committee were committed to bringing diverse global perspectives into play during the conference.

Following the call for theme tracks, the call for papers resulted in 470 submissions of which, after a rigorous peer-reviewing process, 218 (46%) were finally accepted for presentation and publication. This is a slightly decrease in the acceptance rate from the previous conference indicating a corresponding increase in the quality of the proceedings papers. Although some papers were submitted to an open call, the majority of papers were submitted to theme tracks, with each track being managed through the peer-review process by a track chair and all peer-review overseen by the Programme Committee. In total nearly 1000 paper reviews were written by 330 reviewers. The opportunity for authors to rate and comment on the reviews they received has further helped drive up the quality of peer review for future conferences.

DRS2018 reflects the coming together of many different perspectives and themes. As with previous conferences its design has been emergent, developing over the two years prior to the conference. It has been the result of many discussions and collaborations both within the Limerick team and the DRS more generally. The conference, and the proceedings that have resulted, are an extensive collaboration between many people but we would especially like to thank the local organising committee comprising members from the University of Limerick (UL), The Limerick School of Art and Design (LSAD) at the Limerick Institute of Technology, as well as members of other Irish academic institutions all of whom contributed valuable insight and experience. We'd also like to thank the track chairs who worked tirelessly and diligently to organise their tracks, and the reviewers who have ensured the high quality of the papers within those tracks.

Lastly but not least, we need to acknowledge the system that helped shape the way we worked together and made our decisions: the ConfTool conference management system. For the uninitiated ConfTool represents an awkward and mysterious interface. For the initiated it represents an indispensable way to manage the complexity of every stage of the conference process. In a way that echoes the conference theme, ConfTool has been a catalyst for our collective effort in bringing DRS2018 together.

In this sense *Design as a Catalys*t becomes a *thing*; a thing in the Heideggerian sense of a gathering of different entities coming together to deliberate on shared issues and reaffirming the role of DRS as a leading forum for discussing design research from multiple angles. But also a *thing* in the sense of something that escapes a specific definition, reflecting the impossibility and perhaps undesirability of a specific definition of what design research is, and should be.

With this sentiment in mind, we sincerely hope that these proceedings catalyse positive change and that the changes propagate to DRS2020 and beyond.

Go raibh maith agaibh,

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Volume 4

Section 12.

Designing with Data, Democratisation Through Data

Editorial: Designing with Data, Democratisation Through Data

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Economic production and distribution processes have become interconnected at an unprecedented rate and have spread across complex networks (Castells, 1996) simultaneously operating in a multiplicity of geographic, social, and cultural markets and contexts (Julien, 2007). This activated a variety of services build upon continuously flowing streams of data, which are gathered, interpreted and processed to provide an offering that is adapted and tailored to the (oftentimes presumed) needs and wants of customers.

On the one hand, this phenomenon touches upon sensitive and alarming areas such as how this massive amount of data allows for the tracking of individuals, groups and even objects at an unprecedented level of granularity (Ciuccarelli, Lupi & Simeone 2014), or how algorithms processing these huge quantities of data are increasingly regulating our lives (O'Neil, 2016). On the other hand, big (and, especially, open) data are seen as an instrument to better control important functions of our life and the inner dynamics of organizations and societies (Ratti & Claudel, 2016) which can be utilized to build more inclusive services and government processes (Townsend, 2013; Dove et al, 2014).

While keeping a critical eye on these emerging issues, data can also be considered a resource, which comes with a set of already configured practices, particularly if we refer to the technical procedures that allow any user to exploit it. It opens a promising role for design enabling social innovation through more participatory and bottom up approaches. These design practices could empower a community of users not limited to public authorities, large corporations or data experts. Indeed, there are few examples that demonstrate the use of data as a new resource for empowering citizens. Designing, however, means to enable citizens to harness opportunities coming from the use of this new resource, and offers a substantial promise for social innovation and democracy.

While analysing the reasons behind the current challenges faced by data, Kalampokis and colleagues pointed out that "gaining access to raw data, placing it into a meaningful context, and extracting valuable information is extremely difficult" (Kalampokis, 2013, p. 99).

In this DRS track 7 papers will explore from different perspectives challenges and opportunities offered by data in a design process.

The paper by Kun, Mulder and Kortuem on *Data Exploration for Generative Design Research* presents a method that facilitates a learning curve on gaining holistic data literacy, supporting a design approach where digital data, exploration and sense-making of data is part of the process.

Next, Ricci, Brilli and Tassi in their work entitled *Repurposing Digital Methods* for human centered design explore a specific usage of data in the design process, providing a first methodological tool created at the intersection of Digital Methods and Human-Centered Design: data driven personas.

Quinones as well, in his paper *Orienteering Design Through Data*: the data-driven design model, argues for integrating data into the design process to allow easy access to a huge quantity of ideas and information, supporting designers' creativity and innovativeness.

The challenges that data poses to designers are more complex than the ones that are simply related to transforming a dataset or capturing data through scraping online resources. Prendiville et al (2017) discuss the role of design in making sense of data through processes of translation, visualization and persuasion to turn the abstract and intangible nature of data into human-centred services with social and economic value. Furthermore, the authors claim that one of the critical aspects that should be addressed by designers concerns the transformation of data (something highly technical that we all produce every day, though allowing others exploit it) into something that can be understood and consumed by broader communities, possibly making the general public a proactive agent in data formation and use.

In this respect the paper by Chueng-Nainby and Lee on *Transformative Learning: Co-design with Communities' Collective Imagery as Data for Social Innovation* explores a co-design practice which aims to enact social innovation by connecting local communities' needs to global data networks. Low-fi physical tools are introduced to mediate a community shared imagery and a co-design framework within the systemic view of social innovation processes is then discussed at length.

Physical tools are also used in the paper *Data Sensification: Beyond Representation Modality, Toward Encoding Data in Experience* by Hogan, in which they present an emerging form of representation that encodes data in the behaviour, performance, affordances and resulting experience of a data representation, opening up to the new challenges we face with designing the data representations of the future.

When focusing on publicly available data, or open data, they can be regarded as a new commons (Ostrom, 1990; Bollier 2014), with new communities of users and new practices. The question of open data as a new commons (Morelli et al., 2017; Seravalli, 2014) is also currently under discussion in the design community at large. It raises questions to the next role of designers, such as infrastructuring and collaborating to a democratic use of data, even among the non-experts, and promoting practices of service innovation in public and private institutions. Moreover, framing design and innovation policies around the use of open data and to co-create more explicit value propositions for all the different stakeholders has to be further analyzed.

The paper by Dominitz and Persov on *User Empowerment by Design: A New Domestic Electricity Consumption Model. A case study of young urban tenants* discusses a new domestic electricity consumption management system that deals with the democratisation of managing electricity consumption, transferring knowledge and responsibility to the users, as well as enabling conscious and efficient consumption.

The question of data as a means of democratisation is also developed in the paper by Mengqi, Price, Erp and Socha, *Designing with Meaningful Data: Deep Personalisation in the Air Travel Context*. In their work they present a framework to assist organisations to develop a dialogue with customers through personal data, arguing for a democratisation of the traditional business-to-customer perspective.

To conclude, not only this track brings forward the relevance of data in the design process and in particular the value of data as a democratizing tool, but it also emphasises the role of design in supporting a democratic use of open data as a resource. The ever-growing number of products/services that use data and/or produce data requires the definition of a new working area in which it is important to define new operative tools, methods and practices that can create a higher level of integration of data into the design process while at the same time empowering new communities around this resource.

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Data Exploration for Generative Design Research

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The current work elaborates upon a Generative Data Exploration method, which is a design technique aiming at supporting designers in integrating data in their design activities. Digital data offers new opportunities in all sort of professional domains, yet existing approaches and tools to manipulate data are predominantly targeted at data experts. As access to data is becoming democratised, new types of techniques are needed to leverage the agency of designers and to empower them to utilise data in the design process. Designers without prior data experience can benefit from the techniques, know-how, best practices of experts, if such expert knowledge is codified in design methods and tools. The aims of a Generative Data Exploration method are two-fold. First, the method facilitates a learning curve on gaining holistic data literacy. Second, the method supports designing where digital data, exploration of data and sense-making of data is part of the process.

design methods; data exploration; generative design; fuzzy front-end

1 Introduction

The abundance of digital data has been gaining presence in all areas of life. This datafication trend has been quantifying and digitally describing everyday phenomena, from how individuals are connected to each other to complex sensor systems continuously collecting digital data about the physical world (Lycett, 2013). Under digital data, not aiming for a comprehensive list, we refer to quantitative data, sensor data, open data, data in databases and so forth. Access to such kinds of data is not limited anymore to data experts (analysts, engineers, developers, etc.), but oftentimes to be found in public (e.g., open data) or can be captured relatively easily by anyone (e.g., citizen science and collecting bottom-up environmental data).

The usage of various design methods, techniques or tools has been common in all genres of design for decades. Starting from the seminal "Design Methods" book (John Christopher Jones, 1970), many method and tool collections have appeared to support the conduction of the various steps of the design process. More recent design approaches, such as participatory design or co-design, have established an increasing number of tools and methods utilised at the early phase of design (Sanders & Stappers, 2008). Another area of tools are "Creativity Support Tools" (Shneiderman, 2007) that have made previously complex tasks much easier to be conducted within the design process and by designers (such as using CAD systems for form-giving of physical artefacts). These kinds of codification of knowledge as methods, techniques or tools supports designers of any level of experience to unlock advanced technology and to integrate new techniques into their toolbox.

Earlier, research on data exploration has been focused mainly on two strands; a mathematics-based direction using statistics to describe datasets and to create models to describe phenomena (e.g., Tukey, 1962; Tukey, 1977), and a cognition-based direction using information processes to support domain experts in their sense-making of datasets (e.g., Card, Mackinlay, & Shneiderman, 1999). Compared with these two directions, exploring data from a design practice perspective is still in its infancy. However, considering the trends of the growing ubiquity of digital data, for the future it is inevitable that designers will need to be able to integrate already existing data into their design process or be able to better collaborate with data experts to do so. Speed and Oberlander (2016) have recently presented a theoretical framework to distinguish *“designing from, with and by data”* to categorise existing data approaches. However, little work to date has been done to explore supporting designers with tools to be able to integrate data into the design process, and to link techniques and know-how from data science with design, especially via formats that can be integrated into the design process. In the current work, we present a design method – Generative Data Exploration – to support generative design research. We have designed this Generative Data Exploration method based on earlier work on design tools and creativity support tools. In the upcoming sections, first we position related work, and then introduce the design method we created. Afterwards, we report on an empirical study we conducted with novice designers using the method, and then we discuss the value the method provides for generative design research as well as the impact the integration of data into the design practice might mean.

2 Related work

2.1 Non-experts learning and using data

The field of data science has matured a lot in the past decade (Cao, 2017), and as a consequence, the foundations of teaching data competencies has also evolved: holistic approaches to teach data in undergraduate education has started to take place, teaching a full spectrum of tools to prepare students working with data in real settings (Baumer, 2015). This tactic helps to learn how to think with data, from asking a question that leads the data analysis inquiry and to communicate findings. Compared to this method from formal education, alternative approaches have appeared as well; Hill and colleagues (2017) present their experiences of teaching basic data science skills through community workshops *“democratizing data* science”. Their approach is built on teaching basics of programming for the very aim of doing data science, namely to be able to ask questions from a data, acquire data from online sources and to be able to analyse and visualise such data. The approach by Hill and colleagues provides a flexible set of skills and tools, however with the price of a steep learning curve. D’Ignazio and Bhargava (2016) have approached this space from a different angle. They have created a set of learning tools for data literacy, that explicitly avoids programming, and targets data skill acquisition via tailored, single-purposed data tools – DataBasic – that nevertheless can be used with actual datasets and for actual visualisation and analysis. In another work, D’Ignazio (2017) adds to this work on her experiences with applying data literacy (and its teaching) put into creative work, such as design. Data directly applied in the design process, Bigelow and colleagues (2014) have explored how designers work with data to create visualisations, and Dove and Jones (2014) have shown ways how to inject visualised data (thus, a layer of abstraction over raw data) into co-design activities, and to stimulate creative thinking. These works indicate that visualisation contributes to the sense-making process with data, not necessarily as the outcome of the design process, but as interim thinking tools.

2.2 Toolkits

Sanders, Brandt and Binder (2010) provide an overview and categorization of the tools and techniques for participatory design. In their terms, *tools* are *“material components used in PD activities”*; *toolkit* is a collection of tools used in combination for a specific purpose; *technique* is a description how tools and techniques are put into action; *method* is a combination of tools, toolkits, techniques put together strategically towards a specific design research plan, and at last, *approach* is an overall mindset for conducting the design research plan. In the current work, we expand on this terminology with *know-how*: best practices, practical tacit knowledge turned into explicit that normally comes with experience in a domain.

Data on its own is a rather generic material, and thus we primarily relate to toolkits that support generic processes or that can expand to varying levels of abstraction. Card-deck based tools seem to fit these criteria: card-decks have been effectively used in Information Visualisation – to learn about how to use data and design visualisations (He and Adar, 2016). Many other card-deck based tools are supporting the ideation phase of design in different ways: the Tango Cards serve as an example of bringing theoretical academic work into design practice (Deng, Antle, & Neustaedter, 2014); Hornecker's card brainstorming game turns a theoretical framework into a design tool (2010), and provides an account on how the use of design tools be used in facilitated setups, like a workshop.

To support the design of such tools, theory from Human-Computer Interaction can help: earlier work in Creativity Support Tools laid down design principles (Resnick, Myers, Nakakoji, & Shneiderman, 2005; Shneiderman, 2007), such as: *"Designing with low thresholds, high ceilings, wide walls".* This principle stands for a tool's desired attributes to be easy for novices to begin using, but provide functionalities that experts need, and if possible to provide additional functionalities to keep the number of tools involved in a workflow low.

The Generative Data Exploration method

This section presents our proposed Generative Data Exploration method. Following the terminology of Sanders, Binder and Brandt (2010), we present a method, consisting of a workshop methodology to conduct a time-pressured workshop, suggested *software tools*, and *design tools* we created to support the process. The aim of the method is to empower designers without expertise in data to be able to creatively use data in their design process and to ease the learning curve for gaining data literacy for design.

2.3 Rationale

Our method elaborates upon the four levels of creativity as defined by Sanders and Stappers (2008); *Doing, Adapting, Making, Creating*, which refer to an increasing order of expertise/interest necessary for each level:

- *Doing:* The level of *Doing* – being able to transform a dataset independent of a tool (thus having a sense of how to manipulate a dataset) is part of a generic technical literacy, at least through basic knowledge of spreadsheets software (e.g., Excel).
- *Adapting:* This is the level where appropriation of techniques starts to happen. This appropriation can be guided and inspired; novice data designers appropriating data thinking and data techniques into their processes.
- *Making:* The level of *Making* is *'asserting own ability or skill'*, which we see as the utilisation of data commonly in one's design practice.
- *Creating:* The level of *Creating* is the highest level of expertise/interest in this spectrum, addressing such cases that truly transforms the design practice intertwined with data.

Considering designers' relatively low level of data expertise, we assume that most designers today would be on the levels of *Doing* and *Adapting* to utilise data. Thus, in our design rationale, we mainly address the levels of *Doing* and *Adapting*; with the current work our aim is to create such a method for designers, that builds confidence for designers to *Do* with data, and *Adapt* it, appropriating data techniques for their design process.

2.4 Design principles

After revising related work and previous workshops we have held, we have concluded the following key design principles for data design tools for the fuzzy-front end:

- Data design tools should be open-ended; data can come in various shapes, formats, and topics, and the tools need to accommodate for this broad variety.
- Data design tools should integrate into a generic design process; the design process differs from person to person, thus the tools need to be familiar for designers and compatible with mainstream design tools.
- Data design tools should serve hands-on doing with data; as opposed to tools made for learning, the designed tools shall be used in real design situations.
- Data design tools should support for exploration; analytics tools for data support the process of deducting/inducting insights from data, but what designers need are support to find inspiration.
- Data design tools should generate outcomes that are valuable for the design process; the tools need to take real input into account (instead of requiring an over-abstracted input), and generate outcomes that can be actionable in the design process.
- Data design tools should help navigating through the complex world of data and data techniques; data has been black-boxed for designers, and the early learning curve is daunting. Thus, tools should help the early phase, showing designers a clear path to follow.

From previous workshops we we learnt that novice designers have foundational (or more) tacit knowledge on data and visualisation, however this knowledge needs to be made explicit. Designers have generally been exposed to visualisations (e.g., scatterplots, network graphs and more), but making sense of them might have been only an intuitive process that could be led by guiding questions.

It seemed that card decks as an approach is proven to be successful to these design principles, especially on the principles of open-endedness and suiting a generic design process. In the following section, we present the Generative Data Exploration method, including the workshop methodology and the various design tools we designed.

2.5 Workshop methodology

In keeping with the generic data process from Baumer (2015), the following workshop structure has been developed (see Table 1).

Related versions of this workshop process have been tested in one-day (n=20 and n=38) and three-days (n=26) workshop settings.

Throughout the workshop, we have selected the following software tools for certain tasks. The criteria for the tools are:

- Open source or publicly available for free;
- Working on the major computer platforms (or on the web);
- Easy to learn, providing a high ceiling on functionalities;
- Supporting a non-programmatic workflow with data.

Table 1 Workshop proceeding overview with the basic activities.

Workshop activity (in sequential order)	**Description**
Receiving the design brief	The participants receive the (design) brief. Depending on the available time and the scope of the workshop, a brief can be to 'find three valuable insights that would be interesting for designers to continue a design process with', related to the context of the dataset.
Opening or acquiring the dataset	Being able to open a dataset is an essential step to manipulate it later on. When the data comes in various formats, it may happen that additional steps (such as converting or extracting data from an API is necessary).
Setting direction	To set a direction for the inquiry, the participants are asked to first brainstorm and discuss the topic and formulate three initial research questions or data hypothesis.
Data transformation	Datasets most often require cleaning or steps of transformations based on the specific needs. Further data transformations involve various filtering or sorting and potentially deriving additional data (e.g., adding an additional column of time differences between two timestamps).
Data exploration	Data exploration is done by applying various data analysis techniques on the dataset to extract additional meaning. Such as, visual analytics can show relations between many data points, network analysis can show characteristics of relational data, and so forth. This step is 'messy'; explorative and looking for designerly inspiration.
Communicating the insights	The participants are asked to present their insights, preferably in a visual format. This provides focus and closure for the end of the workshop.

The main recommended tools:

- **OpenRefine** (OpenRefine, 2017)**:** this tool provides functionalities to clean data and to do various data transformations on data, without programming knowledge. Spreadsheet software (i.e., Excel) could perform such functionalities as well, however not as robustly, especially on non-numerical data.
- **RAWGraphs** (Mauri, Elli, Caviglia, Uboldi & Azzi, 2017)**:** this tool provides visualisations beyond the typical charting options of spreadsheet software (such as bar charts, etc.). It is easy to use and the generated visualisations can be exported to vector formats for further editing and additional graphic design work.

Learning the software tools are not the focus of the workshop, thus they can be replaced with better or more appropriate software tools without any further change. Beyond OpenRefine and RAWGraphs, we encourage the use of a familiar spreadsheet software (e.g., Microsoft Excel, Google Sheets, Apple Numbers) and a text editor (e.g., Sublime Text, Atom) for "quick-and-dirty" text operations.

2.6 Design tools

Our Generative Data Exploration method utilises the card decks and booklets we designed to scaffold a variety of data know-how. We aimed to generate card decks and booklets that can be (and preferably be) tailored for certain datasets and situations. This may happen in ways to create additional cards, or to provide cards that dissect a dataset (e.g., different columns or rows as separate card decks). The general aim is to make the comprehension of a given dataset as simple as possible. Making it tangible and off-screen supports novices to better be able to think about it and get the process going, without data transformations and data visualisations.

The actual activities of how to use the card decks and the booklets are left *un-designed*. There are typical activities to do with design card decks, such as *forced pairing* of cards to trigger ideas, or combine the cards to *reverse engineer* and model existing projects. At the current stage, we find the need to have the card decks and booklets used in more settings to conclude suggested activities for their use.

The following of the section shows the card decks and booklets in detail.

2.6.1 Card decks

Basic data types and techniques: The basic data cards provide a quick overview of the basic types of data, and the most common techniques that can be applied on datasets (see Figure 1). They can be used as a reminder of alternative options, as well as a quick reference to navigate through a dataset. One part of the basic data card deck is the cards summarising the various types of data, such as: numerical data, geo-located data, categorical data, textual data, etc. – the most common types of data one can find describing everyday phenomena. Another part of the basic data card deck is the fundamental activities one can perform with data, such as: compare or identify. These activities are so common, that they go unnoticed in most cases. However, when someone is pursuing computational thinking, these activities become very obvious (such as selecting a datapoint - *identify*).

Figure 1. The Basics of data card deck summarises the most elementary data types and data techniques.

Data techniques: The data techniques card deck is a summary of the most typical techniques to apply on a dataset, in order to extract further meaningful information out of the data (see Figure 2). A typical data technique example is *map visualisation*, which can easily be done when there are e.g., GPS coordinates in the dataset. The related data technique card provides a basic overview of what kind of input(s) the technique requires (e.g., GPS coordinates, addresses). One explicit aim of the data techniques card deck is to trigger additional techniques to use for those that are more experienced with data, and in this way to stretch their boundaries. For novices, the techniques are a guided effort to follow their learning curve.

Extendibility: These card decks are just initial decks; normally, they should be tailored to specific datasets or design situations. Such as, relational data, like metadata from a library's records, or open data containing the types of street artefacts and their locations, will probably need different data techniques to extract meaningful information out of them. Furthermore, bespoke card decks can support any layer of abstraction; a card deck of different visualisation charting options could be very valuable when the dataset is full of numbers and categorical data, providing a more detailed level of cards than the *Graph visualisation* card from Figure 2.

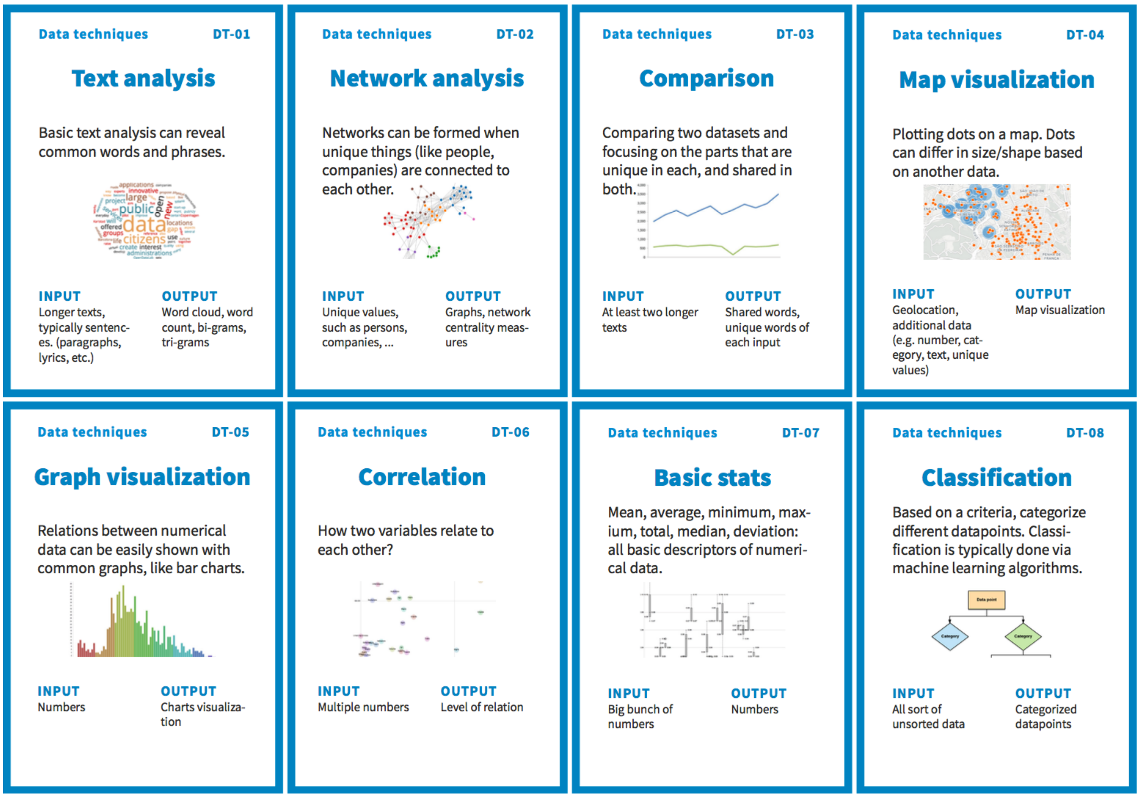

Figure 2. The Data techniques card deck summarises common techniques to extract information out of data.

2.6.2 Booklets

Questions for data: The "Questions for Data" booklet provides guidance for the users of the method to get them unstuck (see Figure 3). The booklet is based on the insight that at first, it is daunting to open a new dataset without knowing its content. The booklet contains triggering questions that can hint towards a successful strategy to process the dataset. Depending on the situation of being stuck, these questions attend the cases of:

- Looking at raw data and not knowing what is the next step;
- Looking at a visualisation and not knowing how to read it;
- Looking at data and not knowing how to extract further insights from it.

The questions in this booklet may state obvious ideas, but having these questions tangible, constantly available around data processing serves as a reminder that it is normal to be stuck, and in that case the way out is shifting the thinking process.

Working with data: The "Working with Data 101" booklet is a practical quick-start guide from opening a comma-separated value (CSV) file – a very typical format for datasets –, to doing more advanced data operations on it (see Figure 4). The booklet contains tips and tricks for the most typically conducted data operations, such as filtering or sorting data, in order to save time during the design process looking up how to do these operations, as well as to emphasise the right terminology in case the user wants to search for further information.

Extendibility: The booklets have been made 8-pages long to keep a concise format, as well as to be able to print and fold it easily. Similar to the card decks, the booklets can be tailored for specific datasets or design situations. The following section presents the empirical study conducted to assess the validity of the design of our Generative Data Exploration method.

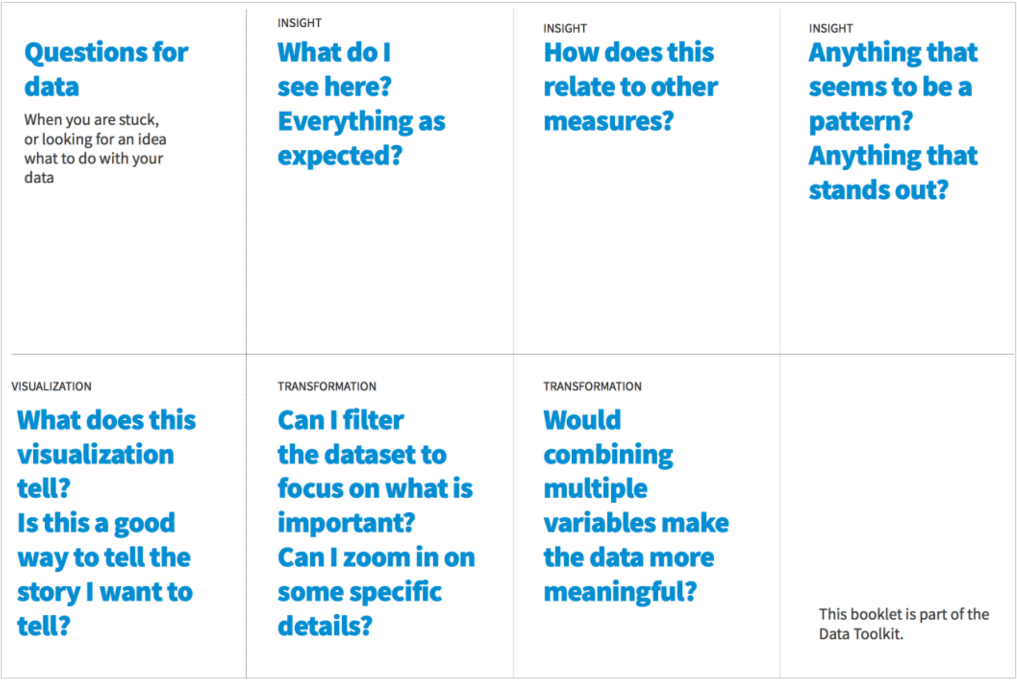

Figure 3. The Question for data booklet contains triggering questions to extract insight from a dataset or visualisation or to inspire next steps of the data transformation.

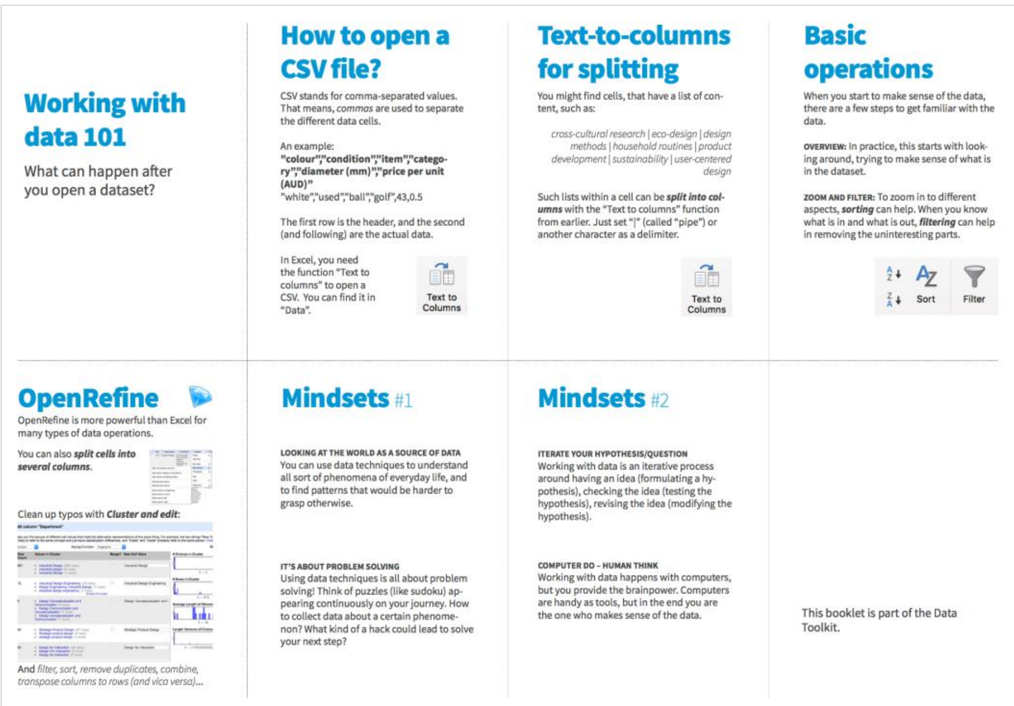

Figure 4. The Working with data 101 booklet contains practical knowledge how to open and manipulate a dataset in CSV format

3 Study setup

We conducted a pilot study to understand how our Generative Data Exploration method was useful in weaving data techniques into the design process and to assess the usability of the approach with novice designers (i.e., design students). Following the descriptions introduced in the previous section, this section details the setup and presents the methodology used. We assumed, that design students likely have tacit data knowledge that might inform their approach with data. Differently put, we expected the participants to have average familiarity with spreadsheet software (e.g., Excel) and familiarity with common visualisation techniques (e.g., charts, graphs).

Figure 5. Impressions from the workshop and the study setup.

Participants and setup: Thirteen students (7 female, 6 male) participated in the current study, as a one-day elective class. The students were first year master students in different orientations of design (strategic design, n= 1; interaction design/user research, n=5; industrial/product design, n=6), of a large, European industrial design faculty. The thirteen participants all had a bachelor degree in design. The study was offered as an elective workshop for the participants, without incentives (other than participating in a learning workshop). The participants' interest about the workshop was to learn more about data and to improve data skills to apply in their design practice. During the study, participants worked in groups (n=2-3). Prior to the workshop, the participants self-assessed their skills as following in Table 2 (for the assessment, see Data collection section).

Table 2 Overview of the study participants' skill self-assessment.

Programming skills (between 1-7, 7 highest)	**Data analysis skills** (between 1-7, 7 highest)	**Technical literacy** (between 1-7, 7 highest)
2.53 (SD: 1.80)	2.46 (SD: 1.05)	3.46 (SD: 2.18)

Apparatus: The participants were provided with a dataset, the Data Toolkit and suggested software tools to use. The dataset was a database of the participants' university's (Faculty of Industrial Design

Engineering, TU Delft) internal repository for master theses at the time of the study, containing 2040 rows and 6 columns of metadata, including the theses' *Title, Abstract, Mentors, Keywords*, etc. The provided materials were the Data basics and Data techniques card decks, and the Questions for Data and Working with Data 101 booklets.

Procedure: The elective workshop was based on the earlier described Generative Data Exploration workshop methodology, facilitated by the first author. The elective workshop started with a basic introduction to using data in design and presenting a generic data workflow. After this, the participants were asked to form groups (n=2-3) and the groups received the dataset and the related design brief, and the card decks and the booklets.

- *Opening dataset and setting direction:* The initial activity during the study was to download and open the dataset and then to define at least three research questions to investigate with the data.
- *Data transformation:* The following activity was to immerse into the dataset, preferably by using OpenRefine as suggested software tool, and try to find answers for the research question. After providing some time for the participants to realise the problems with the data (such as cleaning is needed) and not knowing the various data transformations they could benefit from, a facilitator intervention happened, showing examples of powerful features of OpenRefine as well as RAWGraphs, the suggested visualisation tool.
- *Data exploration:* The following activity was to explore the dataset with OpenRefine and RAWGraphs for insights.
- *Communicating the insights:* For the end of the workshop, the groups needed to prepare a presentation out of their exploration process and the found insights, with the explicit task to make it visual (i.e., present visualisations). The presentations were audio-video recorded for further analysis.

The workshop ended with the participants filling up a reflection questionnaire and a Creativity Support Index (CSI) questionnaire (see Data collection session). Afterwards, an audio-recorded group discussion followed.

Data collection: Prior to the workshop, we asked the study participants to self-assess their related skills, using a Likert scale rating from 1 strongly disagree to 7 strongly agree (for results, see Table 2). The questions were as follows:

- My programming skills are great.
- My data analysis skills are great.
- I'm very technology literate.

For (research) data collection at the end of the workshop, we used online questionnaires and the Creativity Support Index (Cherry & Latulipe, 2014), a quantitative, psychometric tool to assess the workshop setup's assistance in creativity support in the design research process. Furthermore, observations were noted down throughout the workshop, and the presentations and the final reflective group discussion was audio-video recorded.

4 Results

Our observations of the participants' processes clearly showed that it is not straightforward for design students to start exploring a previously unknown dataset with the goal of concluding designerly insights. In general, the groups first defined some "interest directions" as research questions or data hypotheses, and then started with filtering and sorting the data. After seeing the struggles with the *Data transformation* activity, we intervened with a brief tutorial on tips and tricks with OpenRefine; it was important however, that first the participants realise what they don't know, instead of front-loading knowledge in the beginning as technical tutorials. After the initial confusion of how to use a new tool, they managed to "zoom in" on their interests in the dataset, with some groups going even further to deriving new data from the dataset (i.e., based on the raw data in the dataset, add additional data, such as counting the appearance of keywords). The participant groups commented that they needed to shift their thinking with transforming the data, indicating their general lack of practice with computational thinking. For *Data exploration*, the primary mean was visual inspection of the data, using RAWGraphs. The groups noted that RAWGraphs has many atypical charting options that they could use, but they lacked guidance on what charting works best for certain types of data to communicate.

4.1 Creativity support evaluation

The results from the CSI assessment indicates an average 73.85 (SD = 9.44) CSI score for our Generative Data Exploration method in this study (n=13).

Table 3 The CSI results from this study shows that participants rated Results Worth Effort and Exploration factors the most important, and the average weighted score for these two categories have been found highest.

Scale	**Avg. factor counts (SD)** (between 0-5, highest 5)	**Avg. factor score (SD)** (between 0-20, highest 20)	**Avg. weighted factor score (SD)** (between 0-100, highest 100)
Results Worth Effort	3.00 (1.78)	16.15 (1.47)	48.85 (30.92)
Exploration	3.85 (1.07)	14.62 (1.29)	55.85 (16.63)
Collaboration	2.08 (1.44)	14.15 (1.92)	28.46 (23.42)
Immersion	1.77 (1.42)	14.00 (2.38)	28.92 (28.15)
Expressiveness	2.31 (1.25)	13.54 (1.66)	30.46 (15.51)
Enjoyment	1.92 (1.44)	15.00 (1.27)	29.00 (21.94)

Table 3 presents the outcomes of the CSI survey. Following the example by Cherry and Latulipe (2014), we report the results with respect to average factor counts, factor score and weighted factor score. *Average factor counts* indicates the number of times participants chose a given factor important (between 0 and 5). *Average factor score* indicates how well the Generative Data Exploration method scored (between 0 and 20) for certain factors. The high rankings of *Exploration* and *Results Worth Effort* indicate that participants found these factors most important. The *average weighted factor scores* are most sensitive to factors that are marked more important, and in both Exploration and Results Worth Effort the Data Exploration workshop scored higher than the other factors. The outcomes of the CSI analysis confirm our design direction that exploration and generating meaningful outcomes that are worth the effort are of importance, and the method's direction is validated, however with room for improvement for future iterations.

5 Discussion and further work

We see the main contributions of our Generative Data Exploration method in empowering designers to discover meaningful insights from datasets, and to find inspiration that complements qualitative contextual research and informs the following steps in the design process, such as ideation and prototyping. Expanding the framework by Sanders and Stappers (2014), we place the Generative Data Exploration method primarily in the generative phase of design (see Figure 5).

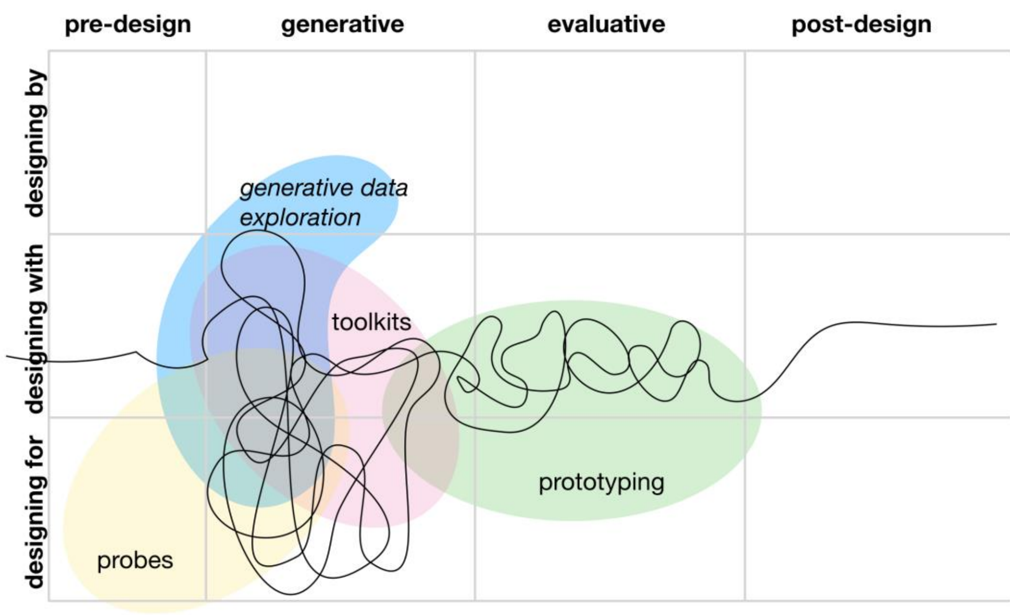

Figure 6. The Generative Data Exploration method placed in the co-design process (based on Sanders and Stappers (2014)

5.1 The value of digital data for generative design research

Our Generative Data Exploration method supported the participants in approaching and utilising already existing digital data in the fuzzy front-end. By using the method, designers managed to conclude designerly insights from data, which could be used as complimentary to traditional user and contextual research methods, such as contextmapping (Visser, Stappers, van der Lugt and Sanders, 2005) or design probes (Mattelmäki, 2006). Other researchers have explored complementing qualitative research in the fuzzy front-end with data collection by sensors: emerging examples, such as using everyday objects as data-collecting ethnographers to collect rich contextual insights (Giaccardi, Cila, Speed and Caldwell, 2016), or the use of data-collecting technology probes to augment rich and contextual data with sensor data (Bogers, Frens, van Kollenburg, Deckers and Hummels, 2016) have shown alternative paths to bring data techniques into the fuzzy front-end. However, both of these examples are technologically complex, often beyond the scope and resources available for a design team. Furthermore, these examples do not address how to utilise already existing data, for which we see the Generative Data Exploration method's main contribution. Exploring digital data, and used in complementary to the traditional qualitative methods, can provide *scale* – through making sense of large datasets –, and access to a digital footprint of human activity – such as networked interactions on a social network, that would not be accessible easily via qualitative methods.

5.2 Empowering designers with digital data for generative design research

The primary motivation for introducing our Generative Data Exploration method was to support the study participants to feel confident about utilising data in their design process. The study results indicate that the method and the contained tools indeed helped design students to make sense of a dataset and enabled them to successfully manipulate the dataset to extract insights. While doing, they gained confidence and familiarity with the basic mindset necessary to work with data. Data requires a specific skill set to be able to effectively transform and utilise it, and these skills are rarely included in design education (but common, though possibly addressed indirectly, in software engineering, business analysis, and similar). Our Generative Data Exploration method can be a valuable point of departure from the traditional design tools used to guide thinking in the design process, given the designers that use it are willing to approach research problems with a different mindset and by practicing different skills. A core of this is computational thinking, a skill that most tech-savvy designers possess, who have experience in programming. Computational thinking as a skill might not be practiced in design, however it is essential knowledge for data. In our experience, using non-programmable software tools in the beginning, the computational thinking problems for different data manipulations are not complicated, and designers with basic programming knowledge can get far enough to remain engaged. Thus, considering today's designers, a large set of people would be able to gain sufficient data skills (and learning about appropriate data tools) and contribute to the democratization of data, as far as guidance is provided how to do so.

5.3 Profiling the future types of data designers

Integrating digital data in the design practice will happen more and more, and this will transform how we do design (at least the design of interactive artefacts). We see that design does not only happen by expert professionals, but people applying design techniques and a designerly mindset for problem solving on a variety of problems in the world. Manzini (2015) describes this phenomenon as *expert design* and *diffuse design*, where diffuse design happens by people not trained in design, using their natural capacity for creativity and designerly thinking. Similarly, the best practices, know-how, tools, methods and so forth for data are a growing field as data science (Cao, 2017), but it is unlikely that data will remain a field that is limited to experts only. We hypothesise, that in the future, there will be designers that gain average-to-high level of expertise in data (that may exist today already with a niche expertise in data visualisation and similar), and there will be data experts that develop average-to-high level of expertise in design. These new intersections of the data and design will set the scene for new types of data tools for design, new types of design tools for data, and new types of designer and data expert profiles.

5.4 Limitations

A main limitation of this study is that our Generative Data Exploration method has been tested only through the study, in a facilitated workshop format, and thus not by independent designers. Furthermore, the target group of the Generative Data Exploration method is designers of all level of expertise, yet the study participants were master design students. Master-level design students are quite tech-savvy (and thus rather data literate already), which might not be representative for the whole design profession. It is also important to note, that the study's design brief and the provided dataset (metadata of library records) set up a limited problem space with its own properties, which does not model all sorts of potential design problems. With these caveats, it is difficult to assess whether the Generative Data Exploration is applicable in design research practice outside academia and in non-learning settings.

6 Conclusions

It can be concluded that our Generative Data Exploration empowers designers to utilise digital data in the fuzzy front-end. We developed two sets of card decks and booklets and a workshop methodology providing step-by-step guidance to utilise an existing dataset in the fuzzy front-end and to seek inspiring insights out of digital data. The design toolkit is tailorable and extendible for different datasets and different design situations. During the current study, the method has been proven useful in exploring data and in generating outcomes that are valuable for the design process. Furthermore, the method contributed to participants gaining confidence in utilising data in their design practice, mainly due to providing clear guidance while navigating through the workflow of data.

Future work points at various directions. We aim to conduct studies with design research practitioners as well to ensure the validity of the current approach and to explore how do higher level of design expertise influence the outcomes. As a method designed to be extendible and tailored for different design situations, the method and the encapsulated tools could continuously develop if designers keep using the method. Understanding how data can be used creatively, such as what kind of mechanics lead to inspirational insights from data is still in its infancy. To better understand this, further studies are necessary based on research on creativity and sense-making. Furthermore, in this study we explored how designers incorporate data techniques, but how data scientists incorporate design techniques (and follow a design process) could lead to an additional perspective on combining designerly and data thinking.

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Orienteering design through data: The data-driven design model

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Until recently, the processes and methods used by designers have been rather traditional. As times have changed, so too have the tools used by designers to bring their inspirations into reality and develop their concepts. Now, the majority of results of the design process can be attributed to intelligent products or services. We are rapidly advancing towards an era of Industry 4.0, which is radically transforming the creative process. Data can now be part of the creative process in new and innovative ways. Many businesses in a wide range of fields are already using data to provide personalised experiences to millions of people through their products. The ever-growing influence of data management has not yet been fully appreciated in the field of design. Information derived from data allows the designer to understand context, learn and evolve with the consumer and create unique experiences. In this research paper, a new way of working is defined and new models to follow are developed.

big data, design process, methodology, creativity.

1 Introduction

Today, the objects which present greatest complexity of design are smart objects. We now have an enormous range of devices available to us which have internal computer technology and are partially or fully connected via the internet. We use these devices differently than we did even just a few years ago. All smart products are connected, making objects or people identifiable, locatable, directable and/or controllable, allowing us to complete our tasks and generating huge amounts of data. New technological advances are drastically changing the creative processes used to make smart objects and the ways in which these objects are used. As yet, there are no known methodologies which both make use of big data integrated into design's creative process and provide solutions considered to be of genuine creative value. Our proposal, therefore, becomes increasingly important; the present study is intended to identify the determining factors in this evolution, including the shifting role of the designer brought about by emerging technologies. The current role of big data will be contextualised and an analysis of how big data can add value to the creative process, the evolution of the creative process and its methodological application will be presented.

2 How big data is revolutionizing our environment

The rapid evolution that we are able to observe in the current context of Industry 4.0 supposes that it will be possible to include artificial intelligence in every object, in such a way that central agents will be able to communicate with every object, and every object with one another. We are able to see that in many sectors (healthcare, agriculture, education, industry, finance, security, marketing, etc.) data, and the information they generate, are being exploited to predict future scenarios (figure 1). Data have always offered a means to analyse past events, but the situation is now changing. Quantitative change has led to a qualitative change. It was in sciences like astronomy and genetics that the data explosion was seen for the first time in the 2000s.

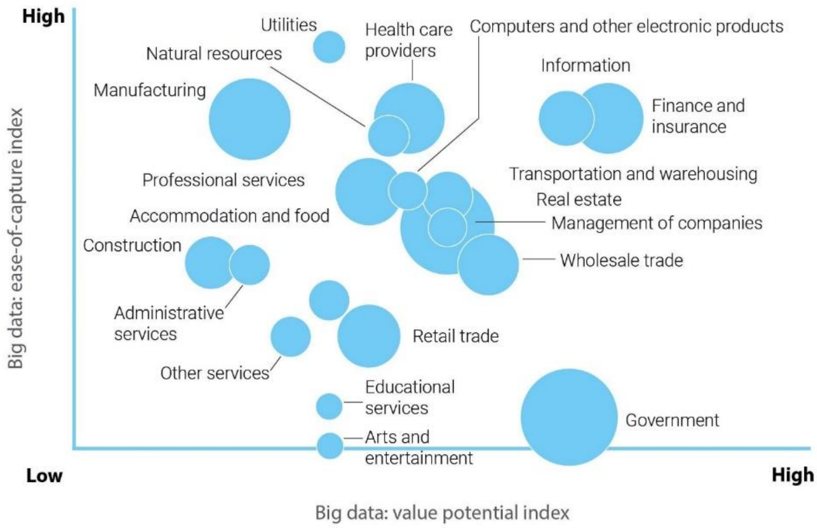

Figure 1. Value potential of big data. Source: US Bureau of Labour Statistics; McKinsey Global Institute analysis.

Researchers in the fields of health and technology are collaborating, attempting to change our current reality through experimentation with artificial intelligence (AI) and machine learning using big data. The computers and algorithms that they use are capable of processing colossal amounts of data, much more quickly than human scientists or medical professionals. Thereby identifying patterns and making predictions which improve the diagnosis of diseases and informing the planning of treatments, improving public health and safety. Innovation is occurring at an ever-increasing speed and it is predicted that more advances will be made in the fields of medicine and economics in the next forty years than were made in the previous four thousand. Based on the extraordinary impact that improvements in healthcare systems could have for so many people and their potential to save lives and money, healthcare has become a key area for investment and development in AI and machine learning. Many businesses, like IBM and Microsoft are carrying out their own healthcare projects based on AI, just as many start-ups and smaller organizations have begun their own initiatives to develop medical assistance tools. The study conducted by McKinsey ("How big data can revolutionise pharmaceutical R&D", 2017), estimates that big data could save up to $100billion per year in medication and pharmacies as a result of the increased efficiency of clinical trials and research, a more informed decision-making process and new tools which would aid insurers, regulators, doctors and consumers to make better decisions. There have already been strong indicators of big data's potential to aid the monitoring and prediction of disease epidemics around the world as Google Flu Trends demonstrated in 2009 (Author, 2017) or the algorithm that identified the Ebola outbreak nine days before the World Health Organization. The computer studied social media, news reports and government websites to identify the outbreak's existence. As with any algorithm, the more data that it is provided, the more it learns and thus the better its prediction will be. Although tools such as that used to identify outbreaks are not yet perfect, it is clear that it has great potential.

3 The use of Big data and the creative industries

Creativity has recently become an important subject of reflection, analysis and controversy – possibly even revolution. It is considered from economic (Hawkins 2005), sociological (Joas 1996; 2012) and psychological (De Bono 2006; Csikszentmihalyi 1996) perspectives and has become part of debates ranging from industry and urbanization to social class and education among other issues. However, since the publication of Richard Florida's (2010) "The Rise of the Creative Class" in 2002, creativity has become an increasingly popular topic in the social sciences, provoking countless studies into the creative classes. It is not currently possible to understand the creative classes outside of the context provided by two other expressions: the "creative economy" and the "creative industries". Fourteen sectors of the creative economy which have a significant artistic element exist in most countries. These include: advertising, architecture, the arts, craftsmanship, design, fashion, publishing, cinema and video production, television, recreational software development, music, the performing arts, photography, IT services, etc. However, Hawkins (2005) suggests that creativity exists in almost every area of collective life. Gaggioli, Riva, Milani & Mazzoni (2013) indicate that the sociocultural analysis of creativity has also emphasised the role of financial, economic and historical factors in the development of creative progress. Technological advances like big data and the internet of things (IoT) are likely to fundamentally change how we live and work in a new open and online world (Greengard, 2015). For the potential of these advances to be fully exploited, they must form the basis of digital technology:

> *…the increasing integration between devices, and the nature and quality of our reception and interpretation of this content. It is the case, then, that 'the digital revolution' pivots on user experience and the effective use of design" (Design Commission, 2014)**.***

Economic, social, cultural and political decisions are increasingly being influenced by big data, but a disparity still exists between the creative industries and users ability to determine how big data is collected and how it is used. The amount of data we generate has grown exponentially (Helbing & Balietti, 2011) from 150 exabytes in 2005 to 4,423 in 2015, meaning that important opportunities may exist if these sources can be exploited effectively (Dove & Jones, 2014).

The evolution of the creative process

Creativity is a complex concept which is very mysterious for the majority of people. It has been advocated that although people have difficulty pointing out exactly what product creativity is it would seem to be identifiable by the majority (Amabile & Kidd, 1983). The approach to the appreciation of creativity drives an ongoing interest in researching the relationship between product creativity and science during the creative process. According to this research, creativity will be seen as an essential component of design (Chakrabarti, 2006), aided through data and using an adaptive, integrated model. A literary review has been carried out identifying the contributions and potential gaps in creative processes throughout history. The analysis shows certain deficiencies in the creative processes as expressed by Guilford (1950), who noted that there was "considerable consensus on the four phases comprising the creative process", which is traditionally recognised as preparation, incubation, illumination and verification. However, Guilford, unsatisfied with the above description, wrote: "that such an analysis is very superficial from the psychological point of view". It does not reveal anything about the mental operations involved. Guilford identified several factors that influence creativity, including problem sensitivity, the abilities to generate a large number of ideas, transform one's mind-set, reorganise, deal with complexity and evaluate. Following over fifty years of research, our understanding of the cognitive processes of creativity has grown substantially, incorporating radical innovations at an extraordinary pace. Many researchers have based studies into creativity on the four-phase model which remains relevant today. (Busse & Mansfield, 1980;

Cagle, 1985; Goswami, 1996; Ochse, 1990; Osborn, 1953; Stein, 1974; Taylor, 1959; Taylor, Austin, & Sutton, 1974). Following and analysis of over 100 creativity and design processes, about half of which are included in this research, possible characteristics include: (1) Creativity is deemed to involve adaptation to the requirements of reality. (2) It is the quality of being original or novel. (3) Definitions are wide-ranging. (4) The product of creativity is a qualitative or structural advance. (5) The product of creativity is unpredictable even to the creator. Researchers including Brown (2008) indicate that computational creativity may reinforce the creative process due to higher precision and the use of computable constraints. The study of creativity may be supported by computer science with the creation of support tools enabling collaboration, difficulty management, history and rationale maintenance and facilitating exploration. (Lubert, 2005; Shneiderman, 2007). One of the most recent updates of the four-phase model corresponds to Amabile (1996) which incorporated a new vision, describing the creative process in several phases: (a) identification of the problem, (b) preparation (collection and reactivation of information), (c) generation of responses and (d) validation and communication of responses. Key to Amabile's proposal is the suggestion of a final decision-making stage performed after a result is obtained, which makes it possible to end a process if the outcome is successful, suspend it if unsuccessful or return to an earlier phase, allowing iteration. Amabile's proposal forms an important part of the present study, conceiving of the creative process as one in continual evolution. Guilford (1950), among others, submitted that the creative process might be analysed by breaking it down into its component sub-processes and examining these. The theories put forward by Guilford and Amabile form the foundation of this study.

4 Can big data improve the design process, offering better solutions to users more quickly?

In the current industry of the Internet of Things, it is understood that everything is connected and is capable of collecting and sharing data about how it is functioning. Ries (2011) refers to a new generation of services, products and systems which aims to alter users' behaviour. Chakrabarti (2006) suggests that developments like the qualified self (ISO13407, 1999) and wearable technology may help find solutions to major challenges faced by society. Parameters which are nearly invisible to human perception, can be measured with the help of advanced analytical tools like machine learning, which means that through data analysis techniques, such as predictive analytics, events can be predicted before they occur and become a problem. Predictive analytics is used, for example, to foresee serious mechanical or structural faults: placing sensors in machines, motors or infrastructure such as bridges to monitor data and detect changes that could become problematic in the future. Artificial Intelligence (AI) allows us to collect and process a huge quantity of data, obtain better results and make better decisions in a more systematic and organised manner (Solares, 2017). Algorithms, neural networks and reasoning patterns, which are in theory similar to those used by humans, are applied in AI (Nilsson, 1980). How would we approach a new project if all of the collected data were available to us? Currently, the use of correlations is growing. Aviva, a large insurer, has used credit reports and consumer marketing data to approximate blood or urine tests applicants (The impact of big data on the future of insurance, 2016), allowing it to identify those which have a higher risk of suffering from conditions, such as high blood pressure, diabetes or depression. Aviva's method uses data related to the subject's lifestyle which include hundreds of variables: hobbies, web pages visited, hours of television watched, as well as income level, Aviva's model of predictive analytics, developed by Deloitte Consulting, has shown positive results in identifying health risks. A few years ago, Google began its first trials of driverless cars in California. As tests are carried out, the car analyses each obstacle that it encounters and finds a solution instantly. The car then shares its information with all of the other cars operated by Google. From that moment on, the new obstacle will no longer pose a problem. The Google car is equipped with sensors, processors and communication devices. The connected car will be just one of millions of devices sending and receiving information to and from the cloud every second. Considering the integration of the data into the design process, based on the examples above, it can be seen that data can have two clear directions. The first describes the use of data gathering through software applications and behaviours. Usage data, mainly with qualitative component, are based on correlations, generating data of an abstract nature through predictive analysis. The nature of this data will allow it to be used as creative material, providing high-value insights in the early stages of the creative process. The second direction, according to Google car's example, describes a method for detailed and remote observation using sensors. The use of sensors provides a rich and detailed understanding of performance. The data obtained here are concrete, giving flexibility and new opportunities to collect quantitative data. Such data can be useful for both validation and improvement, allowing the design to be optimised even further. Speed & Oberlander (2016) indicate that there are three types of data used in the design process, which are: (1) Design from data: Systems are designed by people, so show quantifiable qualities of humans, computers, their contexts and their conditions. (2) Design by data: Systems are designed by humans and account for the data-flow through the system. (3) Design with data: Systems autonomously designed by other systems.

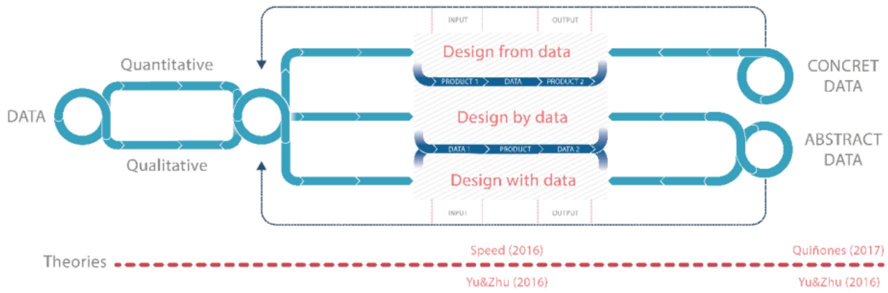

Figure 2. Data within the design process

The existence of two separate forms of data, "abstract" and "concrete" data, is proposed by Uu & Zhu (2016). Abstract data is conceptual, not existing in reality, while concrete data exists, and can be collected and processed. However, in the present study a more specific classification, as proposed by Author (2017) will be used (Figure 2): (1) Concrete data: Produced by processing existing data sets. (2) Abstract data: The recontextualization of existing data to be used in predictive analytics, giving additional insight into, and aiding exploration and understanding of the data. Author affirms that, in accordance with the above definition of data use, abstract data will facilitate the development of novel concepts in the design process, while concrete data will aid in defining and improving design. Studying data in the creative process will allow us to learn how users use products, services or systems, what problems they encounter and what characteristics they ignore. CTO of Teradata, Stephen Brobst suggests that this will improve processes, stating that collecting all kinds of data is not practical, nor is constantly asking for it and ruining the user experience. Data-driven design aims to engage users in real-world usage contexts. Through a combination of different data sources and the ability to probe remotely, it is possible to build empathy with users in the field. The availability of AI systems and easy access to large amounts of data during the design process will mean that designers will find fewer unwanted surprises at the end of the process, leading to better products that can be marketed much more quickly.

5 The model: Data-driven design process

Design has begun to adopt processes and methodologies used in other disciplines with the intention of focusing the design process on the user, providing both users and markets with valuable solutions. We have outlined what the impact of insights derived from data analysis could mean to the normal operations of many companies worldwide. With the integration of sensors and data collection mechanisms, the flow of data has dramatically increased, facilitated by the Internet of Things. The exploitation of this data is propelling innovation, creating and connecting ecosystems and providing

many opportunities for businesses. The present research proposes that it will also be possible for design to exploit data through the use of a new, more advanced model. Many authors have concluded that new methods must be developed to advance design further.
Research ranging from Guilford to Amabile last century to the most recent studies, have indicated the need to develop more advanced models. Julian (2002) states that it is a common belief that a prescriptive model of the design process and methods is necessary, an approach that Doesburg and Gropius (as cited in Julian, 2002) were proponents of from the early 1900s. It was not, however, until the middle of the 20th century that the study of design methods became relevant, faced with an increasingly complex design process. Based on the research presented in the previous sections and the need for an advanced design model adapted to the new reality influenced by big data presented herein, it is understood that while large data sets can improve design by stimulating creativity in its initial phase, design can provide greater understanding of the data, driving innovation, such is the hypothesis upon which the present study is based and is is represented in the data-driven design model proposed by Author (2017). The data-driven design model aims to bring the fields of data science and creativity together, building synergies and interaction, while improving effectiveness and efficiency throughout the lifecycle of the process.

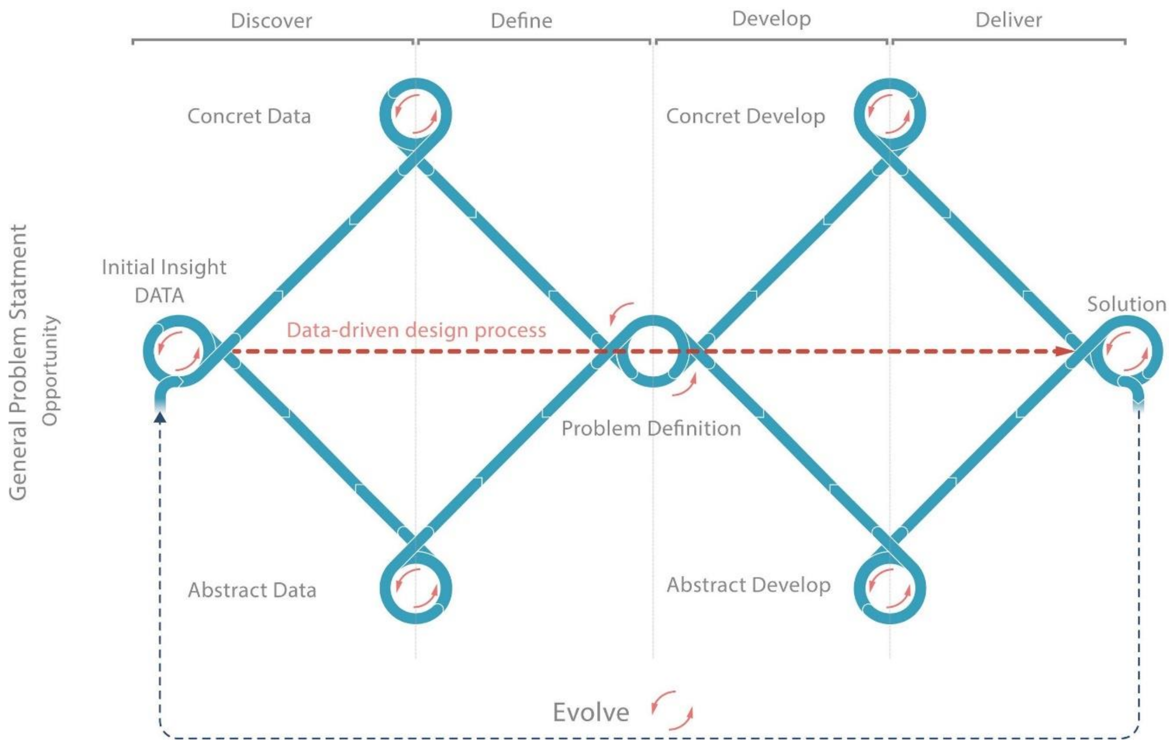

Figure 3 Data-driven design model

Following the research presented above, the present study is based on the double diamond model, which is considered an advanced model which unifies the common features of design's creative process caused by its evolution. According to the Design Council, every discipline of design shares the same creative process, which it refers to as “The Double Diamond” ("The Design Process: What is the Double Diamond?”, 2015). Each specialisation within the field of design has different focuses and ways of working, but they all have some points in common, as can be seen in the double diamond diagram. These consist primarily of four different phases which are shared by the majority of models of the creative process, as can be seen in the summary (Lubart, 2001): Discover, Define, Develop and Deliver. The Design Council stated that “in all creative processes a number of possible ideas are defined (divergent thinking), before refining and reducing them to the best idea (convergent thinking)”. This can be represented in the form of a diamond. The double diamond indicates that this pattern of divergence and convergence happens twice, both to define the problem and as part of the creation of the solution. The model illustrated in figure 3, based on prior studies and adapted from the "double diamond" model is intended to be an evolution; responding to the flexible and changing environments, aiding creativity. The result is a dynamic model that can adapt quickly to the requirements of the process and, clearly, the market. In the initial discovery phase, the Data-Driven Design model (DDD model) proposes the collection of all available data, extracting knowledge from data. Having access to large sets of data during the design process is assumed to aid creativity and as such allow a greater number of potential solutions. Such an abundance of data grants the designer freedom to explore more concepts and new perspectives or analyses while paying closer attention to certain facets of the process without losing the central focus. The design process is potentiated by the data collected from the thousands of connected devices in use today; transmitting information about their use and functioning.

Through the integration of concrete and abstract data, as in the Data Driven Design process (Author, 2017) (Figure 3), we are able to perform analyses to identify trends, in turn generating abstract data which may be used in predictive analytics, helping identify future performance scenarios or support a products, service or system continued development. The proposed model is more developed, transversal and flexible, although further research will be needed to ascertain its potential impact. Following this methodology, the data collected at the start of the process could be concrete (shown in the upper section of the diagram) or abstract (shown in the lower part). During the second phase, definition, analyses are performed to identify higher-level patterns, which can be used to define the design problem. It is now when the designer must give equal weight to the quantitative and qualitative aspects of their work. For example, if concrete data show that users perceive a problem that is not supported by data, it may be necessary to re-evaluate the situation and ask different questions in order to determine the actual problem. This is represented in the model by its bi-directionality: the iterative flow of the process. Conversely, abstract data may provide us with a more conceptual interpretation of a problem that must be solved, as the analysis is predictive and based on correlations that will help us define the present to improve the future, as shown in the example of Aviva and Deloitte. In the subsequent phases of Develop and Deliver, the process is similar to the double diamond with the proposed difference that the final solution evolves based on data collected after its implementation or the product's release. This provides early feedback, allowing the solution to evolve and improve, or for an alternative solution to be developed. As well as integrating big data, the model improves traditional linear models via iteration, becoming a more agile and flexible model, allowing the final solution to be continually improved, reducing risks.

The implementation of the data driven design model is a step forward in the design profession, which aids creativity and strengthens our capacity for invention of high creative quality through the use of data. Asta Roseway (Labarre, 2016), principal research designer at Microsoft, states that the designer's role therefore will be:

> *“to act as the ‘fusion’ between art, engineering, research, and science. The ability to think critically while working seamlessly across disciplines, blending together their best aspects, is what will make the design professional a ‘Fusionist’. The challenge and reward for the Fusionist will be in her ability to communicate, comprehend, and connect all parties through design” (Labarre, 2016).*

This statement captures the essence of what the designer's role in the future will be.

6 Discussion

It was found that traditional models consider design methodologies to come to an end with the launch of a product, service or system that has been tested several times and is ready for the market. However, the DDD-model studied, with the integration of iteration in the final decision-making phase, allows the design process to remain "alive", as pointed out by Amabile, who states that it is possible to stop the process because a successful outcome has been achieved, to suspend it for an unwanted outcome or to return to any of the previous phases and continue working again. Consequently, it is not understood as a process that ends when the solution has reached the market, but it is understood Initially allowing the most important data to be tracked to obtain solutions at the earliest opportunity, and then subsequently to develop improvements corresponding to data of other priority levels. This aims to provide a better user experience. The most remarkable result that emerges from the research is that the combination of a deep understanding of the user and a deep learning of the big data is a step forward in the design process compared to traditional models. It was found that data correlations used in the initial phase of the process stimulate creativity by increasing efficiency and effectiveness on, introducing new patterns of innovation. There is evidence to suggest the hypothesis that the model proposed can provide greater understanding of the data. Given that our findings are based on a limited number of creative processes and models studied, the results from such analyses should be treated with caution. But recent studies show that data is already being used during product development, indicating that the model presented may have great potential for future product, service or system development within creative industries. A more recent and important example that makes use of big data is the Autodesk automotive project Hack Rod. In order to develop the chassis for their racing car, the Hack Rod team fitted hundreds of sensors to the chassis of a test vehicle, a so called "digital central nervous system" which would provide data on the physical forces the driver and car were subject to. Based on the data collected, a new chassis was designed using design software. The Hack Rod is an example of the intersection of qualitative design and quantitative data science. While the model proposed is still in preliminary stages and requires testing and implementation to verify if will be viable, we are hopeful that further research will confirm our hypothesis. The data driven design model's use of big data in the initial stage makes the model more agile and flexible, helping to alleviate Design Fixation, which negatively affects the start of the design process due to reliance on familiar method to the exclusion of new ones that may be more suitable (Jansson, 1991). Mitigating design fixation will allow designers to create innovative solutions. In "A Step Beyond to Overcome Design Fixation", Moreno, Blessing, Yang, Hernández & Wood (2014) indicate that utilizing big data and AI allow usage to be compared, and experiences to be analysed based on correlations brought to light through data analysis, allowing designers to gain insight into problems and implement solutions.

7 Conclusion

Current advances show that smart objects in the era of AI will change how the design process is carried out. The rapid and continuous changes in society have provoked the creation of new creative methodologies and processes, as have the new patterns of innovation to which the designer must adapt. In this context, the designer's expertise would shift form creativity itself to facilitating creativity. Our study is intended to open a debate about the space created and the opportunities which arise around the creative industries, as well as serving as the basis for an exploration of the emergent space of design generated by emerging technologies which use big data. This includes the application of data in the design process with the objective of improving it and serving as a tool for the industrial designer, but it must be emphasised that the use of data is not a substitute for creativity. New opportunities are available to designers thanks to big data. As has been argued, data can be a determining factor in design's creative process, but it is essential to consider that data analysis does not explain why there is a problem, only that there is one. Data allow us to define the problem, but we use the power of creativity to solve it. Direct contact with the user is still essential, as it will now be necessary to collect data related to emotion, feelings, reactions and interpretations. We are currently unable to imagine the potential of data and must rely on instincts. It may now no longer be necessary, but the unquantifiable value of creativity cannot be disregarded. Creativity should continue guiding the creative process, so that its application may represent real value for design. Big data, which provides us with more reliable user data obtained in the field, if used responsibly, can be a useful tool to make rational decisions and can make the design process more effective. Accommodating the integration of data and creativity will be an important evolution and advancement for design. Applying these methodologies to the creative industries and their subsequent evolution are the basis of thought responding to needs, the entire process being applied via creativity, balancing intuition with reason and design with science. The background research for this paper included an analysis of empirical studies and literature in the fields design and models of design and the creative process carried out through history. Based on the arguments and evidence presented in the present study, the following statement can be made: integrating big data (which is based on near infinite data) into the design process will allow easy access to a huge quantity of ideas and information; it represents a tool of great potential for designers, strengthening and supporting human creativity, creative results and innovation. As mentioned by Norman (2017):

> *"We need to think more about the design of human-machine teamwork. And we need to continue to expand the concept and tools of design, from design as specification, to design for use, to design that includes new business models" (Norman, 2017).*

As such, the objective of integrating AI systems into the creative process of design is to aid it and that it may be more effective. In this situation, the designer would not lose their control over the process, on the contrary, their individuality and the personal nature of their idea would be reflected. The model being proposed is still in its nascent stages and requires full testing and implementation to ascertain its viability. It could be implemented through an online platform to aid data management. Post factum studies of the proposed model would also be necessary to determine whether the user experience could be optimised. In practice, given the appropriate approach and making use of artificial intelligence, the data-driven design model allows data to be reused intelligently, as well as serving as a base for computational creativity systems; becoming a wellspring for innovation. This model's potential resides in the integration of data used iteratively, allowing continual internal feedback within the system, the designer to evolve the solution and establish levels of solutions to be implemented, becoming an “entity into which the designer inscribes value and from which the user infers value” (Zingale & Domingues, 2015). It is the designer's responsibility to create a flexible environment so that iteration may occur as fluidly and quickly as possible. The digital explosion and smart objects have shown us that there are no constants, nor certainties and that designs must evolve as the end users' needs do.

As such, this study contributes to improving how we understand the use of big data, establishing objectives for future research. Viewing the future development of design from a strategic and anticipatory perspective represents a different way of facing the new scenario of Industry 4.0. In summary, I am inclined to think that traditional models of design are becoming obsolete in a new, changing, and flexible environment where immediate response and reaction are crucial: where design is a means of creating innovative solutions, guided by big data.

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Transformative Learning: co-design with communities' collective imagery as data for social innovation

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This paper reports a co-design practice which aims to enact social innovation by connecting local communities' needs to global data networks. We introduce low-fi physical tools that mediate a community's shared imagery as the creative space for collective meaning-making. We discuss our practice of a co-design framework within the systemic view of social innovation processes. By discussing a community workshop method that structures locals' "collective imagery", we seek to develop insights into the potential linkage of social innovation to systems of open data. We discuss three village regeneration projects that encourage a community's transformative learning enacted through an analogical installation. We explore the concepts through broader practical and theoretical considerations, especially connectivist and transformational learning processes, and the use of information technologies in engaging social innovation with communities. We propose the need to consider ontological differences between a local community workshop and the open data for social innovation to impact a systemic change.

co-design; social innovation; creative imagery transformative learning;

1 Co-design with Community as Social Innovation

Design researchers often face challenges when directly engaging communities to co-design for large-scale social innovation (Fuad-Luke, 2013; Manzini, 2013; Kimbell, 2012). Not only are the design problems often undefined and the outcomes not immediately evidential, the challenges lie in devising creative tools that can facilitate communities in visualising their collective imagination (DiSalvo, Clement, and Pipek 2012). With the undertaking encompassing many activities and processes at many levels, design for social innovation becomes a very different creative process from the traditional design process.

It is useful to view such a process by adopting the concept of the Social Innovation Spiral (Murray, Caulier-Grice, and Mulgan 2010), moving from narrow-scale, local activities outwards towards broader, more global implications (Figure 1). The phenomenon involves "the use of mapping techniques to reveal hidden needs and unused assets" at the local level and the "creative blending and recombination of disparate elements and ideas". Success will depend on processes that create or promote "alliances between the top and the bottom, … the 'bees' (the creative individuals with ideas and energy) and the 'trees' (the big institutions with the power and money to make things happen to scale)" (ibid.).

In facilitating the social innovation process, we ought to engage directly with the communities (DiSalvo, Clement, and Pipek 2012; Kimbell 2012a; Kimbell and Bailey 2017). Manzini (2016) urged the importance of the use of global digital networks to empower local communities for good causes, with ***the design workshop*** as a sense-making and meaning-making local process. Insights gathered from these workshops are relatively local and therefore need a way to connect globally to achieve systemic change. This requires new frameworks to combine smaller innovations across many elements to achieve real change in social, business, law and data infrastructures.

This paper proposes an extension to a co-design framework that seeks to create a conceptual space for often isolated local communities to connect, to learn and contribute new ideas at a global level. We discuss a systemic framework for locating the local workshop within the global context and digital network: social challenges, data flows, and institutions. We hope that the workshop will facilitate the local communities in the co-design of a learning experience that is potentially globally impactful for social innovation.

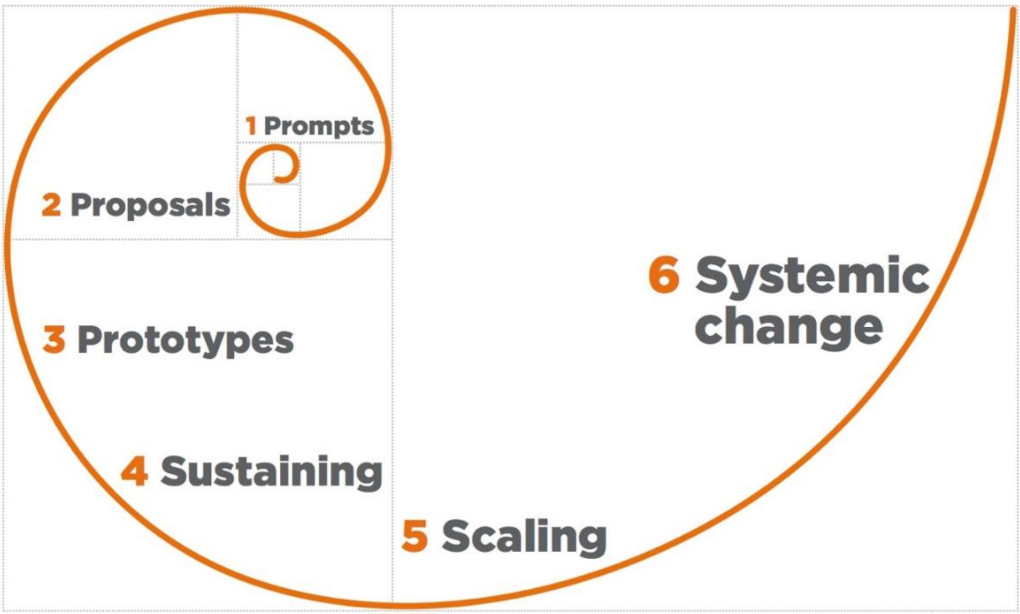

Figure 1. The Social Innovation spiral (Murray, 2010, p. 11)

The social innovation spiral (Figure 1) depicts a nonlinear process in six stages from micro to macro: prompts, proposals, prototyping, sustaining, scaling and systemic change. In theory, the design should happen iteratively at all stages and in parallel to a digital system. But in practice, the designer often only manages to influence the first three stages while the global digital network works backwards from the systemic change level to meet design research at the stage in between prototyping and sustaining. We argue that this in-between gap is the cause of why a design workshop often falls short in its influence at a systemic level. And the reason lies in the ontological differences between elements of a design space and a digital network. An integrative framework is desirable for design research to bridge over these ontological differences.

Herein we discuss an established co-design practice with a creative ontologically-informed approach to guide creative workshops to be carried out directly with the local communities with low-fi physical tools. We explain how the use of these tools promotes the development of innovative thinking through creative learning processes that result in a largely implicit, analogical representation. This representation nonetheless implies commitments to a conceptual structure – a creative ontology – that can be seen to underlie the understanding of the issues and any solutions at the local level. We observe that, at the global level, “open data”, recognised in the explicit formats of the semantic web, is the key to integrating these levels – connecting the “bees” to the “trees” (Murray, Caulier-Grice, and Mulgan 2010) across local practices and digital networks. To achieve connection, we need to integrate the ontologies at the local and global levels.

We approach this through an analysis of the workshop activity as a form of transformative connective learning, exposing insights into the conceptual shifts and alignments that allow the group outcome to emerge. We are enabled to propose a certain parallelism between learning processes at local and global levels, and also to explore a process of reflection that allows the local ontology to become more explicit and able to be digitised in future. Currently we utilise low-fi tools to formalise the local ontology to connect to the global data. This conception of the nature of ontologies informs the theory of collective imagery as the foundation of a co-design practice leading to a structured, albeit implicit, representation of the collective intelligence.

1.1 When Everybody Co-designs

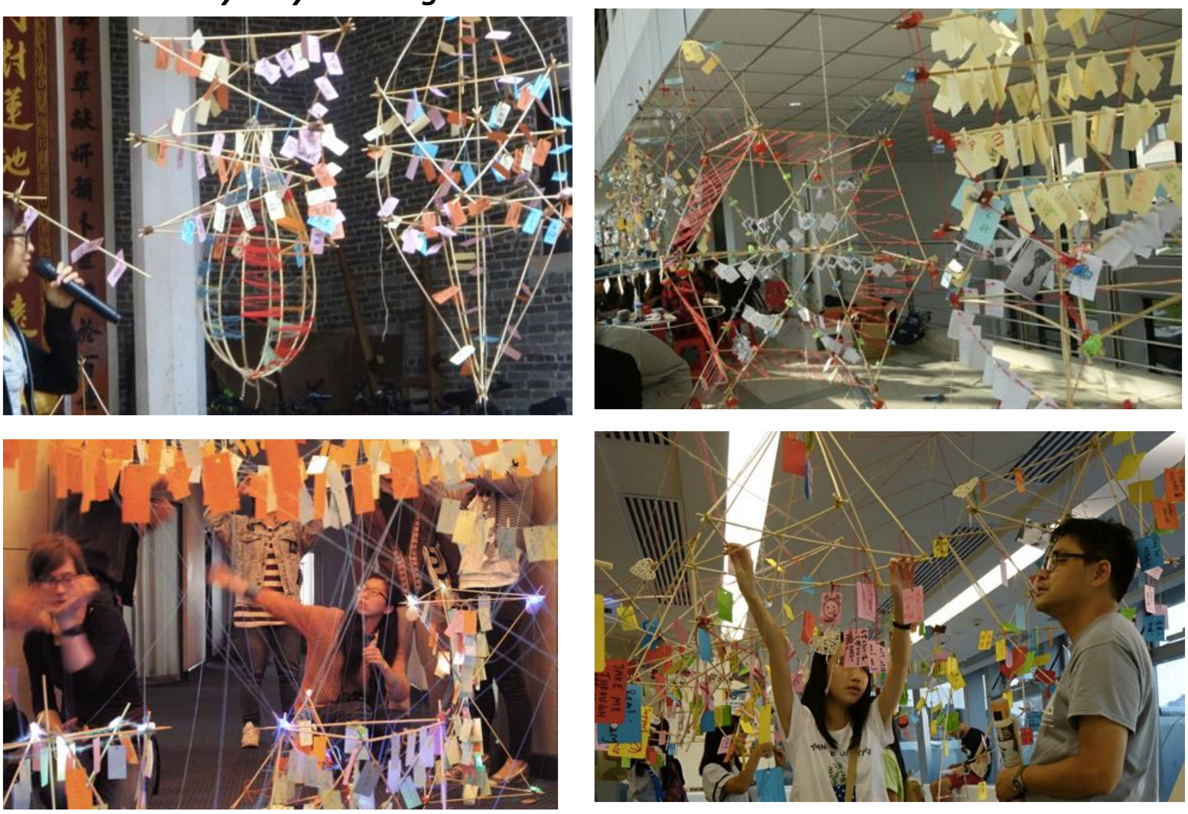

Figure 2. Forms of Collective Imagery Weaves (Chueng-Nainby, 2017)

The co-design workshop is conducted with local communities to visualise and structure the hidden and disparate elements in societal issues to create transformation through collective imagination (DiSalvo, Clement, and Pipek 2012). Lucy Kimbell (2011, 2012b) connects the local-global link through the designer who has the unique capability to enact design thinking embodied in the manipulation of physical artefacts. In some way this workshop practice enables design prototyping with the public through the workshop with design thinking (Kimbell and Bailey 2017). By bringing together various stakeholders, we lead the community to unexpected revelations and shifts in thinking. In this, we can conceive of the possibility for everybody to come together as the designer for social innovation (Manzini 2013; Manzini and Coad 2015).

When everybody co-designs, we need coherent tools that take into consideration diverse cognitive styles and creative processes (Sanders, Brandt, and Binder 2010; Sanders and Stappers 2014). We have developed the "collective imagery" framework (Chueng-Nainby, 2010b; Chueng-Nainby & Gong, 2013), in which the design space and interaction are mediated in an embodied analogic installation termed the Collective Imagery Weave (hereafter "Weave"). The Weave enacts a co-creative space as a systemic act of collective meaning making (Figure 2, 3, 5-7).

Figure 3. Collective Imagery tools for village regeneration (Chueng-Nainby, 2015)

This research has two objectives: 1) to examine the Collective Imagery framework to facilitate any community in collectively imagining their future to design for social innovation; 2) to consider the Collective Imagery Weave as a systemic process to bridge the local-global transformation "from the bees to the trees" on a wider scale. The first objective involves a study of a collective imagination phenomenon within a socio-cognitive framework; while the second challenge involves the study of an integration of the ontological differences between design elements embodied at the local (community) and the global (open data) levels.

1.2 Co-design with Collective Imagery

Much work in design cognition has focused on externalisation of imagery as pictorial and figuratively useful (Goldschmidt 2014; Kavakli and Gero 2001). The Collective Imagery framework draws inspiration from the notion of creative imagery and the Geneplore model with a broader view of imagery to facilitate pre-inventive forms and the divergence of insights (Finke, 1989; Finke, 1990; Finke, 1995a; Finke, 1996). Figure 4a shows the process of creativity in the Geneplore model: generative and exploratory. During the generative phase, a designer constructs mental representations called preinventive structures, which are used to devise creative ideas in the exploratory phase (Finke, 1996). In the pre-inventive phase, ideas (design elements) are structurally connected for the emergence and restructuring of creative concepts. Finke (1995b) describes "connectedness" and "imaginative divergence" as two distinct qualities that can be incorporated into the Geneplore model for creativity to be relevant to reality.

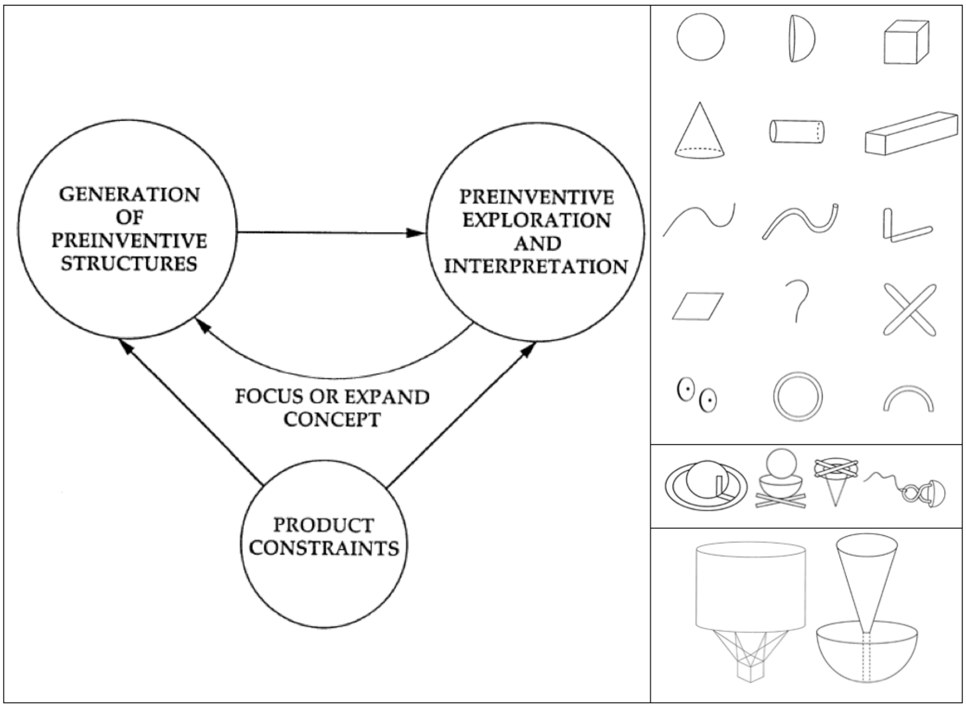

Figure 4a (left) Geneplore Model and 4b (right). The formation of preinventive structures (Finke, 1996)

Figure 5. The iterative process of Collective Imagery (Chueng-Nainby, Lin & Hu, 2015)

The Collective Imagery framework extends the notion of creative imagery to collaborative settings. To overcome the problem in the observation of a phenomenon which is largely internalised within a diversity of cognitive styles in the pre-inventive phase, we adopted the *practice-based* and *research through design* approaches (Koskinen et al., 2011; Gaver 2012) in several action research iterations. We first devise an analogic installation – the Weave – to envision and enact both the internal and external representations of the communities' Collective Imagery within a community workshop. The resulting Collective Imagery weave installations may take different forms (Figure 2, 3, 5-7).

The Collective Imagery is a conceptual structure of design elements that mediates communities' shared imagination space. It can be taken partially as collaborative imaginaries, mentioned by Disalvo et al. (2012) and Kimbell (2012), though it draws further upon a cognitive aspect with emphasis on the pre-inventive structure of the imagery (Finke 1995), which works not only at the level of consciousness. Design elements in the forms of ideas, facts and possibilities are represented in an analogical and narrative structure constructed by the communities in an iterative cycle of deconstruction, construction and reconstruction (Chueng-Nainby & Gong, 2013). Two tools are generally implemented as the design interventions at the workshops: 1) a Collective Imagery *weave*

(Figure 2-3, 5-7), which is a physical form of collective imagery, and 2) *drama improvisation* (Figure 6), which is an experiential form of collective imagery.

Figure 6. The workshop process and activities (Chueng-Nainby, 2016)

1.3 Past work on Collective Imagery

The Collective Imagery framework has been implemented across products, systems, and service designs for health, heritage tourism, village regeneration, for both private and public sectors; locally and globally (Chueng-Nainby 2014, 2017; Chueng-Nainby, Fassi, and Xiao 2015; Chueng-Nainby & Gong 2013; Chueng-Nainby, Lin, & Hu 2015; Chueng-Nainby et al. 2016; Mulder-Nijkamp & Chueng-Nainby 2015; Preez et al., 2015) through which we seek to identify co-design tools that can externalise a community's shared creative imagery. The co-design workshop process is identified as an emergent creative process in three iterative stages: deconstruction, construction and reconstruction (Chueng-Nainby & Gong 2013). The tools have evolved from a two-dimensional brainstorming method with yellow sticky notes to a large community-led weave installation utilising colour tag cards, wool and later bamboo sticks and rattan (Figure 2, 3, 5- 7), with the use of drama improvisation as an experiential prototyping tool to explore possible solutions (Chueng-Nainby, Lin, & Hu 2015). We have witnessed the positive impact of low-fi tools that are familiar to the communities especially when physical and embodied. The tools are so versatile that even the locals can find their own version. We observed this at the Yangzigoucun village when the villagers visualised their ideal home design by using stones and willows, pointing and sharing with a long stick on the soil-ground (Figure 3).

The workshop activity involves an initial phase where concepts are exposed, brought into conjunction – possibly conflict – and potential connections pursued. Imaginative divergence is sought in which the concepts are structured into narratives, and the narratives combined into larger structures, where new kinds of connectedness are developed. The imagery involved here is not in the simple sense of pictures; rather it is a structure that facilitates connections, especially the emergence of those unanticipated combinations.

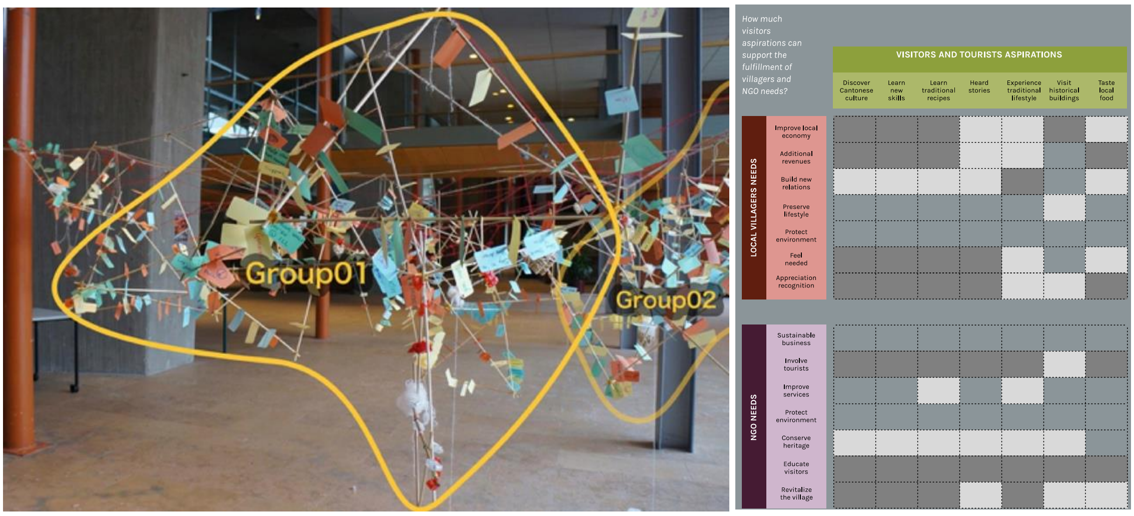

Figure 7. Analysing Collective Imagery (Chueng-Nainby, 2015)

2 Co-design Services for Regeneration

The intersection of service innovation and co-design offers an understanding of the complex structure of design space where everybody can design (Manzini & Coad 2015), which helps us to bring contextual understanding of wicked design problems to a holistic solution (Sangiorgi 2009). This paper draws upon the complex nature of village regeneration as a design goal in three villages: Heritage service design as architectural conservation at YangZiGoucun at Inner Mongolia and CangDong in Guangzhou; and farming services at Gokceada Island in Turkey. The studies also addressed the call to establish a framework for co-design tools and processes that can be evaluated for its impact (Meroni & Sangiorgi 2012; Sanders, Brandt & Binder 2010).

2.1 The Communities' Collective Imagery

Everyone in the villages is invited to the workshops that were centred around the weave structure as the physical manifestation of a self-organising creative activity where elements emerge from within the system itself. Each workshop was carried out for less than a week, shown in pictures at Figure 6 from left to right and top to bottom: a) idea generation - in keywords, drawings and pictures on tags; b) element gathering - collect and display all the tags; c) narrative linking - find five to ten related tags to make a narrative stick; d) narrative structuring - connect a few sticks according to the narratives to make a weave structure; e) conceptualisation - generate a micro concept on the emerged themes on the weave; f) concept mapping - select and connect the micro concepts into a macro map; g) story making - drama improvisation in exploring possible solution; and h) story telling - present the solution in drama for the community's evaluation.

The iterative process of deconstruction (ideation), construction (sorting), and reconstruction (the Weave) occurs with the Collective Imagery weave facilitated by tools that allow easy iteration and to finish with collective meaning making. The first two days involved constructing the Collective Imagery weave with the local villagers and authorities to collectively generate the ideas of service through imagination. This led to the themes of the service areas they agreed collectively to work on. From the third day, the designers worked collaboratively to reconstruct solutions with the help of the weave and drama.

Prompted by a facilitator's probe such as "imagine all the good things about the village ten years ago, write in one or two keywords or sketch a picture on the red colour tags", with the next probe about ten years ahead, the communities generate a big table full of design elements in colourful tags. Each workshop typically includes four to six probes during generation. Prompted by probe questions, conceptual structuring begins with connections of two elements or more to make a narrative connection that will later combine to form facets into a coherent structure (Figure 5 and

6). The resulting weave, when orientated to a design context, offers a conceptual structure of a design solution.

Two types of emerging structures have been observed (Figure 7): 1) a system of connections which gives rise to clusters as concepts (left); and 2) a conceptual structure constructed from narratives connected into stories of thematic design concepts (right). A story is a system (sequential or not) of interconnected narratives, seen as an abductive way of linking elements.

2.2 The Weave Structure

The co-design process for social innovation, however envisaged, cannot be entirely explicit and logical. It is a practice that emerges among the participants, of recognising that a physical structure captures something important about the connections between narratives (Figure 2-3, 5-7). This structure is *a network*: it represents connections between narratives, and overall the outcome and sometimes history of the group process, which can be characterised as connectivist (Dron 2014). The participants assemble the narratives into a structure in just one, concrete and comparatively satisfying representation among the many ways in which the narratives might have been brought together. There is something fitting about the juxtaposition that cannot in itself be clearly articulated, but that leads to particular articulations in the subsequent stage where the structure is described.

We see here a collective, shared, enactive process of reflection in which communities create for themselves a tangible support, a weave structure that tacitly records their development and can promote transformative shifts in their collective understanding of a situation. This is analogous to the way in which external representation is characteristically implicated in creative work: drawing, sketching, writing, modelling, experimenting, are all processes that permit a new perspective to be taken, a new angle to be seen. Design is barely able to occur without some such process – when externalisation can reveal without making explicit: the sketch, the maquette, may be inchoate, vague, merely suggestive, yet revelatory of the thinking of its creator, to its creator. And where the creator is collective, the object provides for each individual a view of the developing thinking of the group. Thus, the design thinking of our community, hung about an externalisation that helps to connect the developing concepts, has the potential to transform through enabling a perhaps radical re-viewing of the situation. It is through this process that Collective Imagery can enable innovation.

The weave structure has been made available to the public, put on display as an art installation that people may view, investigate and interact with. The structure is not a clear statement, an argument or a proposition, but it echoes and invokes the issues, the problems, tensions, constraints that have been instrumental in its creation. The Gokceada example shows the head of the village and the villagers expressing elements of their wishes after a probe such as "tell us what contributes to an ideal day for you in the village".

The observing public have access to the workshop discussion by browsing the weave structure, which presents itself as a provocation to address the issue for themselves, to develop their own discussion – internally, individually or in a group. It does not offer solutions to specific problems, but possible directions and inspirations for the communities to reflect upon over time. It has been observed that people are open to the physical structure, which represents their issues and facilitates a possible change of habits among the communities. The structure opens up thinking to unexpected concepts and approaches.

The weave is aesthetically appealing and it cries out to be interpreted semantically, which offers a route to a wider collective understanding: the content can be codified, digitised and presented in various data forms. The crucial insight for us is that the physical structure emerges as an integral part of the practice supported by the cognitive processes. The Collective Imagery process can be seen as an extended and distributed system of cognition (Clark and Chalmers 1998; Verela and Thompson 1992). It is an especially important phenomenon as it is shared in its preinventive form, which isn't always itself amenable to interpretation in terms of specific symbols and explicit significations for protocol analysis. The weave structure and the elements of it can be said to support ambiguous meaning which can be inspirational and useful for co-design.

Design begins with learning through meaning making (Tovey 2016). The workshop participants are learning about the context and situation that they are addressing, and to connect their own and each other's understandings of it. In a collective space, they are starting the process of designing a new approach to the situation by developing a new organisation of these understandings. The learning process facilitates "creative blending and recombination of disparate elements and ideas" (Murray, Caulier-Grice, and Mulgan 2010). Wals (2007, p. 500) identifies this as *transformative learning* which leads to new or alternative thinking and values, towards a resilient society co-created and therefore co-owned by the reflexive citizens. Through reflection (Schön 1983) and various kinds of dialogue, people come to understand the nature of the process, but generally without being able to articulate it explicitly. They are enculturated into a community of practice (Wenger 1998), which allows them to evaluate and develop their innovation.

During the workshop, transformative learning happens in the form of a collective meaning-making activity. It unfolds in revealing the narratives that concern a community when they start to combine these narratives and investigate a possible consensus, in a dialectical loop of construction, deconstruction and reconstruction (Figure 5) that aligns with the social learning process described by Wals (2007, p. 498) as "a critical analysis of one's own norms, values, interests and constructions of reality (deconstruction), exposure to alternative ones (confrontation) and the construction of new ones (reconstruction)." The making of meaning is enacted through practices that involve external artefacts as an implicit part of the process.

Mezirow (2000) defines transformative learning as "becoming critically aware of one's own tacit assumptions and expectations and those of others and assessing their relevance for making an interpretation". One particular characteristic of transformative learning that is relevant to social innovation is the process of effecting change in a frame of reference – the structures of assumptions within which an adult can define their world to understand experiences, and eventually move towards self-reflection. A frame of reference "encompasses cognitive, conative, and emotional components, and is composed of two dimensions: habits of mind and a point of view" (Mezirow, 1997). During the workshop, participants generate keywords to make narrative structure in the form of a Collective Imagery weave. This activity can be seen as a way of mapping out the habits of mind. The drama improvisation later is a way to establish a new, shared point of view through a rapid prototyping of experiences.

"Meaning-making", emphasises that meaning has to be *made* – it is not simply given, or implied by environmental and causal relationships – and it is made by and between people. Wals (2007, p. 497) notes that "deconstructing the diverging norms, values, interests and constructions" brings an understanding to one's roots and persistence which begins the collective re-making of meaning for change and the emergence of joint actions. This is coherent with Mikhail Bakhtin's interplay of differences as meaning-making to construct the social world, instead of transmitting information in a given world (Baxter, 2006, p. 108).

The long-term effect of restructuring meaning in this way has been felt with all three projects. The restructuring of the community's habits of mind through narrative/story-making both in the weave and drama during the workshop catalysed a transformational process in the individuals within their communities. At Yuanzigoucun where we carried out a performative intervention in the clearing of rubbish, one result was reflection among the family who generated the rubbish, leading them to stop. The Mayor of the Gokceada island has been involved in the project from the very start and continues to work with the communities to bring the proposed solution to the market place. The community in CangDong has adopted the service design of the cycling tourism into their eco-tourism plan. The communities and especially the NGOs have expressed their appreciation of the effectiveness of the workshop to break the ice with the communities, which they have tried very hard to do, but it seems the community-based weave installation has initiated a sense of ownership and hence the motivation to participate in the change.

Social innovation depends largely on learning that transforms attitudes, assumptions, expectations, and ultimately behaviours (Wals, 2007); we can speak of learning on the part of individuals, but also of communities, which equally have the capacity to learn, change, develop and transform. Communities as collections or networks of individuals can be seen to learn through reconfiguration of the relationships between the individuals, much as networks learn through transforming connections between the nodes. It will not be possible to trace transformative learning through specific changes in individuals, but rather a collective shift in reconstructions by the group through tracking their weave construction. But it is the outcome at the community level that will be crucial from the viewpoint of promoting social innovation.

2.3 Collective Meaning Making as Connectivist Learning

The transformative learning processes here can be thought of as *connectivist* learning processes. Siemens (2005) and Downes (2006) proposed this idea as a new "learning theory for the digital age", alluding to the fact that people no longer learn as isolated individuals, but in complex, far-reaching and self-organising networks where interacting with diverse information sources and other individuals are core features. They envisaged these networks typically as large scale and based on digital communications, and this is the pervasive approach in the substantial literature on connectivist learning. However, one can consider these as being sometimes rooted in networks that are much more local and based on processes that are tacit, and shared but not necessarily acknowledged.

From our perspective, the workshops consist of groups who are working together to develop communication around particular issues, and they do this as a network of actors. Our central concern is, unusually, with people who are interacting first and foremost in a physical space; a shared, embodied environment where they construct and exchange information, material and representations. Connectivism often presents as a kind of collective constructivism, and we embrace this in particular. The environment and specific form of our interactions is very different from the usual context of connectivist discussion, but much else is similar. Moreover, we envisage that the activity of the group is itself located within the wider network of connections that connectivism usually invokes – the internet and the web in general. For us, the physical and the virtual can be interpenetrating realms of media bearing the interaction of the group and its wider relationships.

There thus emerges a sort of parallelism between connectivist learning processes at the local level and at the wider level. Locally, we have the practices of the workshop; globally, connective learning practices can work as digital networks, more as posited by Siemens (2005) and Downes (2016), between communities, between individuals in different communities, between members of other communities (e.g. NGOs, governments, educators), to make new meaning based on insights the local communities have derived. This process demands abstraction rather than embodiment, is not founded in enaction, but is nonetheless built on practices of sharing and reconstruction that can result in transformative conceptual change. Deeper interconnectedness can be achieved through a reciprocal informing of the local workshop practice, perhaps in "real time", directly from the global realm: a two-way integration of thinking at different levels. This is where we locate the particular potential of digital technology to enhance the overall process.

3 Local-Global Connections

We interpret the Collective Imagery as a kind of design thinking mediated by the weave structure, through which locals may envision a possible local-global connection. For this to happen, the understanding of the structure itself needs to become more explicit. The elements that act as the building blocks for the structure need to be recognised as a kind of 'data' that in principle can be related to more global data. This ultimately depends on defining a relationship between the ontological structure of the workshop data and that (or those) of data at a more global level.

3.1 The ontology of co-design for social innovation

Ontology, in information science, reflecting its origins in the philosophical concept of "what there is", is an attempt to capture the basic types of objects, properties and relationships in some domain. We can view the conceptual structure of Collective Imagery as a network of ideas within a collective space to be connected and constructed into a systemic design. The system can imply particular concepts relating to the design problem, the nature of possible solutions and contextual issues. These concepts then imply an ontology, a structuring of the possibilities at the most basic level.

The understanding of the ontological structure informs the design of distributed networks of products and services that can empower communities to co-design data-driven informed solutions. We seek a way to identify the ontological structure by analysing the construct of Collective Imagery from the practice of co-design (Chueng-Nainby et al., 2016). This paper attempts to describe the theoretical concepts underpinning the Collective Imagery as a kind of systemic design thinking when co-designing for social innovation.

Seeing the Weave as data requires an extensive act of interpretation: it is a multiply-ambiguous structure, embodying perhaps many conceptual approaches to the workshop problem. Interpretation needs in the end to be iterative and interactive, engaging the workshop participants in a gradual revealing of their own implicit understandings of the material of the situation. Moreover, it will be necessary for the interpretation to be appropriately encoded. We therefore envisage, ultimately, an "intelligent assistant" – a digital tool that the participants can work with to derive the interpretation. The data involved are often vast, hence a machine learning approach is adopted to assist in analysing the often informal and thick data implied by the insights-driven weave. An ontology for the structure is postulated, in a sense, as a grammar for decoding the language of the Weave; a hypothesis that will need to be revised and optimised for the task of capturing the significance of particular elements within the practice. So far, we are working towards a method for interpreting the Weave, which we can then develop as the foundation of the assistant tool.

Once the conceptual structure is identified, the potential here is for local communities to develop and represent their discussions, their innovations, and the basis of their social commons, using a scheme that can be shared widely, even globally, among networks of actors – much like the practice of prototyping for policy making (Kimbell & Bailey, 2017). But much will then depend on finding a suitable relationship with existing information.

3.2 Ontologies of global understanding: the semantic web

The "semantic web" (Berners-Lee et. al., 2001; Shadbolt et al., 2006), offers a vision of "a common framework that allows data to be shared and reused across application, enterprise, and community boundaries" (W3C 2013). It reflects data in the real world that allows human and machine, and particularly applications on different machines, to connect through a set of databases (W3C ibid.). To do this, it depends on defining "common formats for integration and combination of data" (ibid.), which are also known as "vocabularies", or ontologies. The ambition is to allow the "meaning" of data to be captured, so that the web can be understood as "an unending set of databases which are connected not by wires but by being about the same thing" (ibid.); and as far as possible to promote "open data", so that data can be freed from restrictive proprietary and other limitations on its use.

3.3 Creative Ontologies

The ambition that data may all be unified at some deep semantic level evidently depends on the idea that there is a "real world" in which there are things that can be objectively identified and have an existence entirely independent from the agents who operate with them. Typically, this world is conceptualised as consisting of objects, which have properties and relationships among them, all definable in an ontology. If the agents all work with the same ontology, and the ontology correctly represents the real world, then the ambition can be realised. However, Lee (2011) argues that the attempt to derive and agree or impose standard ontologies fails. There is dissent and disagreement, or simply emergent difference, over the entities that should be included, and/or how they should be treated. Moreover, it is not desirable that there should be a fixed set of agreements about ontologies: this tends to stifle innovation, inhibit creativity and restrict discourse. We note that the suggestion here does not undermine the promise of open data; it means, however, that there needs to be equal openness about the ambiguity of data, the intentions behind the ways in which it is collected and the ways in which it is used. We therefore encourage an approach (cf. Lee ibid.) in which ontologies are seen as a way of capturing agreement, where it exists, but also of capturing and focussing discussion of disagreement.

3.4 Ontology and the Weave

In an attempt to identify the possibility of a systemic integration of design elements from local workshops to open data, we discuss an example conducted in a social transport domain (You, 2016), extending insights gathered from an earlier approach to "digitisation" in the Gokceada project (Chueng-Nainby et al., 2016), which attempted to exploit machine learning. Figure 8 shows the process of the digitisation (You, 2016), which in the context of the above discussion means the interpretation of the Weave structure into data. Keywords written on the tags were collected as narratives threaded on sticks (Figure 8a and 8b). The structure was subsequently digitised when the keywords were grouped and categorised, and used to develop a thematic map (Figure 8c).

The map is initially a flat structure, refined into a hierarchical framework, of a kind often seen in semantic modelling, of the initial ontological concepts (Figure 8d). This structure was represented in a typical semantic web formalism as an ontological structure (Figure 8e). It can be evaluated in a number of different ways. A probabilistic model was used to estimate goodness of fit with the original materials of the workshop. A connection with the semantic web was initially modelled through use of the "WordNet" (2015) lexical database to identify synonyms and sub-/super-class relationships that could inform, or contrast with, the assumptions of meanings emerging in the workshops. WordNet here represents a range of open, or other, data sources that could be related in many possible ways to the content of the workshop. Our next step would be to combine this with direct feedback from the participants for a more obviously interpretative process.

Crucially the semantic web, and thus ontologies, is the basis of a means to share and proliferate the processes and outcomes of local design-based discussions such as our workshops, but we do not want to require the participants to think only computationally. In this, an integrative approach to combine with design thinking is sought, rather than a reductionist approach.

3.5 Connecting to the open data

In future when the local workshops' low-fi Collective Imagery tool is digitally enhanced, we propose that the analysis and external linking could in principle be done during the workshop itself – creating a short feedback loop between the local and more global. The use of the web can be a means to pursue the two-way connections between the local and more global, by allowing participants in the workshop to access open data and structuring concepts with the input. The Weave offers a lens for the communities to view their ideas and to engage in collective meaning making through transformative learning; it is also an external representation through which they can identify ontological presuppositions of their thinking. It allows reconstruction to unfold as prototyping the global insights through local workshops, in which process differences among local and global ontologies will emerge as a collision between local expertise and global "knowledge". Such collisions must be respected as an opportunity for potential reconfiguration of knowledge on both sides.

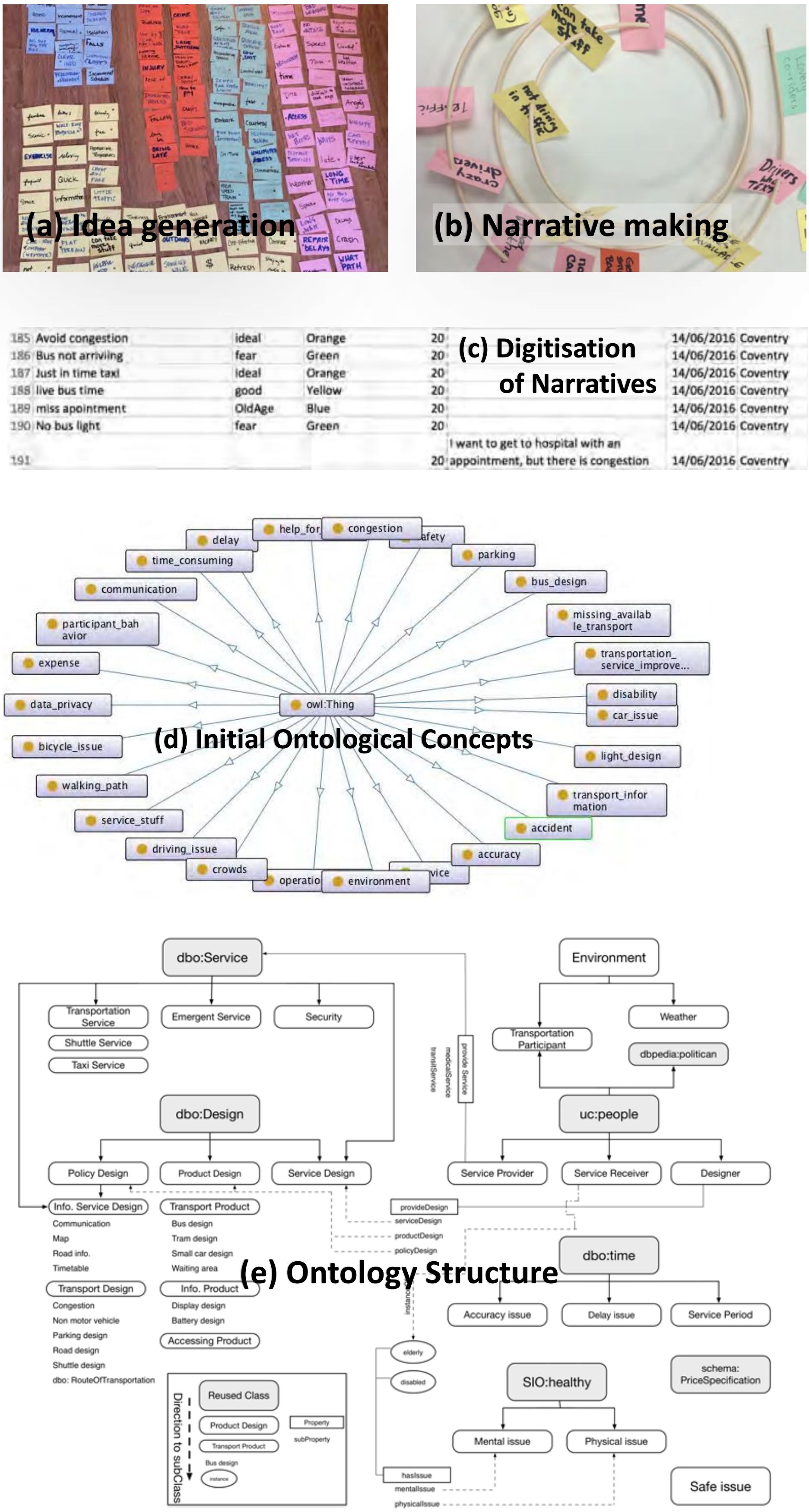

Figure 8. The ontological analysis process informed by (You, 2016)

Table 1 summarises how the various stages can be traced through the social innovation spiral (Figure 1). The first three stages (prompts, proposals and prototypes) are associated with local activities. They tend to emerge from a close familiarity with a specific situation. The second three are more concerned with a global focus. It might be said that stage 4 is on the cusp, in that local sustainability can be pursued in its own right, but ultimately is very hard to take to its full potential without serious attention to the global context within which it is required to subsist. The community workshop has the scope to address all of these issues if it can exploit the links through open data to pursue the global ramifications of local propositions.

Table 1. The Scalability of the Social Innovation spiral

Phase	Locals	Globals	Community Workshop	Open Data
1. Prompts	x		x	
2. Proposals	x		x	
3. Prototypes	x		x	
4. Sustaining		x	x	
5. Scaling		x	x	x
6. Systemic change		x	x	x

4 Conclusion: Transformative Learning in Social Innovation

We have reported Collective Imagery as a co-design framework for social innovation through community-based design workshops. We interpret the phenomenon as an example of transformative learning, in which the communities gather to collectively regenerate, reinterpret and restructure their Collective Imagery to find collectively a new point of view on some familiar topics. Transformation of any kind requires creativity and learning. This creative learning process is deeply entangled with the participants' engagement in the physical, embodied activity of sharing their developing ideas through the accessible structure of the imagery weave and drama improvisation. Thinking of the Weave as the local distillation of the communities' need with the possibility to abstract and digitise into an ontological map to connect to open data is helped through a vision of the semantic web. The local can be thus empowered to inform the global, and also be informed by it. It is envisaged that in future the workshop method will seamlessly cross the physical (local workshops) and digital (open data) – connecting the "bees" to the "trees" for real benefit in the context of social innovation.

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The case of Urban Nature in Paris

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From logs and information left in online spaces to data points self-generated by connected devices, digital traces have become more diffused over the past years, prompting an expansion of Human-Centered Design methods. Along with some *big-data* approaches, Digital Methods of research – treating the actual content of digital users' manifestation on-line (i.e. tweets, Instagram pictures, comments) – offer the opportunity to better understand users through their online activities. This paper investigates how Digital Methods can be repurposed as a full-fledged approach for Human-Centered Design. Grafting on the NATURPRADI project – a research aimed at describing the debate raised by the re-vegetation of the city of Paris by analysing Twitter posts – in the paper we will explain how we have identified and described a set of *personas* characterized by different approaches towards the evolution of the urban nature issue. The final objective of the paper is to provide a first methodological tool created at the intersection of Digital Methods and Human-Centered Design discussing its opportunities and criticalities: *Data-driven Personas*.

personas; human-centered design; digital methods; mixed methods

1 Disciplines in transition: coping with socio-technical complexity, policy problems and digital data.

In the last two decades, the Design discipline has gone through a profound redefinition of its scope of action. We are acknowledging an entire disciplinary field experimenting with new "ways of thinking and doing" (Manzini 2016) in the face of growing environmental, technical and political issues in our society (Cross 2011; Ehn et al. 2014). These issues are characterized by the contested status of techno-scientific knowledge, the difficulties that traditional institutions show for intervening in them and the necessity of redefining political and participative practices (Le Dantec 2017).

On one hand, more and more research institutions, consultancy agencies, think tanks and policy labs have started to apply User-Centered Design methodologies to address socio-technical complex and controversial settings (Kimbell 2015; Blyth et al. 2011). Positioning the user at the centre of the innovation processes helps organizations and institutions to come up with better answers to the complex challenges they are facing (Brown 2008). Furthermore, it allows to develop strategies and solutions grounded into a deep understanding of user needs, motivations and expectations. This understanding is generated through the application of design ethnographic techniques, and requires the researcher to spend time observing the users in their context in order to gain information and inspirations around their behaviours.

On the other hand, more germane fields of study to such complex socio-technical issues and problems (i.e. Science and Technology Studies, Political Sciences, Media Studies and Public Affairs) are experimenting new methodologies fitting into the so called *digital-turn,* expanding the notion of in-field research to the online domain. Research approaches based on the *digital* traces left over the Web and conducted in the framework of digital (Rogers 2009) and *quali-quantitative* methods (Venturini & Latour 2009) are opening the possibility to collect and analyse a wealth of data to observe and describe such complex environments.

The hypothesis of the present paper is that a promising way to cross these two tendencies, extending the contribution of Design disciplines in wider scientific contexts, is to continue and reinforce the circulation of approaches and methods between Design and Social Sciences. In other words, as Human-Centered Design has borrowed and repurposed Social Sciences methods (Hanington 2006; Ingold 2014) - from ethnography and anthropology, for example, to enquiry into situated practices and localised markets —this could continue re-imagining the use of digital data and methods in specific, controversial and complex Human-Centered Design contexts. The main question that this paper will tackle is: How can Digital Methods provide relevant insights and be integrated into a Human-Centered Design process?

2 Human-Centered Design, scope and application

Human-Centered design is a creative approach to innovation and problem solving that focuses on understanding people in order to ideate solutions that suit their needs (Brown 2009). The approach, also known as User-Centered Design, was initially introduced by Donald Norman (1986) – who evolved the concept of usability testing to embrace the need of learning more about user interests and needs. When the design practices encountered broader challenges due to the increasing introduction of technologies and connected systems as well as the strong push towards addressing complex societal transformations, Human-Centered Design approaches have become more and more relevant and asked to drive innovation processes by offering a way to handle that complexity and giving priority to the user perspective in generating and validating solutions (Venturi 2006).

User research is at the core of Human-Centered Design and defines all the activities that the designers put in place to engage users in the design process and gain inspirations and information from them (Steen 2012). User research requires to reach users where they are, spend time in their context, listen carefully. This type of research is by definition qualitative: it studies one individual behaviour at-a-time, and then elaborate on common patterns. *User frameworks*, such as *personas*[1] [1](Cooper 1998), are then used to crystallize and share those patterns, building a narration around the different types of behaviours that the research enlightened and turning those insights into actionable materials for ideation.

[1] Personas are fictional narratives that describe specific clusters of users and behaviours identified during a previous phase of data collection (defined as user research).

The extensive application of Human-Centered Design to address technical, environmental and political issues has raised the need to pair the qualitative understanding with quantitative data to better support decision-making processes. Surveys are a good example for quantitative research used in the Human-Centered Design process. Quantitative research can either set the ground for a more effective fieldwork - by doing an assessment of a large group of users before defining who to engage in the user research- or complete the picture offered by the qualitative study – by adding numbers that refine and enrich the insights emerged during the user research. On top of that, the increasing importance of the digital sphere and the high amount of data available there has challenged Human-Centered Design to look at the online dimension as an additional research context (Seemann, 2012). While marketing agencies have integrated web metrics and social listening tools in their practices to use the big data to better understand and segment their market[2], the Human-Centered Design discipline hasn't offered yet a set of methods to easily collect and use that information in the design process. This information might be extremely useful to mitigate and overcome the common limits (Chapman and Milham 2006) and scepticism (Cabrero et al. 2016) regarding the use of personas and more generally of "simplified accounts of people" (Turner and Turner 2011, Floyd et al. 2004).

With this paper we want to propose a hybrid approach that looks at the digital space as a field for quantitative and qualitative investigation in a sustainable and approachable way, providing a method that could be easily integrated in the Human-Centered Design toolbox.

3 Digital Methods

We argue that using digital data and analyse them both qualitatively and quantitatively can be extremely useful in complex social, technical and economic contexts where design is called to intervene. Proving this hypothesis requires to address different lingering challenges facing design theory and practice (The Design Collaborative 2014): How to cope with a heterogeneous and conflicting spectrum of values and interests? How to collaborate with other disciplines. How to stabilise specific research methods and protocols? How to test them in large scale empirical experiments?

While we will try to tackle the latter two questions further in the article, the first two ones are related to the controversial nature of the issues faced by design intervention. This is the case of all those issues where their very same definition is questioned by various actors and is redefined by the means of new technologies, governance settings and social representation (Venturini 2009). To study them, a specific research methods emerged, called Controversy Mapping (Latour 2007). Controversy Mapping proposes a data-acquisition protocol drawn on the theories and practices of Digital Methods of research (Rogers 2009, 2013). They exploit the wide range of traces that are left on the Web by the very actors of the issue under analysis. Digital Methods further a social research approach taking advantage of the empirical capacities embedded in online activities (Schneider & Foot 2004) with their unique dynamic nature – a mixture of ephemeral and permanent elements – (Hewson 2003).

Digital Methods differ from the *big-data* research programs. The emphasis of Digital Methods is not in the magnitude of digital data analysed but in the critical affordances deployed by the data-acquisition protocol. Digital Methods protocols are deriving significant findings from relatively small, *ad-hoc designed*, data-sets (Marres & Weltevrede 2013). By following a series of iterative steps and refinement procedures, the final formatted data are carved out of informational disarrays and unformed mass of online digital objects. This process has the advantage of avoiding the risk of projecting pre-existent categories on the issue in analysis. Being a challenge of data selection and curation, they provide, through the redaction of their protocols, an evident and traceable inspection of the qualitative decisions taken to compose datasets and corpora.

[2] One of the best example is offered by the Linkfluence (linkfluence.com).

4 Digital Methods and design disciplines

Until now the disciplinary exchanges between Digital Methods and Design disciplines mostly concerned two methodological procedures. On the one side design disciplines, and particularly Communication Design, have strongly contributed to produce the new graphical means required to visualise and represent digital data and information (Ricci 2010, Venturini et al. 2015, Mauri 2017), reinforcing the role of a *visual culture* into social research[3]. On the other, design disciplines have contributed during these experimentation and research projects with some organisational and management techniques. Typical of Digital Methods researches is the concept of sprints. These temporary gathering of social and computer scientists, designers and activists, are often traced back to the *hackathons* (Venturini et al. 2016) or to other compressed, rapid and collaborative forms of collaboration like *Book Sprints* (Berry 2015). Neglected in these two accounts is the contribution of the design discipline in installing a participatory-in-nature work environment, sustained by the creative engagement of the participants. A sprint, in design terms, would be called *design workshop*[4] (Hanington 2006).

While the contributions on data visualization and on the reinforcement of non-conventional collective and participatory working practices have been fundamental to the development of Digital Methods, scarce are the traces of a reciprocal hybridisation. Nonetheless, Rogers (2014) argued that designers involved in Digital Methods learned more about other's disciplines procedure rather than improving on their own. We argue that, eventually, also Design discipline, and particularly Human-Centered Design, could benefit from the synergy developed with Digital Methods. In the following section we will describe an experiment in developing a proper method, the *Data-Driven Personas* that repurpose Digital Methods, for investigating, and intervening in complex social and technical environments.

5 Data Driven Personas

To propose a fertile synergy between Human-Centered Design and Digital Methods, and set the ground for a replicable empirical methodology, a full-scale test has been conducted. The initial hypothesis for this research is that it is possible to understand users' behaviours, needs and expectations we are designing for by collecting and studying their online traces. Distilling relevant information out of these online traces can lead to the identification of clusters of users to be then described as personas. The test has been set up drafting the *Data-Driven Personas* method on an ongoing research project investigating the issues raised by urban nature in Paris: The NATURPRADI[5] project.

[3] One of the best example is the EMAPS project (emapsproject.com), funded by the European Commission in the FP7 "science in society" programme. It was aimed at exploring "the opportunities and risks in the use of the web and the social media as a meaningful information tool and for developing a participatory communication between scientists and the different publics". The project focused on the emerging uses of the web as a tool of collective endeavour and public debate, in two particular techno-scientific issues (aging/life expectancy and climate change adaptation) and developed an "open-air" experiment developing an online interactive platforms (climaps.eu). Other experimentations acknowledged a peculiar assemblage of design research groups and design studios. A successful experiment (chemicalyouth.org/visualising-erowid) has been conducted in the Chemical Youth project by the University of Amsterdam that thanks to the collaboration with Calibro, a small design agency, developed original methods to collect and visualise information about the use of drugs from a specialised on line discussion space.

[4] A typical design workshop such as a research-sprint, constitutes, as noted by Muller (2003), a "third-space" in which different knowledges are catalysed towards a common outcome "which emerge through negotiation and co-creation of identities, working languages, understandings, and relationships, and polyvocal (manyvoiced) dialogues across and through differences".

[5] NATURPRADI – Urban Nature in Digital Practice(s) – is a 3 years research project funded by ADEME (French Environment and Energy Management Agency) as part of MODEVAL-URBA 2015 call for project. It started in September 2016 and is led by the LAVUE Architecture and Anthropology laboratory, which partnered with the City of Paris Office of Green Spaces, the Museum of Natural History Eco-anthropology and Ethno-biology laboratory, the Paris Urbanism Agency, and Sciences Po|médialab.

5.1 *The NATURPRADI project and its Digital Methods campaign*

NATURPRADI is aimed at observing and describing the effects of the many initiatives endorsed by the Paris municipality to revegetate the city. These initiatives are trying to produce *smart* solutions to a growing range of issues created by urban growth[6]. Nevertheless, there is no agreement on the imaginaries and technical practices that should be included into this new urban nature (Gandy 2006). Urban nature issue, while representing a vast field of socio-technical experimentations, on the one hand, nature is seen as an aesthetic strategy to create the perception of a city that integrates (itself in) nature to secure better health conditions. On the other, nature is seen as an engineered process and as a technical solution, for example to the "heat island" effect. But, beyond these objectives, green urban design has also been used as a "mask" for a capitalist urbanization resulting the social inequalities of "green gentrification". Furthermore, engineered forms of urbanity are strongly entailed to corporate and technocratic visions. These mainstream narratives, obfuscates a muffled collection of contested natures (Macnaghten & Urry 1998), fabricated by technological and environmental objects and socio-cultural processes (Gandy 2002), urging for public participation and engagement.

To observe, monitor and, eventually, produce elements of reflections for future urban policies, the NATURPRADI project is mapping the symbolic and material elements of the urban nature debate (Ricci et al. 2017). The research project is aimed, at exposing the different social, political and technological issues associated to urban nature; its actors, and the controversies caused by alignment and misalignment of interests. The NATURPRADI project seeks to explore how the future mosaic of urban nature in Paris by observing how objects, places, practices and technologies are mobilised, re-appropriate and discussed in the public arena. To achieve its objective, NATURPRADI started a Digital Method campaign by collecting digital-native contents produced on Twitter. The online news and social networking platform has been chosen since it is broadly used by a variety of actors getting spontaneously organised around discussion topics by using hashtags. Twitter, presenting the concrete opportunity for "empirical sociocultural research" (Burgess & Bruns 2015), has become, over the years and despite its transformation, an object of study and a data source for research scopes (Rogers 2013b).

The core of the NATURPRADI project is to investigate and elicit users' viewpoints and actors' perspectives on urban nature. In the project it has been possible to observe and describe the different sub-topic composing the debate on such delicate issue. The project has identified these topics and how they are sustained by specific communities and populated by identifiable users, each of them proposing an instantiated vision of the future Parian urban nature. For this reason, NATURPRADI has provided the great opportunity to test a new process moving from users to personas, through a combination of quantitative and qualitative methods of analysis. Here we argue that the critical re-appropriation and the repurposing of Digital Methods could be an efficient resource to support the Human-Centered Design practice when dealing with complex issues.

5.2 *The process of distilling Data-Driven Personas*

The Data-Driven Personas method could be summarised into four macro-phases (Figure 1):

1. **Data collection**, aimed at grafting the Human-Centered approach on Digital Methods defining the nature and the scope of the data harvested as well as their limitations;
2. **Exploration of the discursive space**, aimed at finding an entry point of the investigated topic, displaying the constellation of debates emerged from the collected data.
3. **From cluster to communities**, aimed at finding the cohesive communities composing on a

[6] In the last decade a vast array of new policy devices – the Budget Participatif initiative, the project Du vert près de chez moi, the regulatory grant Permis de végétaliser, the charter Objectif 100 hectares, the Parisculteurs call for project, a digital platform called Végétalisons Paris, have been developed to engage with citizens, national and multinational companies and local public actors, with a mix of bottom-up and economic incentives, to promote greening initiatives, share best practices, and develop communities of urban gardeners and biophilic supporters.

specific issue who can then be turned into personas;

Personas descriptions, aimed at describing each personas, making use of the most relevant qualitative and quantitative aspects of data, emerged during the research process.

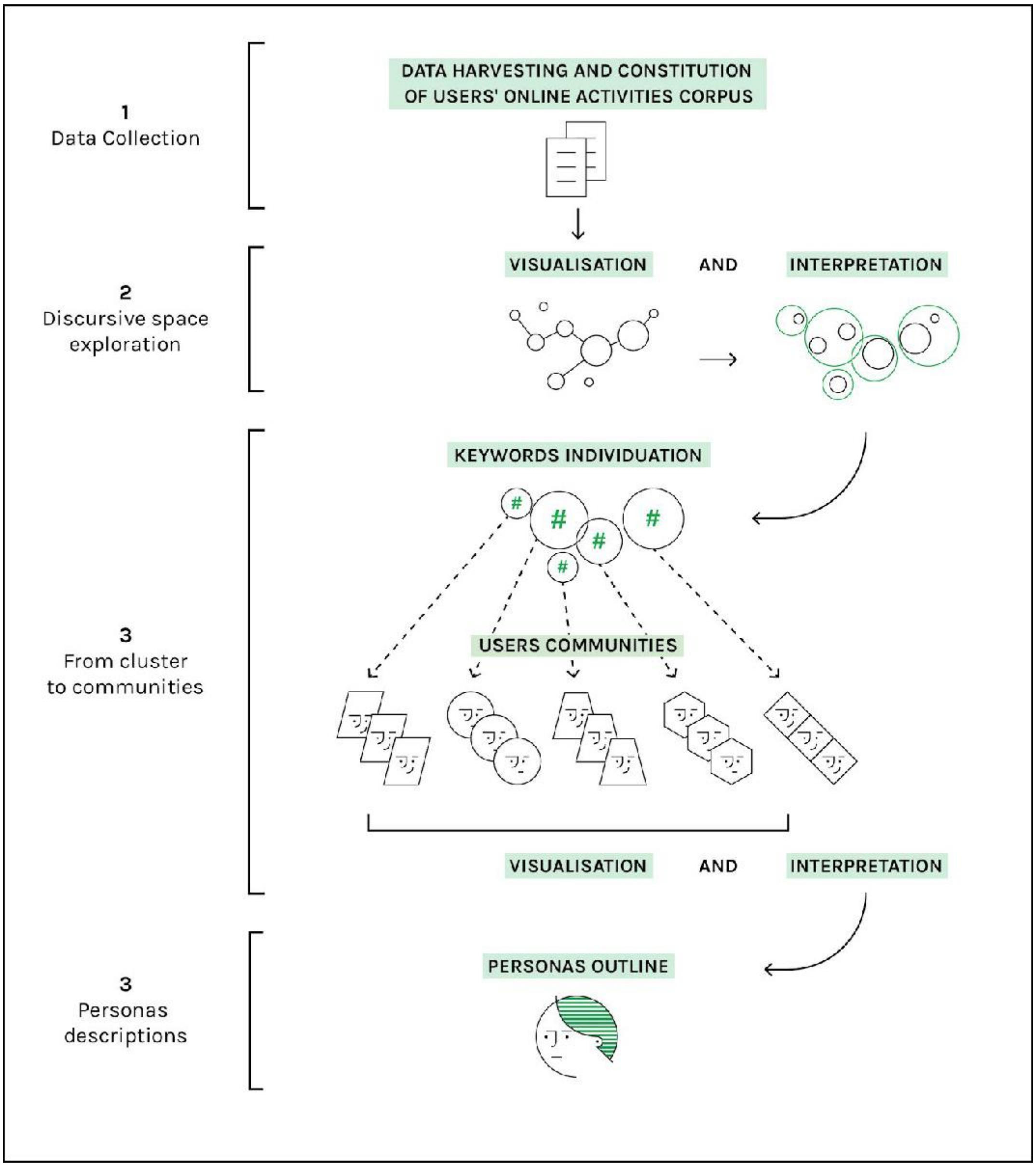

Figure 1. Methodology process

5.3 Phase n.1: Data collection

Objective: Define the nature of the information to be collected and set up the protocol to harvest the corpus of data.

To start harvesting and collecting the data for the distillation of the Data-Driven Personas, requires a deep understanding of the bias induces by the kind of users' traces (e.g. hyperlinks, tags and hashtags, threads, ranks or edits) collected for the analysis and by the services, platform and devices that are *offering* them (e.g. Facebook, Twitter, Wikipedia, blogging platform, search engines). Every Digital Method approach poses under scrutiny which digital objects are provided by the different devices. This has been the case for the NATURPRADI project. After having chosen Twitter for collecting the manifestations of interest, proposition and disagreement towards the Parisian urban nature, among the several methods and technique for harvesting of tweets, the Streaming API[7] has been adopted. It has required to acknowledge and consciously embrace its limitation[8], specificity and embedded politics (Gillespie 2010, VanDijck 2013), technically, rhetorically and culturally expressed (Gillespie 2014). Only their clear understanding, obtained for example through the collaboration with Digital Methods experts, allows later on in the process to mitigate and validate the results of the process.

Among the different approaches for Twitter corpora building (see Mayr and Weller 2017) it has been chosen one based on key expression query. Through a collaborative and participatory procedure among the members of the NATURPRADI consortium a list of 158 expressions (Figure 2) has been used to capture the tweets mentioning them.

It has to be remarked that although this procedure has granted satisfying results, it is impossible to achieve a kind of "completeness" about the tweets referring to a specific issue. Users can always use different wording, or certain pertinent tweets may have been not capture because they didn't mention any keyword of the list. As partial mitigation of this bias, once a tweet part of a conversation has been captured the entire discussion to which it belongs has been retrieved. To assure a territorial specificity to our corpus we queried only for French word. In addition to this, all the keywords are queried by adding the word "Paris"[9].

agriculture - agricultures - agriculture biointensive - agriculture verticale - agroforesterie - agrosylviculture - alimentation proximité - #AMAP - aquaponie - arboriculture - arbre - arbre alignement - arbres alignements - arbre urbain - arbre_remarquable - arbres - arbres urbains - arbres_remarquables - arbuste - arbustes - architecture écologique - aromatique - aromatiques - association_végétale - bande_enherbée - biodiversité - biodiversité batiment - biodiversité jardin - biodynamique - biointensive - botanique - botaniques - cartographie végétation - chantier nature - compost - composts - compostage - compostages - conservation nature - corridor biologique - corridors biologiques - "coulée verte" - "coulées vertes" - développement - durable - éco-habitat - ecoagriculture - écocitoyenneté - écoconstruction - écologie urbaine - écologique - écologiques - écoquartier - écoquartiers - espace vert - espaces verts - ferme verticale - fermes verticales - fleurie - fleuries - flore des murs - floriculture - forêt - forêt urbaine - fragmentation écologique - fruitier - fruitière - fruitiers - génie écologique - génie_écologique - gestion différenciée - graminée ornementale - "guerrilla gardening" - horticulture - horticulture urbaine - îlot - îlot chaleur - îlots chaleur - incroyables comestibles - infrastructure verte - jardin - jardins - jardin communautaire - jardins communautaires - jardin ouvrier - Jardin-forêt - jardinage - jardinage collectif - "jardin familial" - "jardins familiaux" - "jardin public" - "jardins publics" - "jardin sauvage" - "jardins sauvages" - jardinage urbain - jardins ouvriers - matrice écopaysagère - micro-agriculture - micro-ferme - micro-fermes - mur végétal - mur végétalisé - murs végétalisés - murs végétals - naturalité - nature - observatoire paysage - patrimoine naturel - paysage urbain - paysages urbains - permaculture - plan climat-énergie territorial - plante - plante grimpante - "plante utile" - plantes - plantes grimpantes - polyculture - potager - potagère - potagères - potagers - prairie - prairies - prévégétalisation - "produit local" - "produits locaux" - alimentation proximité - renaturation - "réseau écologique" - "réseaux écologiques - résilience écologique - soutenable - soutenables - stratégie biodiversité - sylviculture - système d'information sur la nature et les paysages - terrasse végétalisée - terrasses végétalisées - toit-terrasse - toits-terrasses - toiture - toitures - trame verte - trame_verte - trames vertes - végétale - végétales - végétalisation - végétalise - végétalises - végétalisée - végétalisées - végétation - verger - vivrière - grenelle environnement - effet serre

Figure 2. The final list of expressions used to retrieve the tweets. All of them have been used in combination with the word "Paris"

[7] These API offers the possibility to retrieve only live data, imposing bandwidth limitations coming into effect when the requested tweets exceed the 1% of the all traffic flowing in the platform.

[8] A limitation affecting Twitter based researches is linked to its representativeness (see Blank 2016). Although Twitter is widely used all across the world, its adoption rate changes accordingly to different social milieux and the way it is used may differ significantly from country to country. In the NATURPRADI project there is no assumption about the possible exact extension of the observed digital population to the general one.

[9] To assure that the final corpus would not been biased by tweets not related to Paris or to the urban nature, a further curatorial procedure has been applied. Through a custom and open-source software (the source code is available here: https://github.com/medialab/catwalk), every tweet has been read by the research team and evaluated in terms of its pertinence. This approach, distinguishes the NATURPRADI project from many other big data ones. Furthermore, the close reading of the tweets enabled us to have a constant overview of the state of the discussion, gaining a deep understanding of the dynamics of the issue. This aspect resulted to be extremely useful in the analysis and interpretation of the data.

5.4 *Phase n. 2: Exploring the discursive space*

Objective: Visualise the corpus in order to get a synoptic view on the issue under analysis and identify the main components.

Many controversial and complex issues, as the case of urban nature, emerge from social, biological, political and technological interplays, requiring a series of mixed analysis and visualisation approaches able to document and expose visually the different discourses that emerge from them. In order to grasp the complexity of the issue, a set of visualisations aims at exploring the different topics that constitute it and how they are related to each other constituting in this way a heterogeneous discursive space.

Identifying the clusters of people and verbal expressions for each topic results in a first formulation of *personas hypothesis*[10][10] (Cooper 2014).

In the case of the test with NATURPRADI, the visualisations consisted in a series of graphs[11] showing how different users are attached to each other and the specific words used in the tweets. Reading and interpreting the graph it could be remarked the centrality of an institutional cluster featuring linked to the municipality (@Paris, @Anne_Hidalgo, @PKOMITES and @vegetalisons). On the left of this group, there is a cluster concerning urban farming and bio-agriculture activities. In this cluster is located the municipality's initiative *Parisculteurs* that finances interventions relate to green and agricultural urban areas. On the right of the institutional accounts, lays a cluster about participative initiatives deployed by the municipality of Paris to promote the citizens' engagement, like the *Permis de Végétaliser*. Furthermore, another relevant cluster is located under the institutional accounts, it features ecology and recycling related topics. Looking at the right edge of the discursive space, there is the cluster where all the famous green areas of Paris are mentioned. Finally, at the opposite edge, can be detected the cluster about innovative agricultural techniques and startups.

On the basis of this quali-quantitative interpretation of the graph, sustained by a visual analysis of the network[12], five key clusters can be identified (Figure 3):

A. **Technological Development**, featuring innovation initiatives and project in the agricultural field;

B. **Urban-Agriculture**, featuring bio-agricultural projects developed inside the city of Paris;

C. **Co-design of Public nature**, featuring all the debates around the participatory activities endorsed by the municipality;

D. **Ecological attitude**, featuring the concerns about the ecological transition like the domestic recycle of wastes.

E. **Relaxed Contemplation**, featuring the discussion about outdoor activities around Parisian gardens.

The exploration of the discursive space and the description of these key-clusters allowed to identify the topics most vibrant and relevant for the users are the most vibrant and. Drawing upon these overlapped delimitations, the process has moved towards a finer description and characterisation of the users present in each cluster.

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[10] The persona hypothesis is a first attempt to define the different kinds of users for a product or service. The hypothesis serves as an entry point to start with the interview planning.

[11] The graphs have been produced using the tweets of the trimester January-March 2017, the same range has been used throughout the entire process. To produce the networks, the elements contained in a single tweet
—mentions to other users and hashtags and other relevant n-gram has been transformed in a clique. The combination of these cliques produced the final network.

[12] The visual network analysis is based on a spatialization achieved through the ForceAtlas2 algorithm (Jacomy et al. 2014).

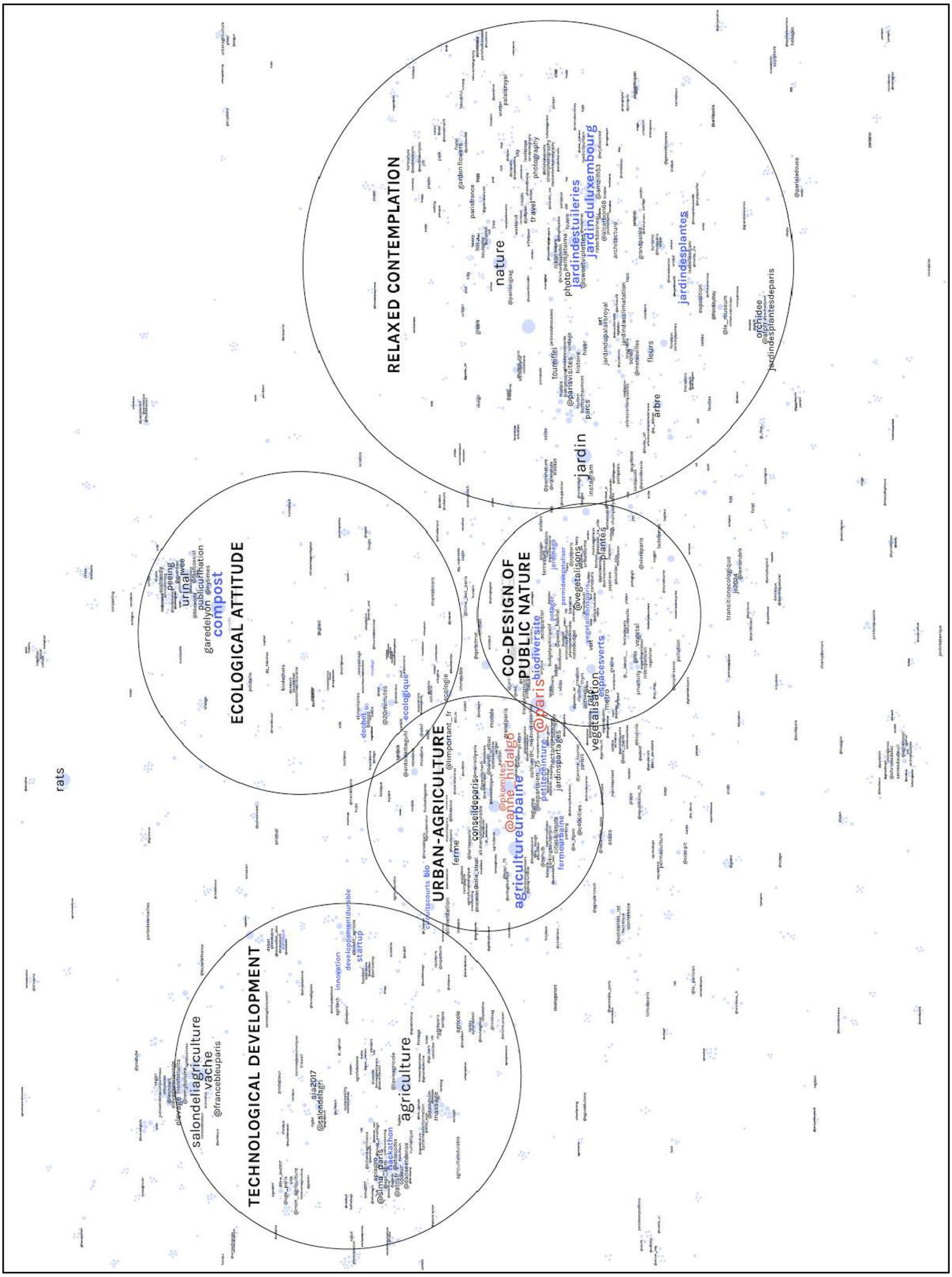

Figure 3. The trimestral tweets user-object networks

5.5 Phase n. 3: From cluster to communities

Objective: Analyse each sub-topic, identify the communities linked to them, and understand if they represent a unique behaviour.

While the *exploration of the discursive space* allows to quickly highlight the most relevant topics and clusters composing a complex issue, through a deeper analysis it is possible to closely identify the users that populate them and discover if they represent a cohesive community. To achieve this objective, it is necessary to detect some distinctive features characterizing each cluster. They might be the most specific used terms or external references used in the discussions. Then the collected corpus of digital traces has to be subdivided into sub-corpora using the detected features in order to isolate the users forming each cluster.

In the NATURPRADI test, for each cluster a list of keywords[13] w produced to assign the users to one or more specific communities. For instance, a user is part of the *Ecological Attitude* community whenever she used at least one of the keywords *compost, ecologique, dechet, tri*. If that same user wrote any keyword related to other clusters, she would appear also in those communities[14] (Figure 4).

SELECTED KEYWORDS

A. Technological development:
startup, innovation, developpementdurable, hackaton

B. Urban-agriculture:
agricultureurbaine, fermeurbaine, petiteceinture, circuitscourts, bio

C. Co-design of public nature:
biodiversite, espacesverts, vegetalisonsparis, potager, jardinage, permidevegetaliser

D. Ecological attitude:
compost, ecologique, dechet, tri

E. Relaxed contemplation:
jardindestuilleries, jardinduluxembourg, jardindesplantes

Figure 4. The selected keywords for each cluster used to retrieve the communities of users which used these words in their tweets

The corpus is then used to understand if, besides debating about the same topic, they also debate in a similar way. Just like when the researcher carries out field investigations to collect more insights about how people live, the visualisation and interpretation of different aspects of users' online activities become an iterative process that enables to progressively validate the cohesion of communities. This iterative process consists in visualising the multiple dimension of the corpus (e.g. images, texts, links), then in interpreting the results to understand if there are similar communities

[13] The keywords have been selected by their frequency, their specificity (for example nature has been discarded because too generic) and their non-ephemeral nature (for example fashionweek). Furthermore, when there two or more terms share same root, only the most recurring one has been chosen (e.g. ecology and ecological).

[14] A user can belong only to one community as well as more than one. In the latter case, one could imagine analysing more thoroughly only those users belonging both communities to see if they constitute a separate and distinct behaviour.

which can be merged together and considered as a unique behaviour or, on the contrary, if inside a community more than one distinctive behaviour can be discerned.

In our test, we have focused on the two main elements of a tweet, its textual content and the possible images attached to it. In this way the iterative process leading to the definition of the validate behaviours has been concerned with both the textual and the visual sphere and their overlap.

5.5.1 Digging into the textual sphere

Analysing the most frequent and relevant vocabulary elements that a community use to discuss a given issue, is extremely relevant to identify both the commonalities and distinctive traits of each community. In our test, the visualisation of the textual sphere shows the 150 most recurrent terms for each community, sorted from the most to the least frequent (Figure 5). The size of each bubble is proportional to the frequency of the word. The colour of the bubbles describes how much each word is shared with other communities: the lightest the colour, the most shared the word; the darkest the colour, the least share the word – which means that it is uniquely used by a specific community.

While the most used words by the *Technological development, Urban agriculture and Co-design of public nature* have proved to be in accordance with the initial depiction of these communities, the interpretation of this visualization lead to an interesting observation concerning the *Relaxed contemplation* and the *Ecological attitude* communities. About the *Relaxed contemplation*, the names of several famous French photographers occurred among the most frequent words. This could suggest the presence of a smaller community with an interest in photography and in the historic representation of the city. The *Ecological attitude* community seems mostly linked to the uproar news of the urinal-vases installed in Paris by the municipality. Furthermore, the textual sphere appears comparable with the vocabulary used by the *Urban-agriculture* community. This could suggest that the two communities share parts of same debates.

5.5.2 Digging into the visual sphere

Analysing the images that are produced and shared by the users enables a quick introduction to the imagery of each community. While in Human-Centered researches, visual information, to better understand the users, are collected through mostly analogue methodologies like *photo-journals*[15], Data-Driven Personas make use of the images produced by users during their online activities. In order to depict the visual sphere, the images are automatically plotted according to their content similarity[16].

By interpreting the visualisation, it can be remarked that, in the *Relaxed contemplation* cluster, the sphere depicts the most famous Parisian architectures and green areas (Figure 6). This seems to be coherent with the fact that this cluster is composed mainly by tourists and those who appreciate the aesthetic role of the Parisian nature. In the lower part of the network there is a significant group of historic images, which corroborates the presence of a sub-community of *Nostalgic* users.

Repeating the process for the other clusters, the visual sphere analysis helps to understand communities' cohesion (Figure 7-10).

[15] The photojournal consists in asking a group of user to take some pictures in accordance with an assignment. BROBERG, Ole; ANDERSEN, Vibeke; SEIM, Rikke. Participatory ergonomics in design processes: The role of boundary objects. Applied ergonomics, 2011, 42.3: 464-472./

[16] For this task, it has been used the Image Tagging API provided by IMAGGA (https://docs.imagga.com/#auto-tagging). The model used by this service is trained on generic images, therefore it was considered suitable for the NATURPRADI dataset, composed of very different type of images (photos, drawings, posters, screenshots). In this way a set of tag is generated and attached to each image. A weighted bipartite network is then built using images and tags. The weight of the edges corresponds to the confidence interval that the algorithm gives for the association image-tag.

The *Start-up entrepreneur* works on agricultural research and innovation, the *Sustainability aware consumer* is interested in locally grown and produced products, the *Overactive neighbour* participates in every municipality greening initiative, the *Forever tourist* always looks at Paris with enchanted eyes, the *Nostalgic* remembers the better time of Parisian nature with a bitter smile (Figure 11).

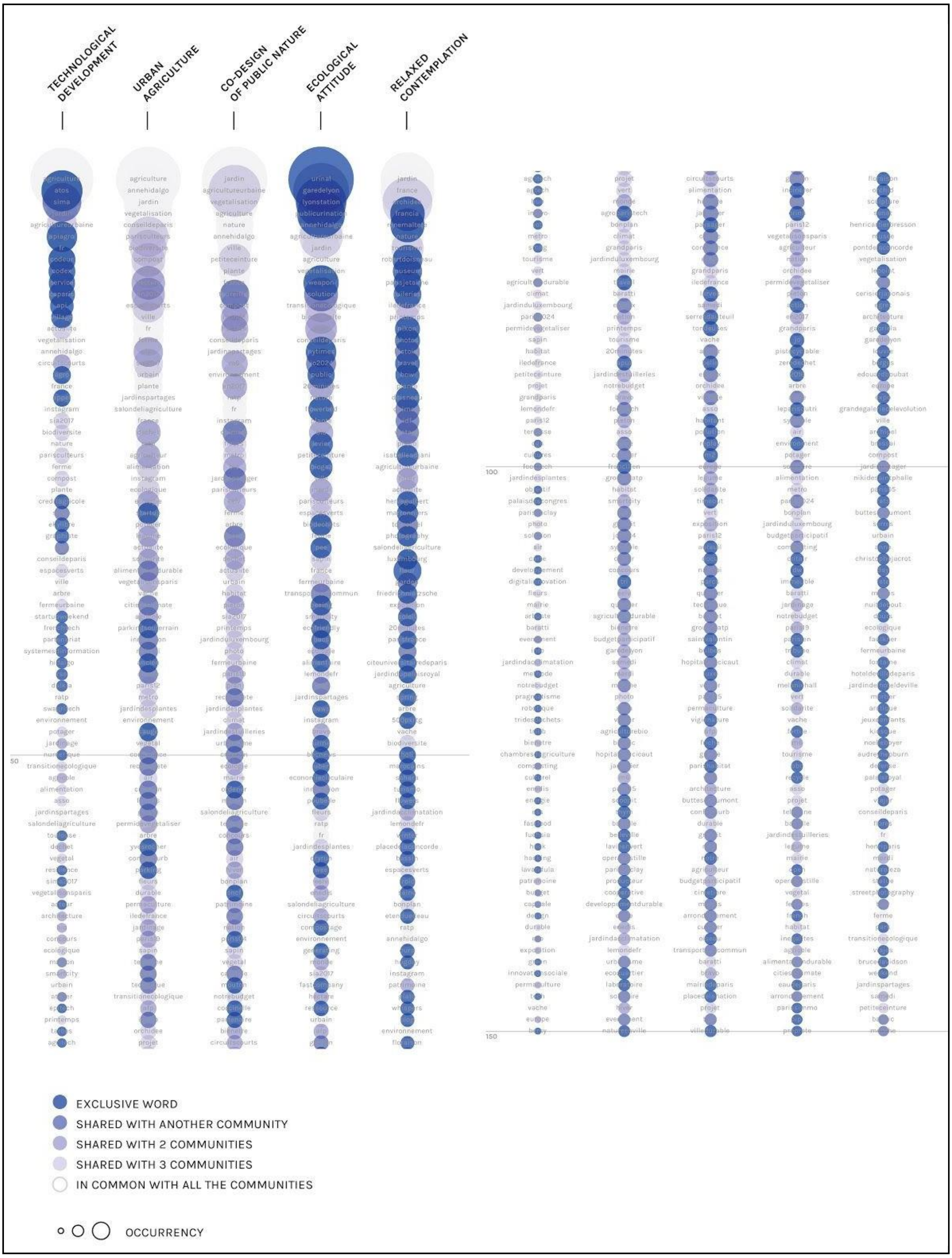

Figure 5. The textual sphere visualisation shows the 150 most used terms for each community

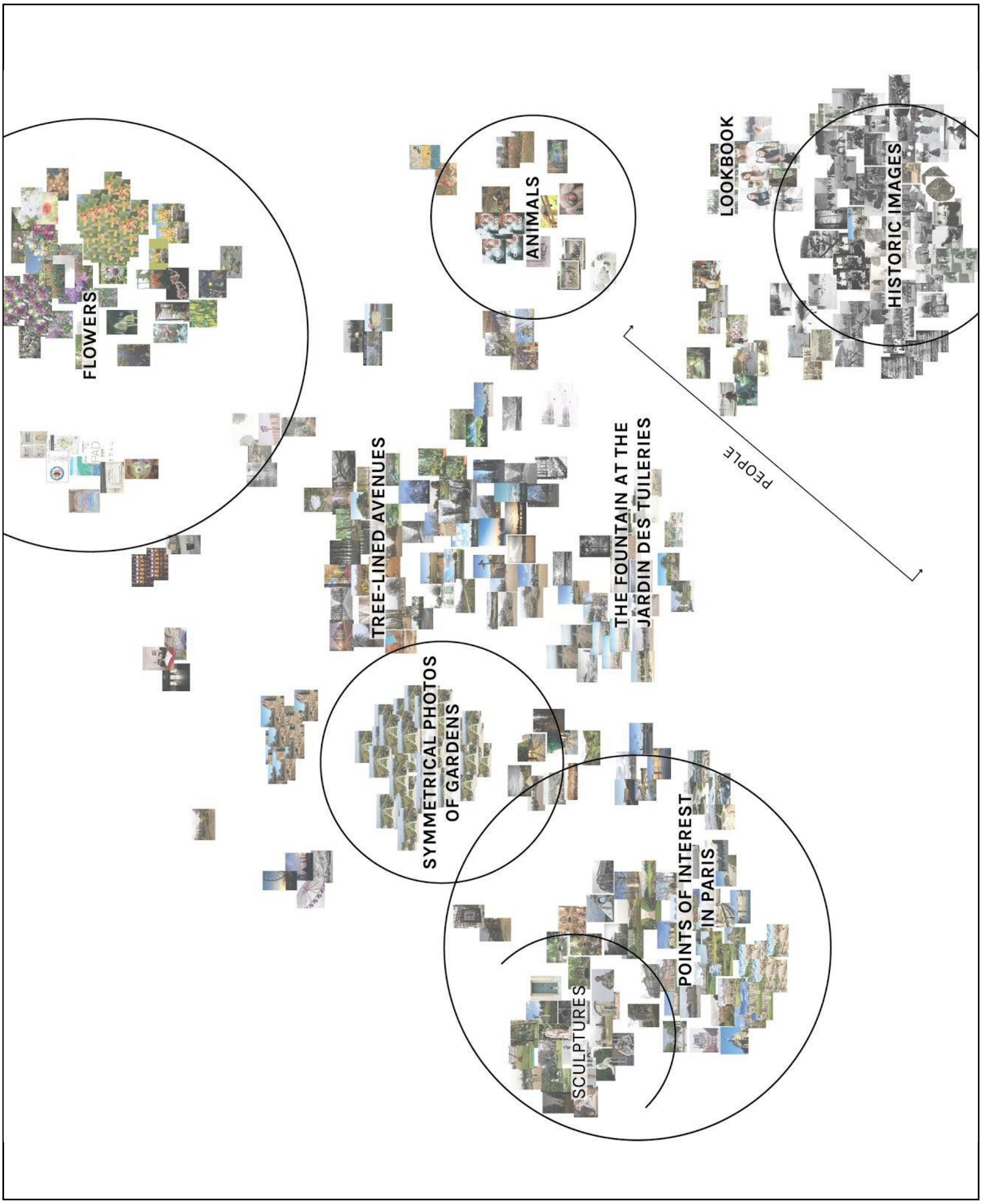

Figure 6. The visual sphere of the "Relaxed contemplation" community

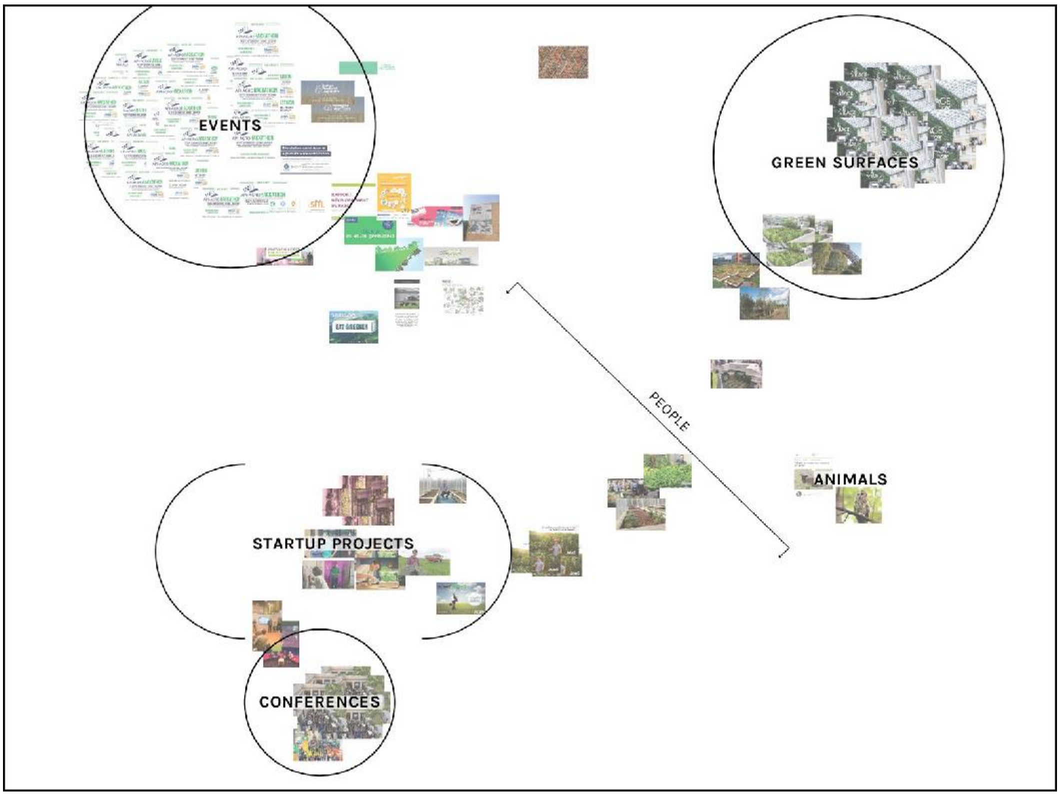

Figure 7. The visual sphere of the "Technological development" community

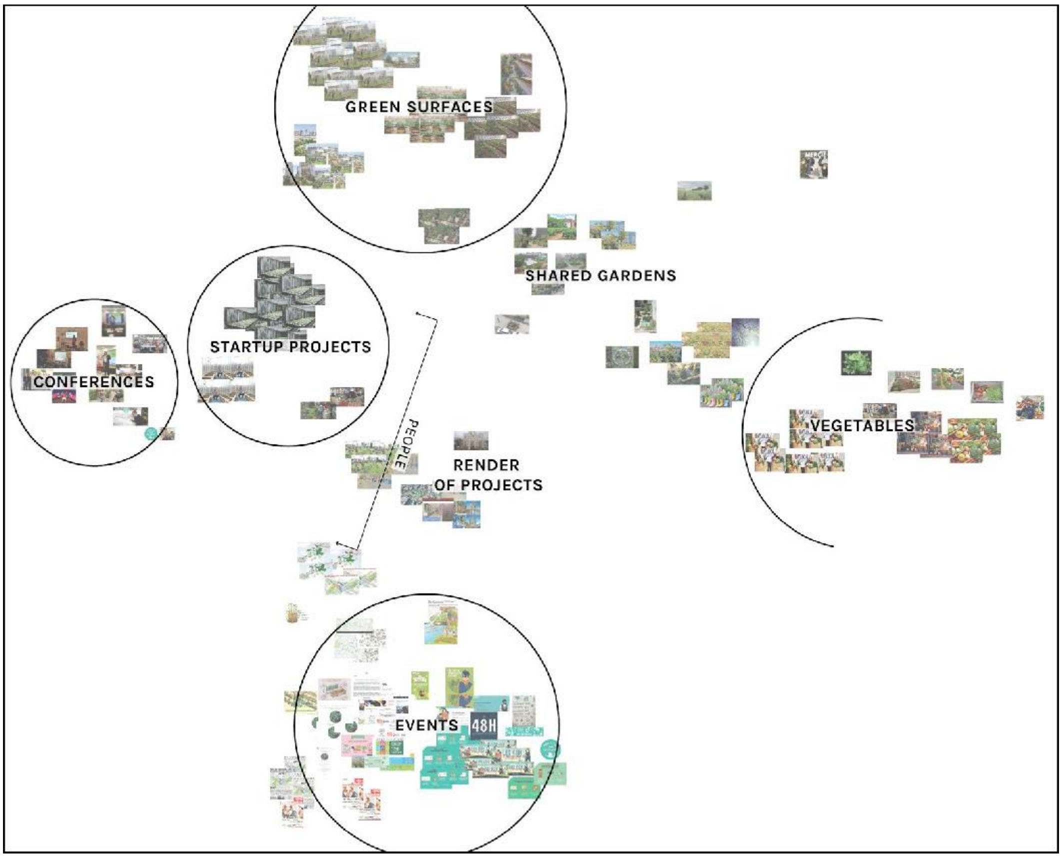

Figure 8. The visual sphere of the "Urban-agriculture" community.

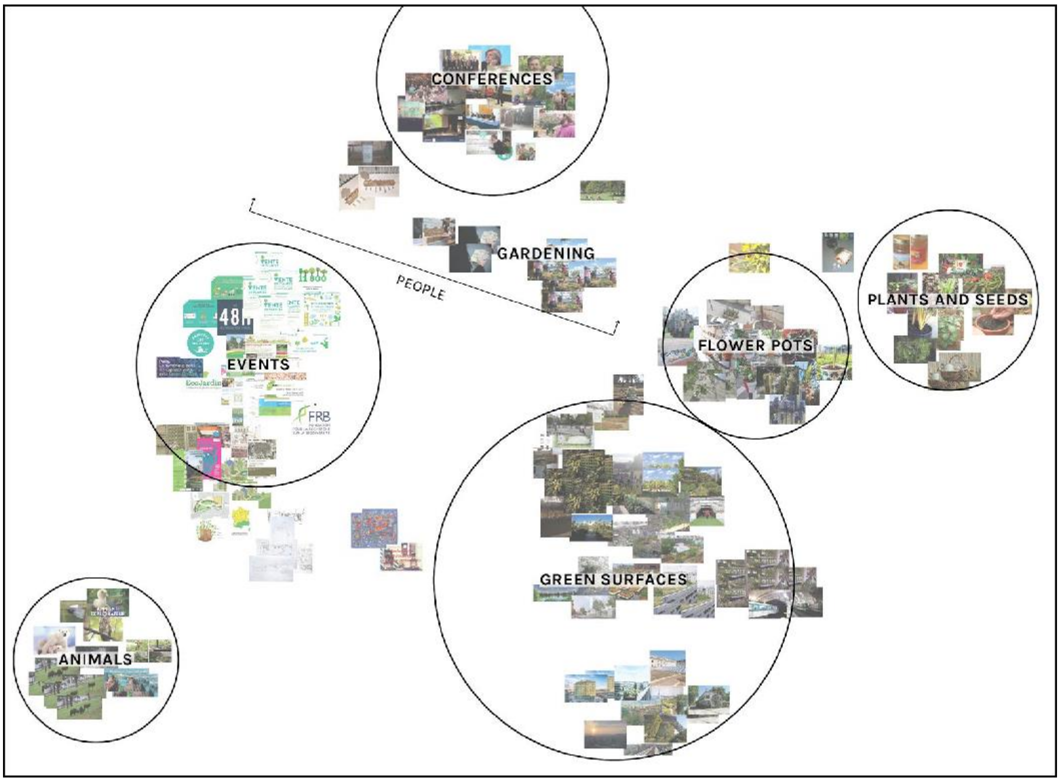

Figure 9. The visual sphere of the "Co-design of public nature" community

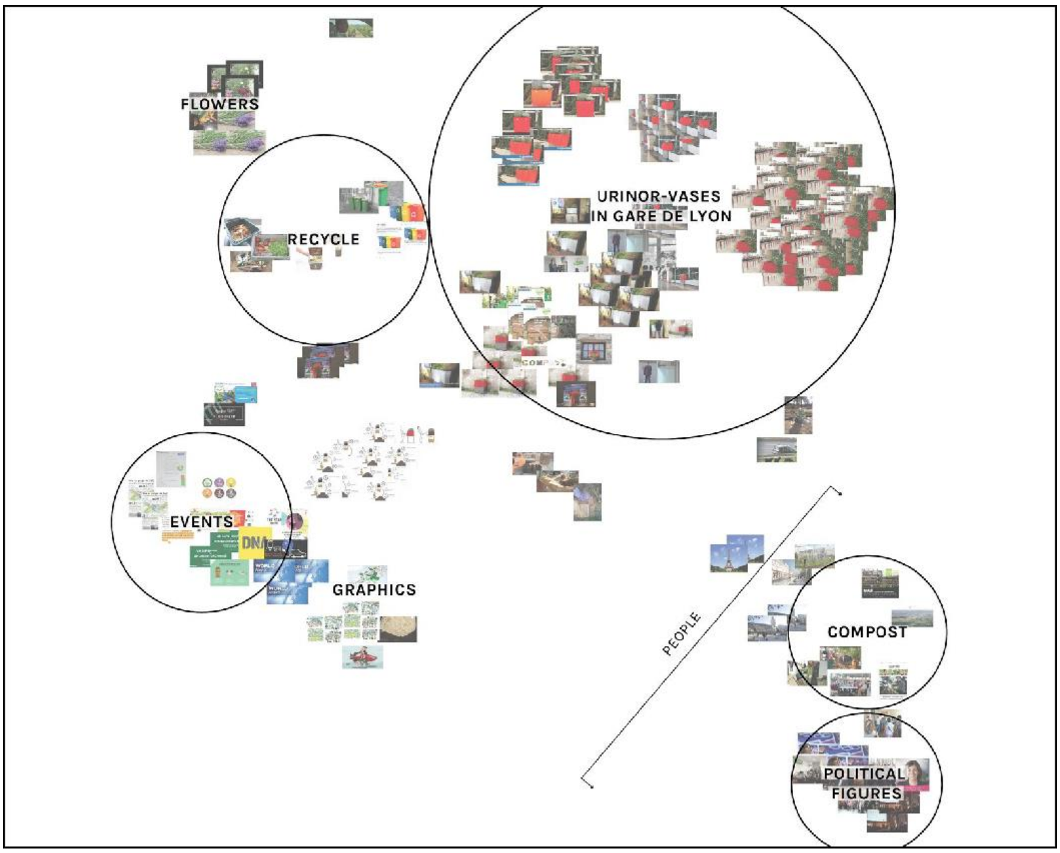

Figure 10. The visual sphere of the "Ecological attitude" community

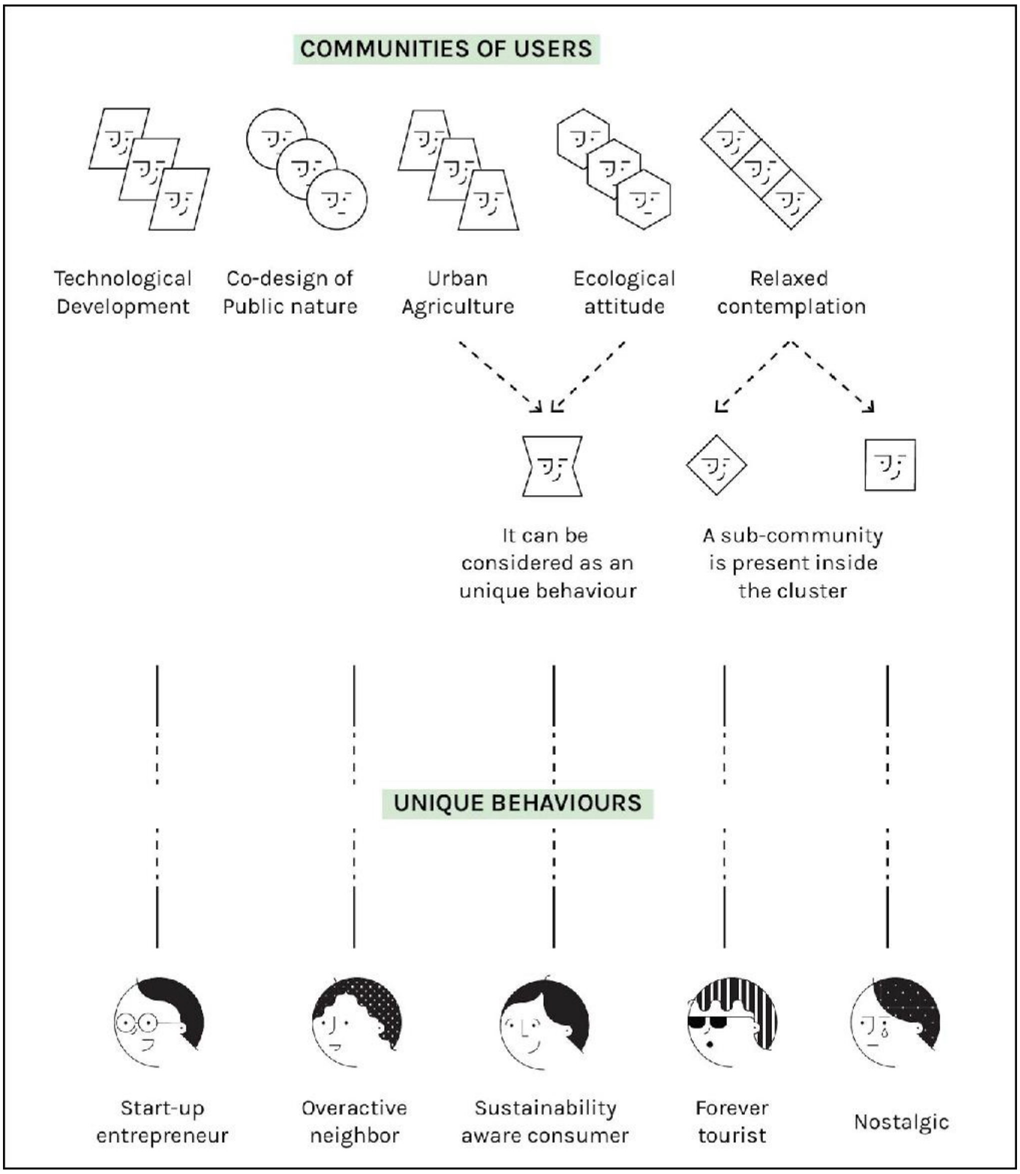

Figure 11. The visual sphere of the "Ecological attitude" community

5.5.3 Phase n. 4: Personas descriptions

Objective: Outline personas through the most relevant insights gathered during the process.

The last phase consists in moving from validated communities to personas and to build an engaging narration around those personas. Vivid descriptions of personas enable to bring fictional user profiles to life (Cooper 1998, Grudin & Pruitt 2003) and —as regards to Data-Driven Personas— this can be done by using the data generated by users during their online activities.

An advantage of the Data-Driven method is that researchers can build the profiles in a semi-automatic way by mapping users' information on the various aspects of the persona profile. At

this stage, data visualisation shifts its objectives from an analytical research tool to a way of synthesising the main aspects of each persona.

Inspired by the key elements that traditionally characterize the narration of a persona - such as a portrait photo, a relevant quote, a day-in-the life and key attributes - the descriptions generated by Data-driven personas can offer a similar narration, built through the type of data available in the digital observed sphere. The elements that compose the description of a Data-Driven Persona are susceptible of variation, since they depend on the nature of the data collected, the digital platform used for the research and the insights gathered during the process.

In the test on NATURPRADI, each persona has been outlined with the data produced by the group of users from whom that personas was created. The narration starts with the picture and the name randomly picked from those of real users belonging to that persona. The keywords which initially brought to the definition of the community and then of the relative persona are listed as its most connoting hashtags. A tweet has been selected from the data corpus, in order to represent the usual way that persona would talk about urban nature in Paris. The Twitter descriptions of users are used to narrate how each persona would describe themselves: a bubble chart visualise the most occurred terms. The most engaging images of each persona are also part of the narration, showing their visual imagery. The relationship between personas, as well as their similarity, is represented by a diagram showing how many users are unique to the personas and how many are shared with other personas, since a user could be present in more than one cluster. Each persona can be also located along the "expertise axis", telling us if - in their relationship with nature - that persona is more a contemplator or an expert. Finally, the tweets activity over time of each persona can help understand the engagement with the topic (Figure 12-16).

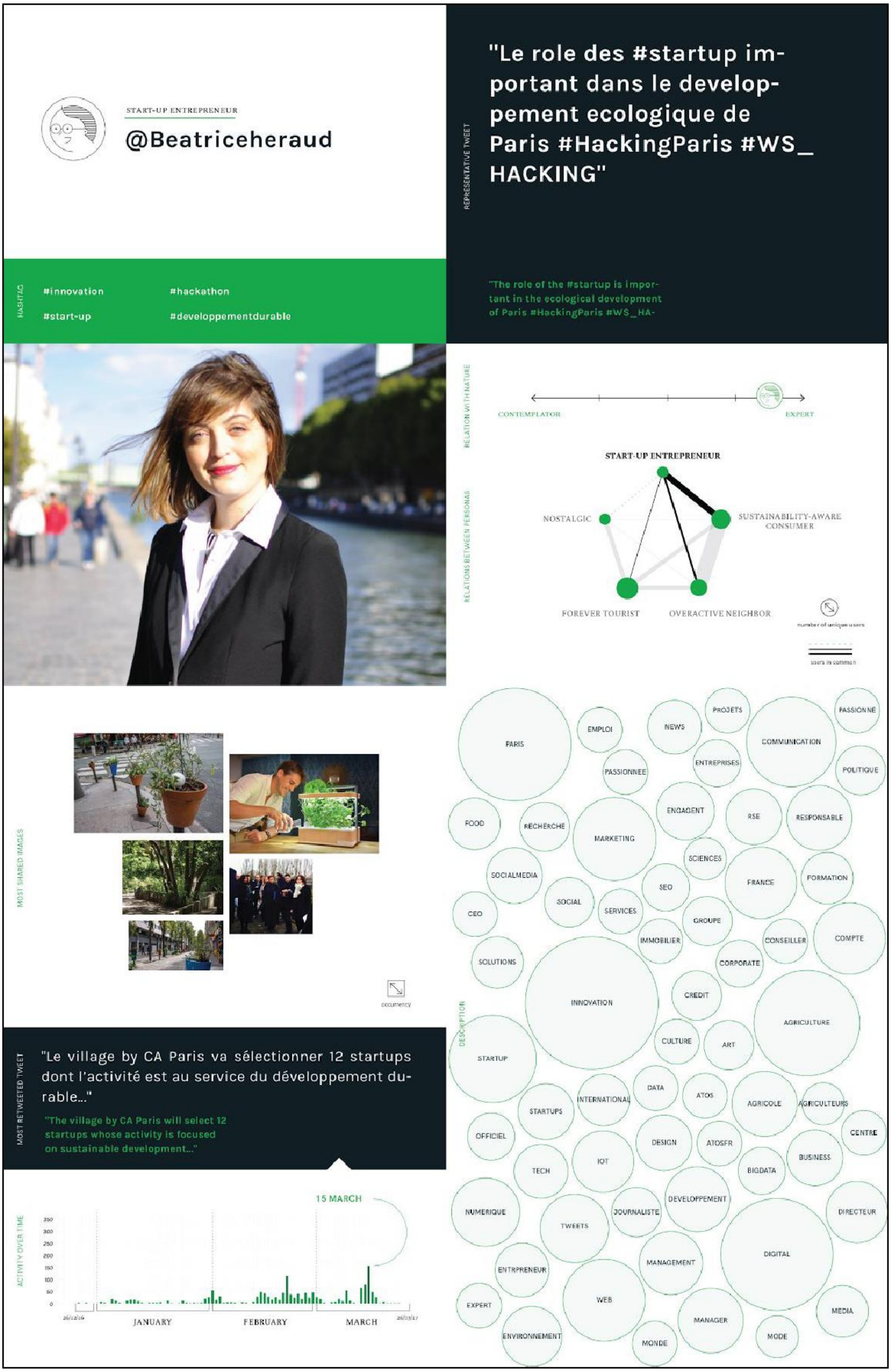

Figure 12. Description of the "Start-up entrepreneur" persona

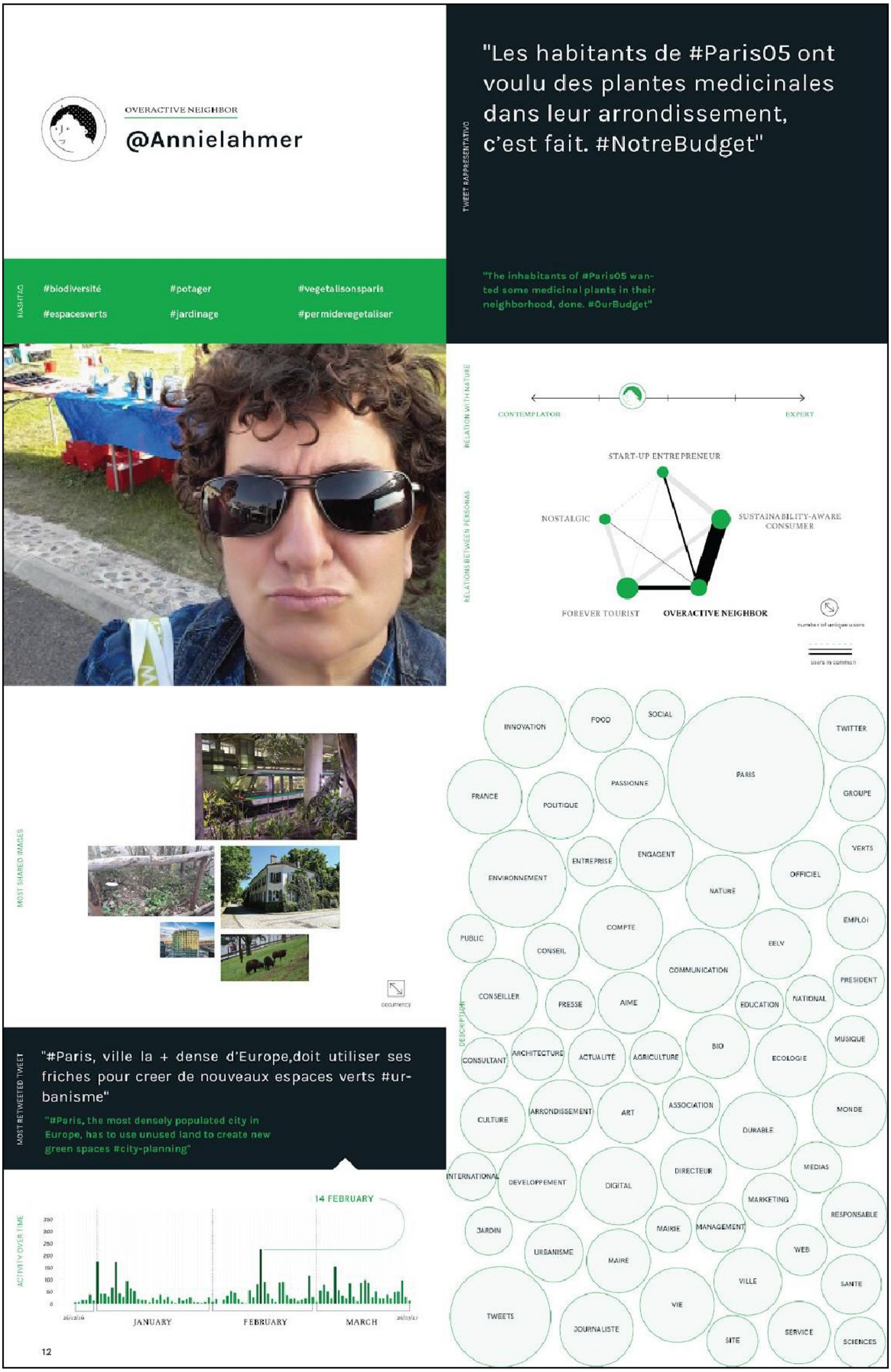

Figure 13. Description of the "Overactive neighbor" persona

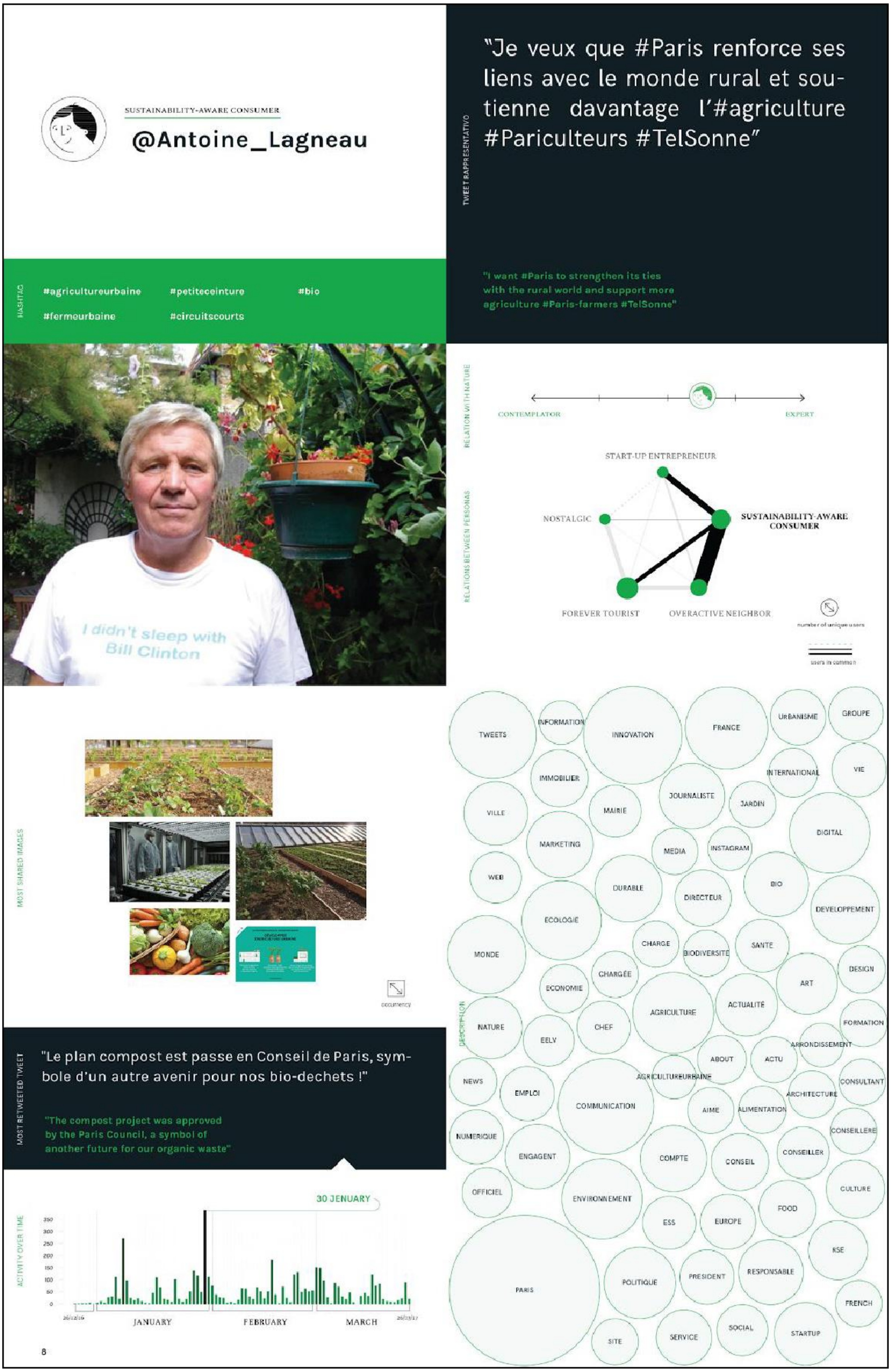

Figure 14. Description of the "Sustainability aware consumer" persona

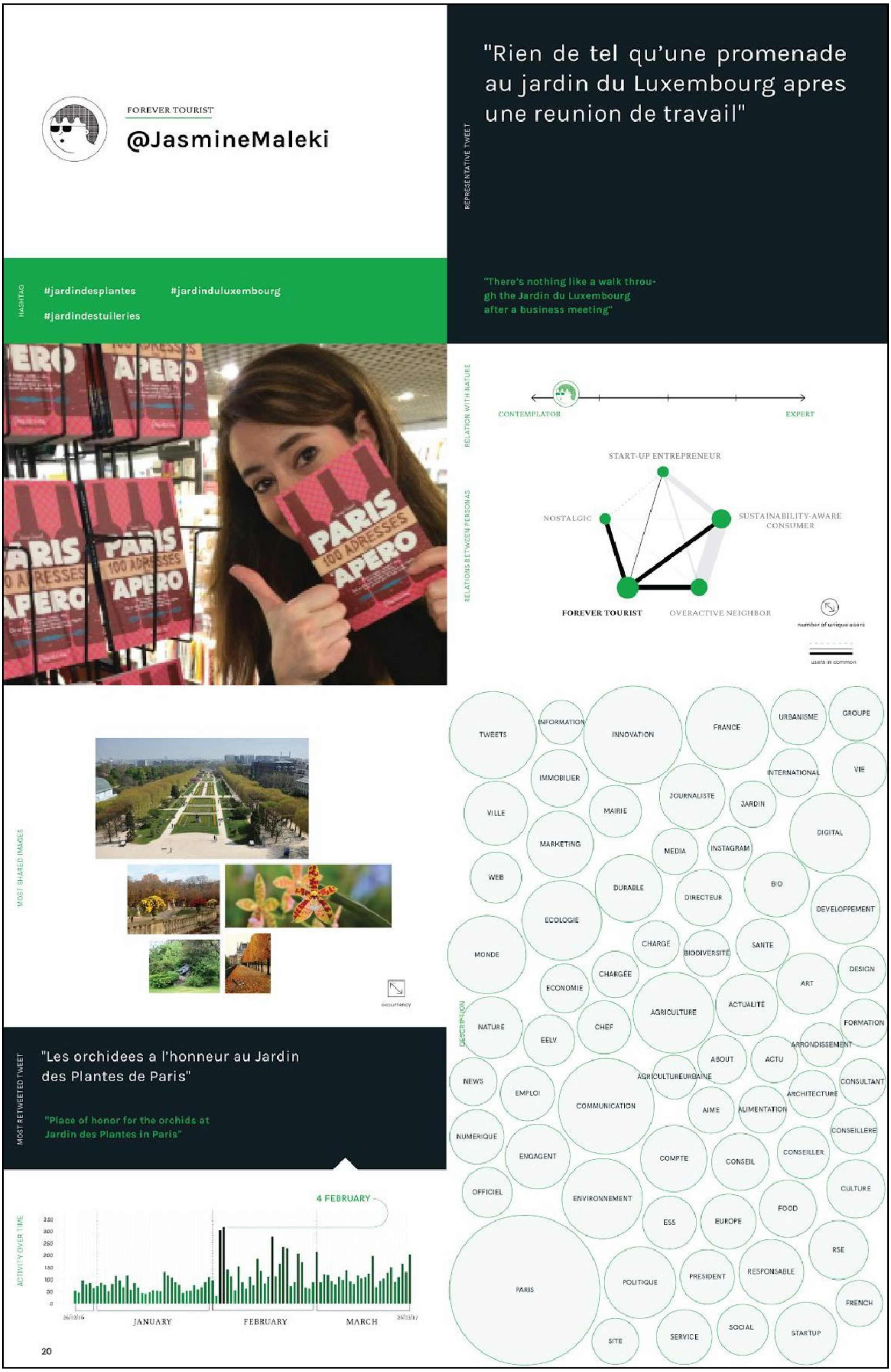

Figure 15. Description of the "Forever tourist" persona

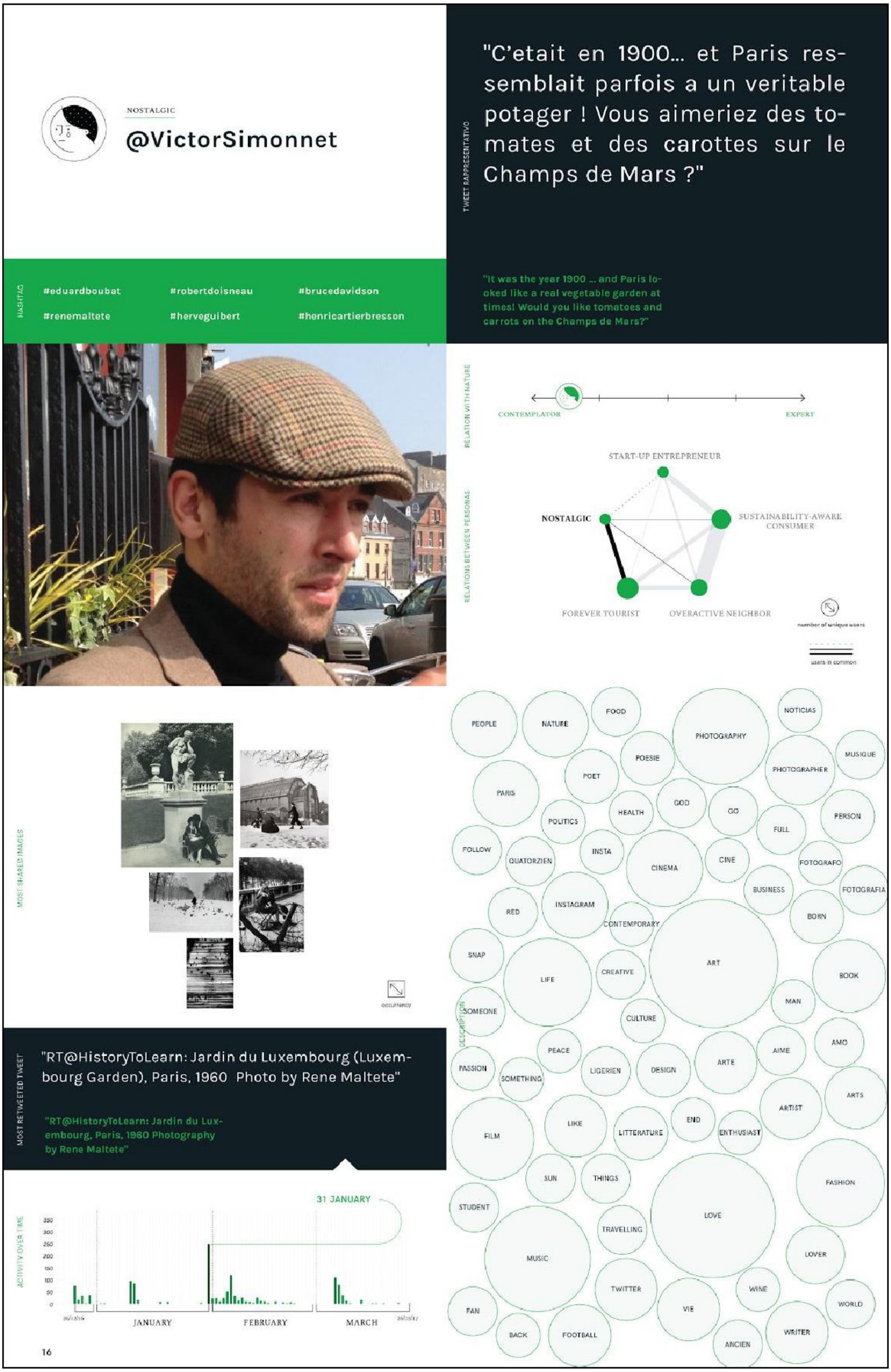

Figure 16. Description of the "Nostalgic" persona

6 Opportunities and Challenges

The new Data-Driven personas method aims to expose how Digital Methods can be integrated into Human-Centered Design, deploying new *"techniques which communicate, interact, empathize and stimulate the people involved"* (Giacomin, 2014).

Digital Methods could allow to scale up the magnitude of data and information collected. The proposed approach offers significant advantages in terms of time and costs, if compared to traditional qualitative research techniques: it allows to quickly collect and analyse a wide dataset and develop key insights even before activating the field-research and start investing on it. Nevertheless, there are some activities in the process that shouldn't be underestimated, such as:

- **Data collection:** setting up the necessary infrastructure for collecting data might take some time. Depending on the scale of the data to be collected, simple solutions like storing it into spreadsheets or plain text files (i.e. CSV) might be not appropriate and the setup of a proper and efficient database might be required. Furthermore, the API provided by the digital platform, as well as the interface through which the data might be scraped, tend to change rapidly. This may affect the quality of the harvesting, or at least, require a continuous monitoring, tracking and adjustment of the collection procedures. Working with digital data means to respect the ever-changing privacy policies and terms of use of the platforms involved in the research. Along with the respect for these standards, an ethical reflection on how to handle personal identifiable information is always needed.
- **Data cleaning:** in some cases, sorting noise out of the stream of data collected can be done in a quick way (e.g. filtering out objects that are less frequently encountered, or conversely, the ones that are mentioned too much). In other cases, as for the NATURPRADI project, a careful reading of the collected data is necessary. Regardless the specific strategy adopted for reviewing and cleaning the dataset, a constant control of the data harvested is always necessary. While this operation helps the researcher explore the material they are going to work with, it also requires the setup of an appropriate infrastructure (i.e. from generating reports containing random samples of the data to *reading* the single data points one by one).
- **Data visualisation:** distilling information out of a dataset is more and more simple thanks to the growing numbers of techniques, libraries and software. Nevertheless, the ultimate scope of the visualization, exploratory visualisations and procedures are needed in order to continuously offer different views on the data through multiple and non-exclusive visual models, especially in the first part of the process. The production of interactive visualisation should be preferred to the static ones, to better support the exploration of the views and ease the identification of key insights and learnings.
- **Data interpretation:** what Digital Methods offers to Human-Centered Design is a better understanding of the user space and consequentially the reduction of the methodology concern raised by Chapman about the risk of projecting pre-existing categories, or missing unknown parts of the debate. (Chapman & Milham, 2006). The insights and clusters that emerge during this type of analysis need to consider possible limitations and bias. Collecting data over social media, for example, implies to cope with the digital divide issue and with the different *platform culture* (e.g the more or less marked propension to use hashtags) that might be present in different geographical location. The outcome of this type of analysisneeds to be seen as part of a wider range of research and design thinking activities aimed at understanding the people and context of use. The insights can be used for example to inject new hypothesis in a user research phase, or to enrich the existing knowledge with a different perspective.

Digital Methods need to be considered an opportunity in integration, and not in replacement, of current HCD tools and techniques. For example, along the process of creating Data-Driven Personas, the researchers may use the emerging clusters as a way to define potential participants for a set of in-depth interviews. The interviews will provide both a validation of the analyses carried out previously and, above all, add a deeper qualitative layer to the understanding of the different personas. Following this example, Digital Methods can ease the preparation of a field-research, by raising important themes upfront and offering an alternative strategy to recruit research participants.

Another possibility for synergies is offered by the attempts to make the Human-Centered Design process more lean and agile, in order to cope with the challenges and speed that are typical of digital transformation processes. In order to streamline certain steps, the Lean UX approach has introduced, for example, the idea of proto-personas (Gothelf 2013). Proto-personas are user profiles developed as assumptions, by elaborating on the existing knowledge of a specific team or organization, prior to conducting an ethnographic study. Similarly, to Proto-personas, Data-Driven personas offer an assumption based on data that is already available in the digital space, and can be used as starting point to understand user behaviours and attitudes, before activating a field-study.

The Data-Driven Personas protocol is a first attempt to provide a sustainable and replicable approach to effectively apply Digital Methods to support the Human-Centered Design research process. This protocol is applicable to all those cases where the research environment involves a community of users who drive a series of debates inside an online space. Other protocols could be explored in the future, investigating the possibility to derive a broader set of user-centered frameworks from the analysis of the online discourse (e.g. experience journeys, system maps, future narratives).

We have argued that personas can be created on the basis of online information shared by users, using Digital Methods as a set of practices to gather this information in a renewed way for the design research. This first attempt requires additional experiments to pursue new ways of repurposing Digital Methods at different stages of the HCD process.

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Data Sensification: beyond representation modality, toward encoding data in experience

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Humans have represented data for thousands of years, yet the design process we use to encode data remains almost exclusively related to modalities such as visual, haptic, auditory, olfactory and gustatory. This paper proposes a novel approach to designing data representations, where we move beyond mapping data to a modality or combination of modalities and instead facilitate an understanding of the underlying data through people's overall experience of it. Based on a review of existing data representations that fall into this research area, but have not been discussed under one common term, this paper defines, for the first time, the term Data Sensification. Data Sensification is an emerging form of representation that encodes data in the behaviour, performance, affordances and resulting experience of a data representation. This research contributes to the on-going research on data representation beyond the visual paradigm as well as conceptualizing a new approach to representing data beyond representational modalities.

data sensification; representational modality; design; experience

1 Introduction

We live in a society where we are surrounded by various forms of data representations on a daily basis. The process of designing data representations is also practised across a broad spectrum of disciplines, including science (Nielson, Hagen & Müller 1997), human-computer interaction (cf. Hogan & Hornecker 2013), art (Viégas & Wattenberg, 2007), geography (Kraak & MacEachren, 2005), education (cf. He & Adar 2017), and the humanities (cf. Segel & Heer, 2010). While the design goals of data representations produced in these fields may vary, two things remain consistent: (1) the use of representational modalities to encode the data, and (2) the dependence on sense making - through the identification of patterns in the data representation to gain insight and generate meaning. This paper proposes an alternative approach by representing data beyond representational modalities and enabling people to generate data insight - not by seeking patterns - but instead through people's overall experience of the data representation.

The relationship between data representation and representational modality is extremely tight. Today, research fields and classes of data representation are delineated by their use of representational modality. The terminology used to describe these is also derived from the modality of choice. For instance, the research field that focuses on the visual modality is known as Information Visualisation (InfoVis). InfoVis is also the term commonly used to describe interactive computer systems that provide the user with external visual models of abstract data (Card, Mackinlay & Shneiderman, 1999).

While InfoVis is arguably the most prominent and active of all data related fields of research, the others are also identified by the modality that they focus on. For instance, Sonification is defined as "the use of non-speech audio to convey information" (Kramer, 1993). Here researchers study how data is represented through sound by mapping data values to audio variables such as pitch, volume, rhythm, loudness, and timbre. Whereas the study of data represented through the haptic modality is commonly known as Haptification (Paneels and Roberts, 2010) or Tactilization (Card, et al, 1999). This type of data representation has been applied successfully in diverse scenarios, such as a science museum to represent astronomical data (Hogan & Hornecker, 2013) and virtual surgery to provide feedback during simulations (Kaber & Zhang, 2011). Closely related to these, but moving in the direction of making data representations physically graspable, Zhao and Vande Moere introduced the notion of Data Sculpture which explores how physical embodiment can be used to analyse the connection between data and physical representations (Vande Moere, 2008; Zhao & Vande Moere, 2008). Following up on this research, Jansen and colleagues coined the term Physicalization as: "a physical artefact whose geometry or material properties encode data." (Jansen & Dragicevic, 2013, p.3228) and have established a framework for visualizations beyond the desktop paradigm (including Physicalization) to help describe, compare and critique non-screen based data representations (Jansen & Dragicevic, 2013). Data Physicalization is now an active research area, and a large number of projects exist that encode data in the physical and tactile properties of objects; in both static (cf. Stusak, Schwarz & Butz, 2015) and dynamic forms (cf. Taher, Jansen, Woodruff, Hardy, Hornbaek, & Alexander, 2017).

While the representational modalities discussed already have a relatively long historical tradition of investigation and practise (ranging from decades to hundreds of years), the remaining modalities (taste and smell) have received far less attention from the scientific and art and design community. This is mainly due to the innate technical difficulties in producing and controlling the output from these modalities. They also lack a commonly used neologism to describe the research and output associated with these modalities. Representing data through smell is still underexplored - however, there are some examples in the literature. For example, Dollars & Scents is an olfactory display that represents fluctuations in the stock market by releasing scents into the air, such as rose when the market is rising, and lemon when it is contracting (for more see Kaye, 2001). Much like olfactory, the information transmission capability of the gustatory sense is still largely unknown (Basdogan and Loftin, 2008). There are, however, some rare, but intriguing examples, including BeanCounter by Dan Maynes-Aminzade, who was one of the first to explore this space and introduce the concept of Edible User Interface (EUI) (Maynes-Aminzade, 2005). Another example that uses food to represent data is Data Cuisine. This initiative, led by data researcher and practicing artist, Moritz Stefaner, consists of workshops where the participants explore food as a means of data representation or as Stefaner refers to it – "edible diagrams" (Stefaner, 2014).

The study of data representation was once inextricably linked to the visualisation research community, but recent developments have offered opportunities to broaden the field of investigation to include the study of alternative representational modalities. As the medium used to encode data has moved from the printed page, over digital pixel, towards tangible objects, sonifications and other modalities, we have seen the research community fragment across the lines of modality. This paper proposes that we contemplate a new approach to data representation, where we don't encode the data in the properties and variables of modalities but instead we encode data in our surroundings or the properties of everyday familiar objects. Humans have built up a familiarity with everyday objects and we intuitively understand how they work. The question then must be asked: can we harness this awareness and familiarity when representing data to enable people to generate data insight. HCI researchers have for some time now explored our surroundings as a means to communicate information. This area of research dates back to Weiser and Brown's work on defining ambient displays and calm technology as approaches to help ubiquitous computing applications enter our everyday life (Weiser & Brown, 1995). Ishii and Ullmer also explored the physical environment to present information when they coined the term ambient media as: information displays designed to present information in the periphery of the user's attention (Ishii & Ullmer, 1997). These concepts were subsequently adopted by the InfoVis community to address, for instance, the use of visualization in casual scenarios (Pousman, Stasko, & Mateas, 2007) and to explore the potential of information visualization in everyday life (Skog, Ljunglblad, & Holmquist, 2003; Willett, Jansen, & Dragicevic, 2017). This paper seeks to leverage this research by not only embedding data in our surroundings, but by moving beyond to embodying data in the properties of the objects that occupy our surroundings.

Hogan and Hornecker first discussed this notion in their exploration of the design space for multisensory data representation (Hogan and Hornecker, 2016). As part of this, they identified examples of data representations, which do not encode data in sensory modalities but instead in the experience people have with the representation. This paper seeks to extends Hogan and Hornecker's research by: (1) formalizing the notion of Data Sensification and defining it as a new class of data representation, (2) discussing current examples of Data Sensification and (3) pointing toward potential usage scenarios for Data Sensification, as well as the deign challenges that need to be addressed in the future.

2 Defining Data Sensification

The aim of this research is to classify data representations that fall outside the current list of categories, including: visualizations, sonifications, haptification, tactilization or olfactory and gustatory representations. There are, however, other types of representation that have already been defined, which do not ascribe to a specific modality, these are: Multisensory data representations (Hogan & Hornecker, 2017), Sensualization (Ogi and Hirose, 1996), Sensification (Tak & Toet, 2013), Perceptualization (Card, et al. 1999) or Cross/Multimodal displays (Hoggan, Crossan, Brewster, & Kaaresoja, 2009). However, in the context of this research these definitions pose difficulties, as they remain focused on modalities, or in these cases combinations of modalities as a means to facilitate data insight. There are types of data representations that have emerged over the years, which do not align themselves to representational modality, these include Information Aesthetics (Lau, & Vande Moere, 2007), Artistic Visualization (Viégas & Wattenberg, 2007), Data Art (Manovich, 2008) and Casual Visualization (Pousman, Stasko & Mateas, 2007). The focus of these is not on the modality used but on the aim, goals and target audience of the representation. These types of representation more closely align to the focus of this paper as they seek to: broaden the use of representation modality (cf. Vande Moere, 2008; Zhao & Vande Moere, 2008), widen the target audience (cf. Skog, Ljunglblad & Holmquist, 2003), and expose alternative data insight (cf. North, 2006; Cernea, Kerren & Ebert, 2011). While there are clear parallels with the later set of definitions, this papers proposes a formalisation of a new classification of data representation and in doing so we reappropriate the already used neologism Data Sensification to be redefined as follows:

> *"A class of data representation that has a clear intent to reveal insight by encoding data in the behaviour, functionality, performance, or affordance of an object and data insight is generated from the overall experience of the Sensification."*

At this point it should be noted that in proposing this definition of *Data Sensification* it is not meant as a replacement of the various definitions currently in use, nor is it meant to replace Tak and Toet's definition of *Sensification.* It is also not aimed at directing criticism at current approaches to the design of data representation. Instead the goal here is to broaden the research agenda on data representation to include aspects beyond representational modality and toward data experience.

3 Data Sensifications Examples

To understand the issues raised by Data Sensifications, it is helpful to have a set of concrete examples in mind. The following provides descriptions of six projects that map data to properties beyond representational modalities. The aim here is not to provide an exhaustive analysis of the design space - such an undertaking is beyond the scope of this paper. Instead, this paper focuses on a selection of projects that highlight some of the central qualities of Data Sensifications.

3.1 The World's Best Spintop

The World's Best Spintop is an art piece created by Melanie Bossert[1], which consists of a number of 3D printed spinning tops, where the structure of each piece is a translation of political, environmental, health, education, quality of life and economic data from a specific country (Bossert, 2012).

Figure 1 The World's Best Spintop by Melanie Bossert circa 2012

Once the data for the country is collated, an algorithm generates the shape of a spin top. If a country performs 'poorly' the generated shape will be asymmetrical and the handle will be short, which results in the spinning top being difficult to set and maintain motion. However, if the data indicates that the country has performed 'well' the shape will be more symmetrical and the handle will be long enough to grasp (making it easy to set in motion). The data mapping procedure used, as well as three examples produced by the algorithm, are illustrated in Figure 2. The choice of using a spintop as a form of representation is highly significant as it reflects the various challenges countries face in order to balance what is needed to provide a high quality of life for its' people. Although the data is encoded in the physical properties of the spinning top (much like the other physicalizations mentioned already) the data cannot be fully interpreted and understood until the spintop is in motion, which means the data has been encoded in shape, behaviour, usability and experience of using the representation.

[1] See http://www.spintop.cc

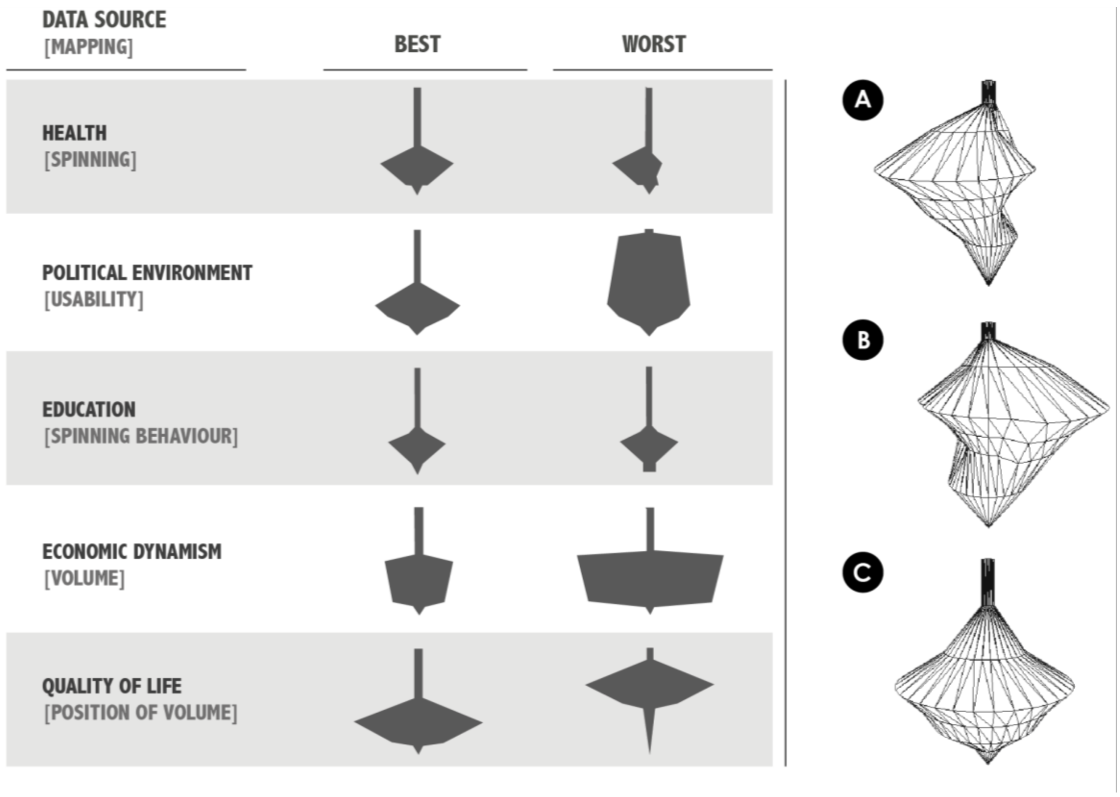

Figure 2 left: Algorithm used to generate the spinning top. Right: Examples of spinning tops produced by the algorithm (A) Zambia, (B) Burkina Faso, and (C) Ireland.

3.2 Change Ringing

Change Ringing[2] is the collaborative artwork by artist Peter Shenai and composer Laurence Osborn (Shenai & Osborn, 2015). This piece comprises of a set of six bronze bells whose form is derived from graphic representations of climate data collected over the course of the twentieth century (Figure 3).

Figure 3 Change Ringing with permission from Peter Shenai circa 2015

Each bell represents a seventeen-year interval during this period and they are arranged in chronological order. Change Ringing is similar to 'The World's Best Spintop' in that the data is translated into the physical properties of the objects, however, the audience cannot fully interpret it until they hear the different sounds that emanate when the bells are played. There is also an aspect of performance in this piece, whereby the audience is encouraged to play the bells in chronological

[2] see http://www.change-ringing.co.uk/

order so that they can perceive the temporal nature of the dataset through a series of inharmonic spectra that communicate sonically the story of climate change during the twentieth century. The experience provided by this work is also extended beyond the interaction with the bells, as the sounds they produce are also used as a basis for a twenty-five minute composition, scored by Laurence Osborn for a string orchestra and the bells themselves[3]. Shenai and Osborn were deliberate in the choice of bells to communicate meaning from the data. As they see it, the bells are not merely a means to produce a sonic representation but are culturally significant objects that have been used throughout history in situations such as bringing communities together in the act of contemplating, religious and non-religious ritual, political processions and delineating the passing of time.

3.3 #Good vs. #Evil

#Good vs. #Evil[4] could be described as an automated data-driven racing game, which is controlled by social data scrapped from Twitter feeds (Castelli, 2016). This piece was created by Maxime Castelli at a workshop hosted by I&IC (Inhabiting and Interfacing the Clouds), a joint design research project that seeks to explore new approaches and uses of cloud computing (I&IC, 2014). This piece is comprised of a scalextric track and two model cars (see Figure 4). Scalextric cars are traditionally controlled by a user with a remote handset. This handset allows the user to regulate the amount of electrical current going to a small motor in the car, which in turn controls the speed of the car. However, in #Good vs. #Evil the electrical current is controlled by a computer programme that counts the frequency of two hashtags on Twitter: #Good and #Evil. One of the cars is associated with #Good and the other with #Evil. At regular intervals the frequency of each hashtag is computed. The higher the frequency the more current is allowed to pass through, which results in the car increasing in speed. The result is a perpetual race between "good" and "evil" through their online hashtag iterations. Unlike the previous examples, data is not encoded in any physical properties nor is there any active interaction with the artefact. Instead the audience is invited to perceive the data as spectators at a car race. There is however an element of performance, but in this case it is conducted by the cars (or hashtags) competing against one another in a never ending game of good versus evil.

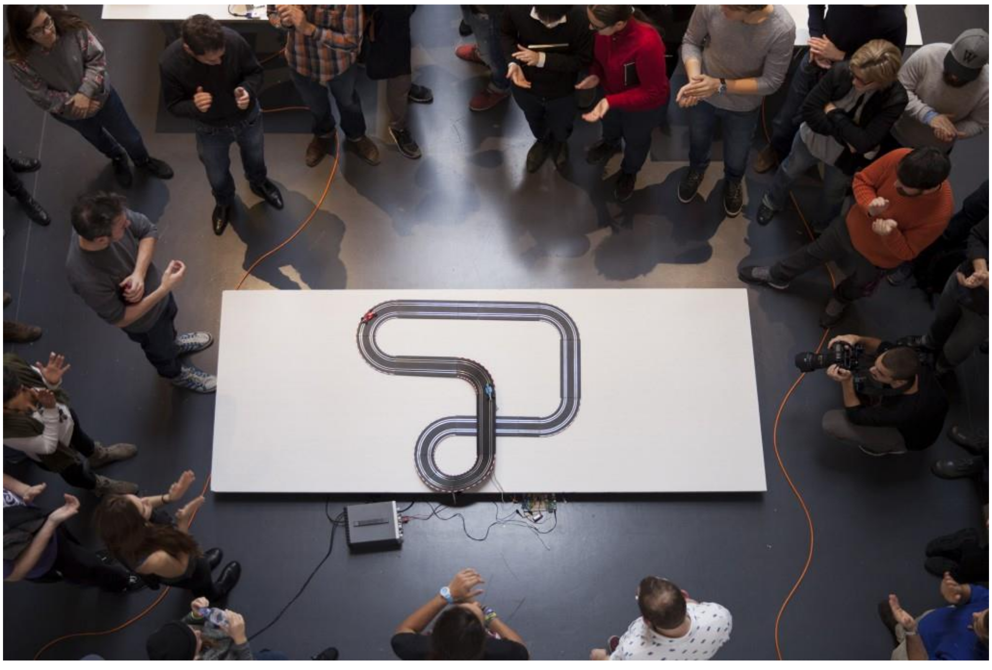

Figure 4 #Good vs. #Evil by Maxime Castelli circa 2016

[3] See more here: http://www.change-ringing.co.uk/really-composition
[4] See http://maximecastel.li/?/projects/TwitterRace/

3.4 *My Life Don't Mean A Thing If It Ain't Got That Swing*

While the previous example provided the audience with a performance to view, the goal of 'My Life Don't Mean A Thing If It Ain't Got That Swing' (see Figure 5) is to provide people with an environment that requires significant levels of active participation to fully perceive the underlining data. This installation, which is comprised of a life-sized swing set, represents data related to the satisfaction levels of a country's population. The question asked of participants of the survey was: 'All things considered, how satisfied are you with your life as a whole these days?' (World Values Survey Association, 2015). Again, this could be conceived as a data representation that encodes data in physical and architectural properties i.e. the length of rope, the height and width of the seat. However the means by which people perceive the data go well beyond looking at and touching the representation. In this case the data is embodied in the levels of enjoyment and overall experience people have when swinging. The designers have accomplished this by mapping the data from a specific country to the elements of the swing, in so much as, if the data indicates that the population responded negatively to the survey question, the length of the swing will be short and the seat will be narrow, making the experience of swinging less appealing or exciting. However, positive responses result in providing people with a more comfortable and satisfying swing experience. This would enable people to map their understanding of the data to hedonistic responses such as pleasure, enjoyment, amusement or their counterparts. Moreover, the swing may also allow people to link the data to fun childhood memories, which is a difficult task to achieve with conventional data representations.

Figure 5 My Life Don't Mean A Thing If It Ain't Got That Swing by Polly O'Flynn, James Pockson and Peter Shenai circa 2015

3.5 *Waste Production*

Waste Production[5] is a data representation created by Nadeem Haidary as part of the In-Formed series (Haidary, 2009). This piece consists of an elegantly designed refuse bin whose form changes depending on the weight of the garbage it contains (see Figure 6). As it fills up the top-half of the bin bends over, making it less inviting and giving you a visual cue as to how much trash you are throwing away. While the data (weight of garbage) is encoded in the shape of the object (bin), much like other data physicalizations, what makes this piece unique is how Haidary has connected the data mapping to the functionality of the bin. When it is empty it functions much like any other conventional bin by enabling easy access to the inner chamber. However, as the bin is filled its shape changes, resulting

[5] See http://www.nadeemhaidary.com/informed/

in its functionality becoming impeded. Ultimately it reaches a point when there is no longer access to the internal chamber. This is an example of encoding the data into functionality and overall experience of using the artefact.

Figure 6 Waste Production by Nadeem Haidary circa 2009

3.6 Drowning Over the Decades

Drowning Over the Decades[6] is an interactive art installation created by Cathy O'Donovan (O'Donovan, 2016). This piece represents data related to the amount of people in Ireland who have died from drowning in each decade from 1916 to 2016. The data, which was captured from the Central Statistics Office of Ireland[7], is mapped to the amount of water contained in each wine glass (one millilitre per death) and each glass represents a decade of data. Similar to *Change Ringing* the choice of metaphor is highly significant in this work. Although the symbolism of bells in Change Ringing is somewhat oblique, in this piece there is an obvious relationship between the data (deaths by drowning) and the use of water as a representational variable.

Figure 7 Drowning Over the Decades by Cathy O'Donovan circa 2016

[6] See https://vimeo.com/165565652
[7] See http://www.cso.ie

While the data can be perceived by viewing the amount of water in each glass, the installation offers a more unique perspective of the data by playing the piece like a glass harp. The glass harp is type of musical instrument that was first invented by Richard Pockrich in the 18th Century. Sounds are created when energy is applied to the glass and the physical properties of the glass start to resonate. Energy is applied by rubbing wet fingers along the each of the glass, which causes the glass to vibrate at its natural frequency. Different tones are obtained by varying the amount of water in each glass. *Drowning Over the Decades* could be considered a multisensory data representation, as it encodes data in visible, physical and sonic properties. However, its performative aspect extends its representational properties beyond the modalities in use, towards a piece that is required to be used and experienced in order to fully interpret the underlining data.

The proceeding sections describe six exemplary *Data Sensifications*, in the following sections the paper addresses related design issues and challenges that need to be met into the future.

4 Designing Data Sensifications

Before exploring the design approach of *Data Sensification* it is important to describe some of the issues that currently confront designers of data representation.

4.1 Issues with Representational Modality

As alluded to already, the current and traditional approach to designing data representations typically involves deciding which attributes of the data should be mapped to each sense. As such, designers must consider how to best represent the given data to provide users with insight by mapping data attributes to modality properties such as colour (visual), volume (physical), frequency (auditory), sweetness (taste), and fragrance (olfactory) or a combination of the previous. In doing so the designer should be aware how the Gestalt principles of perception play an important role in helping people identify patterns and relationships in the representation. For example, by assigning specific colours, shapes, textures, and sounds to different variables in a data set, it is possible to quickly identify groups of information and patterns represented by similar variables. There are, however, known difficulties with this approach. For instance, with respect to the human visual system, research has shown that it is inherently band limited and suffers from perceptual and change blindness (Mancero, Wong, & Amaldi, 2007), as well as occlusion, crowding and clutter (Van der Burg, Olivers, Bronkhorst & Theeuwes, 2009). Researchers have attempted to overcome some of these concerns by increasing bandwidth of information transfer through the use multisensory data representations (cf. Sarter, 2006). This paper seeks to sidestep these issues completely by not focusing on representational modality as a means to transfer information, but instead on facilitating the generation of data insight through the overall experience of the data representation.

4.2 Design Process

The process of designing data representations has remained relatively stable for many years. It involves first collecting and processing the data, which may involve methods such as data mining and filtering. The next stage involves mapping the data to an appropriate sensory variable, such as, for instance, mapping to colour, volume, sound frequency, sweetness or fragrance. The final stage involves presenting the representation, in whatever manner chosen, to the user so that he/she can easily interpret the data. This is typically an iterative process of analysis, design and use.

Card and colleagues published one of the first formalisations of this process and coined the term 'Visualization Process' (Card, Mackinlay & Shneiderman, 1999). The Visualization Process maps 'Raw Data' to 'Data Tables' to 'Visual Structures' and finally 'Displays' into 'Views'. This process has been extended in Figure 8 to account for the other modalities.

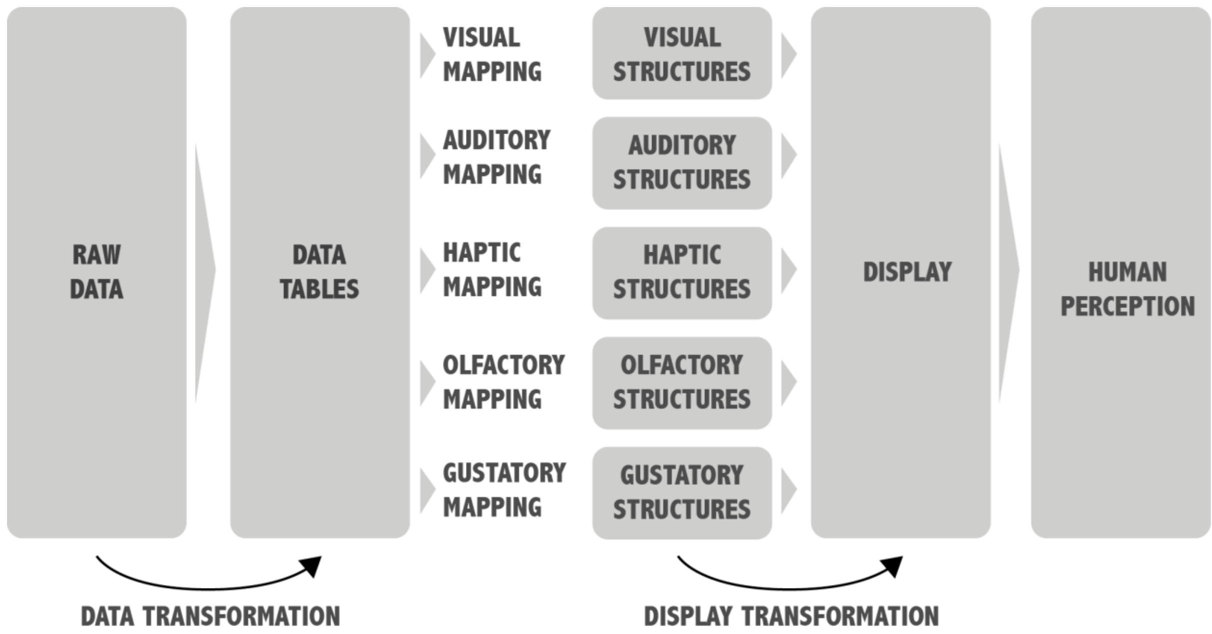

Figure 8 Card and Mackinlay's Visualization Process Model (Card, Mackinlay & Shneiderman, 1999) extended to include all sensory modalities.

4.3 Data Sensification

There are two clear distinctions between the design of typical data representation and that of *Data Sensifications*. Firstly, the role of representational modality in *Data Sensification* is given less prominence. In fact, the choice of modality is of little concern to the designer as the data is not transmitted through representational modalities but through the overall experience people have with the representation. One could argue that the role of representational modality has been replaced by the use of metaphors in *Data Sensifications.* As can be seen in the examples, metaphors and semiotics play a significant role in the transmission of insight. Metaphors are often used as a starting point in designing information displays by only allowing the user to take advantage of existing cognitive models but also "ecologically-developed perceptual skills" (Nesbitt, 2001). This paper argues the heightening the use of metaphors for the design of *Data Sensification* to a point where the metaphor becomes the central aspect of the data representation. For example, if we look at *The World's Best Spintop* (Figure 1) the notion of a country attempting to balance the social, economic and political conditions of its population is engrained into the difficulties we have controlling a spinning top, especially when its form has been dented. The same could be said for the *My Life Don't Mean A Thing If It Ain't Got That Swing.* Here, data related to the quality of life, is embedded into the functionality of the swing, meaning that the user embodies the data through his/her levels of enjoyment. Peter Shenai, one of the creators of this swing installation, talks about this approach to data representation as allowing him to push the interactive medium to its limits, up to and including the point of malfunction, as the malfunction or breakdown of the artefact, in this case a swing, serves as a reminder to the user that the data has been skewed strongly in one direction (Shenai, 2015).

The other difference relates to the process followed when designing *Data Sensifications*. Once the role of representational modality has been removed from the design process we need to rethink and reformulate the current approach ('Visualization Process'). This paper proposes an extension of Card et al's 'Visualization Process' by replacing the sensory mapping of structures to data values, with the mapping of metaphorical attributes to data values (see Figure 9). To help understand the proposed representation process of Data Sensification let's use this to understand how one of our examples has been created. The 'raw data' used for *The World's Best Spintop* was collected from sources such as the World Bank, WHO and CIA amongst others. Once the 'raw data' is collected it is parsed into ‘data tables’ and sorted for each country. The next step involves formulating a ‘metaphor’ to carry the data representation. While we do not have any insight into this design decision, it can be surmised that the spinning top metaphor is a significant aspect to this piece. Haidary mapped the functional attributes of the spinning top (i.e. volume, symmetry, usability etc.) to different data values. The next stage of process involves Haidary ‘displaying’ the representation by 3D printing a collection of spinning tops that represent each of the countries data. The *Data Sensification* is then presented to the audience who interprets the data by attempting to set the spintops in motion.

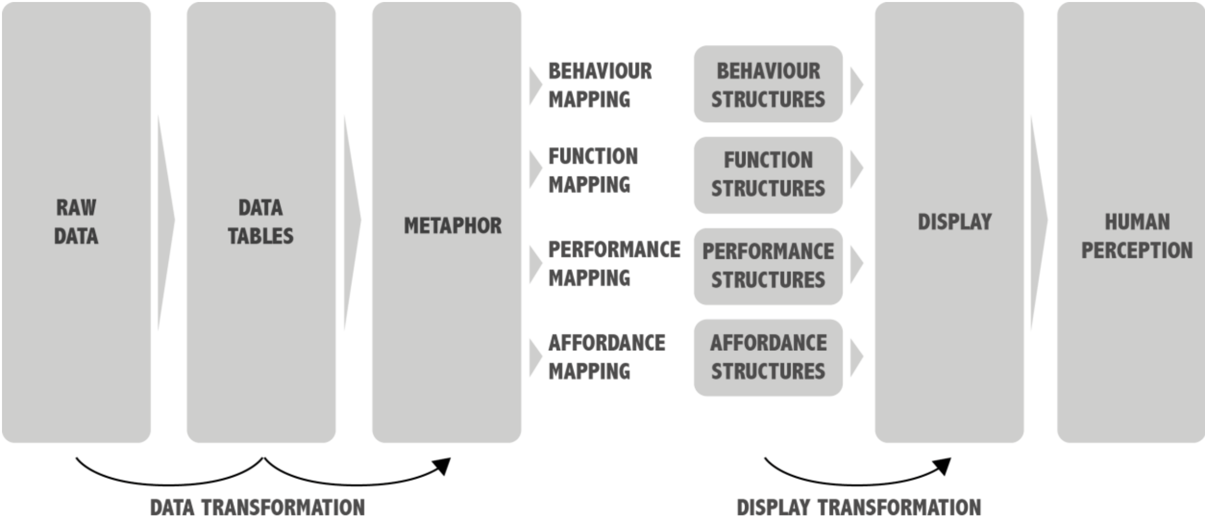

Figure 9 The Representation Process of Data Sensifications, an adaption of Card, Mackinlay & Shneiderman’s ‘Visualization Process’ (1999).

5 Discussion and Future Directions

The study and practise of *Data Sensification* is only in its infancy, and although there are only a few examples available, the exploration of these has raised a number of questions. These include: what are the potential usage scenarios for *Data Sensifications*? What are the key design challenges for *Data Sensifications?* And, how do *Data Sensifications* affect people’s user-experience of data representation? The following paragraphs present a first step in addressing these questions, which is followed by a more personal perspective on the future direction of *Data Sensification.*

5.1 What are the potential usage scenarios for Data Sensifications?

Five of the six examples discussed in this paper are situated in the field Data Art (Manovich, 2008), with one exception (*Waste Production*, see Figure 6), which is situated in the field of product design. While the current usage scenario for *Data Sensification* is very narrow, one alternative explored here is: *Data Sensifications for childhood learning*. Research has shown the use of information visualizations in the classroom can be a positive pedagogical tool (Gwozdz-lukawska, Janiga, & Guncaga, 2015) - however, they can also cause cognitive challenges for children (Schneider, 1996). The main difficulties arise when presenting children with complicated visual presentations. An alternative, and less complex approach, is to represent data through visual metaphors. This approach has been proven to be a positive addition to the classroom (Leslie & Waguespack, 1989; Gu, Koh, Chen & Duh, 2010). Leveraging on this research, we can surmise the use of metaphors - beyond the visual paradigm - may also have positive impact on childhood pedagogy. A vision of this may involve embodying data in the properties of objects that are meaningful and familiar to children, such as games and toys. These could then be used as tools for learning in the classroom for subjects such as science, math and engineering. *Data Sensification* for childhood learning is but one example of a possible usage scenario, and further research is needed to explore other possibilities.

5.2 What are the design challenges for Data Sensifications?

Unlike other research domains that focus on data representation, *Data Sensification* has no established design principles. Other fields, such as InfoVis, have a rich tradition of investigating design principles, which can be traced back to Jacques Bertin's seminal work on visual variables published in 1967 (Bertin, 1967/1983). Bertin identified seven visual variables (position, size, value, texture, colour, orientation and shape) and presented a set of rules - which are still in use today - for their appropriate use in data visualizations. Research has continued over the years to validate these (cf. Cleveland and McGill, 1986) as well as to extend them to apply to other domains (*computer graphics*: MacEachren, 1995; *InfoVis*: Carpendale, 2003) and modalities (*sound*: Krygier, 1994; *tactile*: Vasconcellos, 1995; *physical*: Jansen and Hornbæk, 2016). There has also been research on formulating guidelines for the design process of visualizations. Card and colleagues proposed an iterative process of analysis, design and use, which they describe as a 'Visualisation Process' that maps 'raw data' to 'views' (Card, Mackinlay & Shneiderman, 1999). Nesbitt sought to extend Card et al's work to account for the design of multisensory data representations. This paper proposes to extend Card et al's visualization for the design of *Data Sensification*, but further research is needed to validate this. In particular, this process suggests replacing the focus on mapping data to representational modality with the use of metaphors to facilitate data insight. Questions remain on how we can provide specific design guidelines on this in order to make the process understandable and repeatable. Further research is also needed to explore strategies that will allow this mapping process to be clear for the user.

5.3 How do Data Sensifications affect the user-experience?

Analysing examples of *Data Sensification* show a range of human interaction, from swinging, over spinning, to musical composition. Also, the type of data insight designers seek to facilitate varies from awareness over intrigue to curiosity. Apart from some rare exceptions (cf. Hogan & Hornecker, 2016) this form of interaction and data insight is seldom facilitated in current data representation. This relatively new approach to data representation opens up challenges that have rarely been addressed in other forms of data representation. Key to this is the approach we take to evaluating the success of current and future *Data Sensification*, which needs to reflect their purpose and goals. This also mirrors the challenges being met by third-wave HCI researchers (cf. Bødker, 2006; Bardzell & Bardzell, 2011). In relation to the InfoVis, Chen and Czerwinski have also stressed the need for improved methods in areas such as task analysis, usability evaluation and usage analysis (Chen & Czerwinski, 2000). However, apart from some rare examples (cf. Hogan, Hinrichs, Hornecker, 2016), the vast majority of prior research in this area evaluates the usability of data representations based on traditional measures such as efficiency and effectiveness. It is recognized that there is an inherent difficulty in measuring non-traditional qualities facilitated by data representations such as awareness, intrigue and curiosity - however, the HCI has a rich history in evaluating such properties (cf. Hassenzahl & Tractinsky, 2006; Wright & McCarthy, 2008). The evaluation of *Data Sensification*s can leverage the research and methods developed in HCI for the evaluation of *Data Sensification*s that have a similar intent: to evoke hedonic responses from their users/audience.

6 A Final Remark

This paper introduced and explored a novel form of data representation and termed it *Data Sensification.* As part of this, a definition was applied that formalises *Data Sensification* as a class of data representation that has a clear intent to reveal insight by encoding data in the behaviour, functionality, performance, or affordance of an object and data insight is generated from the overall experience of the Sensification. Based on this definition six example *Data Sensifications* were identified and described, which led to a discussion on design issues and challenges that need to be addressed in future research.

The aim of this paper is not to act as a definite guide to *Data Sensification*, nor is it meant to be treated as an exhaustive design space analysis. The field is too young for these. Instead it is hoped this paper is read as a call to design and wider communities to draw their attention to an emerging trend in data representation. It should be acknowledged there are many questions that were not fully resolved in this paper, but, arguably, this is to be expected as the topic under discussion is only emerging and there is little research available. The aim of this paper was never to resolve all questions; instead it was to present a range of questions that need to be addressed into the future and also to trigger conversations within the community.

The future holds many exciting opportunities for researchers and designers who work with data analysis and representation and it is hoped that *Data Sensification* will add another layer to the challenges we face with designing the data representations of the future.

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User Empowerment by Design: a new domestic electricity consumption model. A case study of young urban tenants

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The energy sector paradigm with the power station on the one end, and the passive consumer on the other end, is becoming obsolete. This paper offers a rethink of domestic electricity consumption: from the worldview where the electricity provider is the sole manager of the process via its interfaces, and acting out of self-interest, to a broad view of sustainable development. The domestic electricity consumption management system presented in this paper deals with the Democratisation of managing electricity consumption, and dismantling an information monopoly by transferring knowledge and responsibility to the users, thus increasing the possibility for sustainable consumption. Design and design thinking methods are the central tools of this research, aiming to create a behaviour changing solution for the domestic electricity consumers through a new service that will empower them by increasing independence, establish a sense of fairness, and enable conscious decision-making while creating benefits for other stakeholders. The system connects new applications and existing models, generating a whole that is larger than the sum of its parts.

electricity consumption; democratisation; demand side management (dsm); sustainable development

1 Introduction

Electricity production and supply are central factors in most challenges and opportunities that human society faces, when aspiring to sustainable development (UN 2014; Kinn, 2016). When the production and supply of food and water, security, and accessibility of health services, education, transportation, and information, are only some of the fields where reliable, available, and accessible (WEC report, 2000) electricity is essential, then electricity, like other infrastructures, is not strictly a technological or engineering field, but rather a matter of social equity and opportunity (Harris, 2015; Dixit et al., 2014). The research that led to the proposal to change the model of domestic electricity consumption began with mapping the paradigms in supplier-user relations in the energy sector. One of the prominent findings is that despite the dramatic changes in the sector, it seems that the domestic end user is not at the centre of the system's future development (Aloise-Young, Cross & Sandoval, 2016). This may an absurd statement, since the very existence of the electricity grid is meant to address the user's demand, but the complexity and numerous forces acting in the sector, push the user to the margins. The user's absence from future electricity system images is offered here as indicative of an industry attitude. This visual manifestation is one of the impetus that prompted the research and the question at its core: How can a new model for domestic electricity consumption be designed to empower users by transferring knowledge and responsibility to them, improving their sense of control and fairness about electricity consumption, thus increasing the possibility for sustainable consumption.

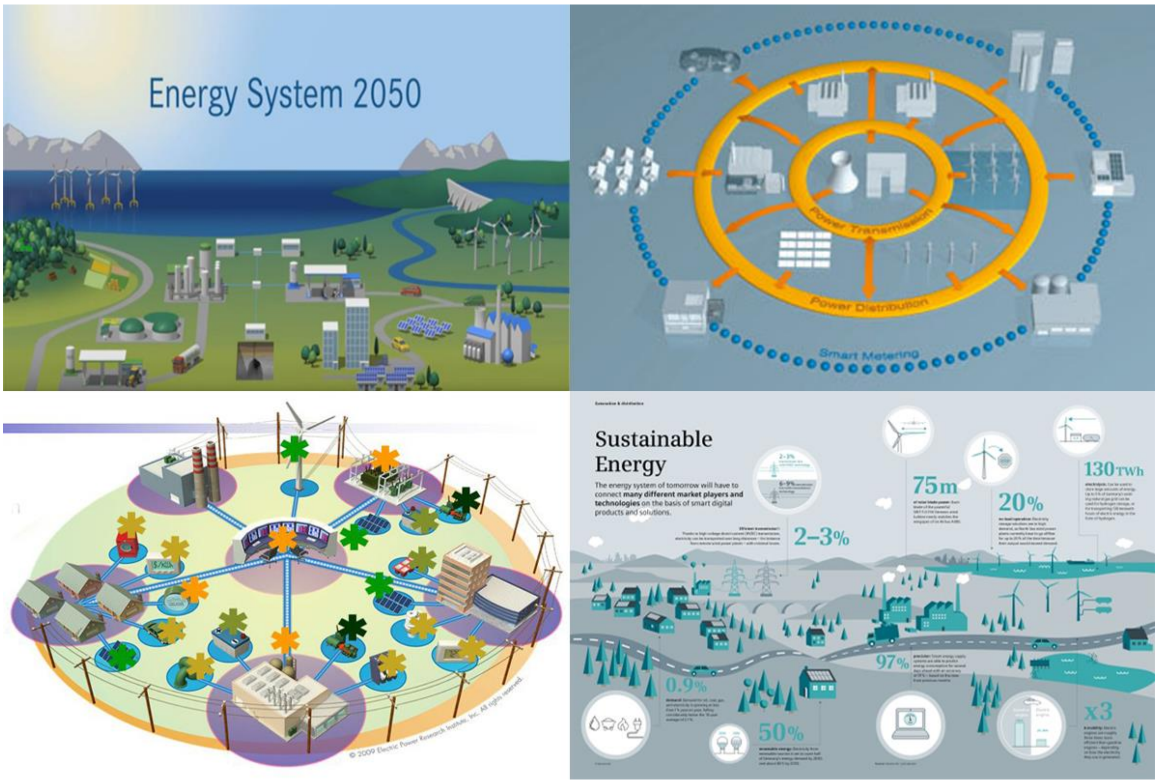


Figure 1. Diagrams of future energy systems with no human figures (Jülich Research Centre, RWE, Siemens, GPRI Electric Power Research Institute)

The research was conducted in Israel, which is home to the Israel Electric Corporation (IEC), a regulated public and government-owned company[1], which is the sole integrated electric utility company in Israel that generates, transmits, distributes and supplies the vast majority of the electricity used in Israel (IEC, Investor Relation Department, 2017). The domestic electricity consumption management system design, based on the finding of the research, is applicable to a variety of electric market structures since:

- The dominant model of today's electric systems is a legacy based centralised system (Tayal, 2017; Kinn, 2016)
- The 'electricity as a product' and its supply has similar characteristics, although differ in market structures, for example: intangibility though concrete manifestations like: light, warmth, etc., billing long after use referring to a lengthy period of use of various devices.
- Measurement of electricity in the traditional form of price per kilowatt hour, is also relevant to consumer sale of energy back into the grid, self-generation of electricity, measuring electricity collected from renewable resources, and so forth.

1.1 Sustainable development and electricity

The literature deals with the range between electricity supply for maintaining a standard of living perceived as 'convenience' (Munasinghe, 1993) and basic accessibility to energy. The main energy

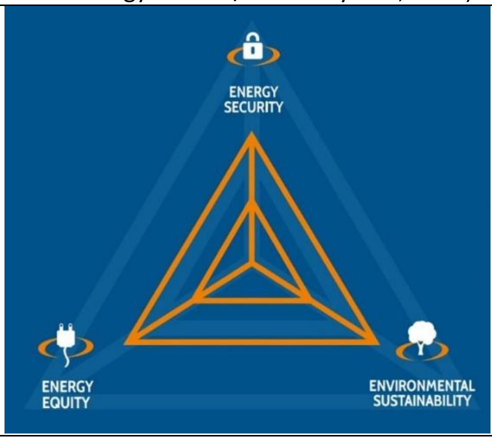
[1] Approximately 99.85% is government-owned

sector trends that have accompanied human society since the second half of the twentieth century are:

- An average 2% increase in consumption per year
- Extensive use of fossilised fuels to produce around 80% of the world's energy
- Population growth, economic growth, and a constant rise in consumption (IIASA, 2012)

As sustainable development perception deals with thinking not only about the "here and now", but also the needs of future generations, the three main objectives of the sustainable development model are about balancing economic, social and environmental values (Munasinghe, 1992). The Energy Trilemma model integrates energy security, energy equity and environmental sustainability (World Energy Council & Wyman, 2016). Both tri-value models show a clear return to the social and environmental values alongside the economic and practical values of electricity supply, emphasising the fact that meeting the energy demand is not only about Increasing the supplier's bottom line (see Table 1).

Table 1 Literature analysis

<table>
<tr><th>The Energy Trilemma
(World Energy Council/Oliver Wyman, 2016)</th><th>The three main objectives of sustainable development (Munasinghe, 1992)</th></tr>
<tr><td>


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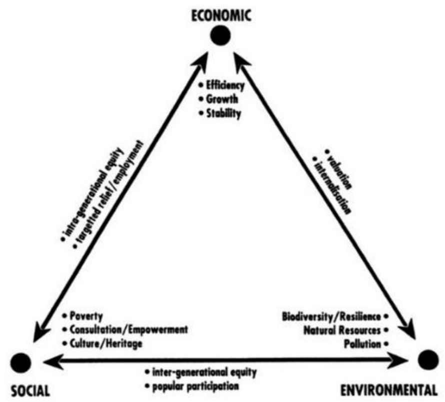

</td></tr>
<tr><td>
Energy security

Effective management of primary energy supply
Reliability of energy infrastructure
Ability of energy providers to meet future demand

Environmental Sustainability

The achievement of supply and demand side energy efficiencies
Development of energy supply from renewable and other low carbon sources

Energy Equity

Accessibility and affordability of energy supply across the population

</td><td>
Economic

Maximum flow of income that could be generated
Optimal and economic efficient use of scarce resources

Ecologic

Stability of biological and physical systems
Preserving the resilience and dynamic ability of "natural" systems

Socio-Cultural

Maintain stability of social and cultural systems
Intergenerational equity
Preservation of cultural diversity
Encourage and harness pluralism and grass-roots participation in decision-making

</td></tr>
</table>

1.2 Design for behaviour change and sustainable development

Changing human behaviour is a prime challenge in sustainability. Design for Behaviour Change (DfBC) is considered a promising framework to drive sustainable change. DfBC encompasses all scales of design, from visual communication to architecture, and from product to service design (Lockton, 2018). However, it is not only the designed outcome that characterises DfBC, but also the design process that integrates the recognition of the human behaviour as an integral part of the design process (Niedderer, Clune, & Ludden, 2018). DfBC is also characterised by a multidisciplinary methodology that assimilates skills and knowledge from a wide range of knowledge fields that impact human behaviour. Another key characteristic is the development of the designer's sense of responsibility to his/her significant role influencing human behaviour that subsequently impacts social and ecological systems (Lockton, 2018).

Clearly, changing human energetic consumption behaviour is a multi-variate task that includes group and personal aspects of values, beliefs, attitudes and adoption of culture-dependent norms (Stern & Dietz, 1994). To cope with the breadth of energetic behaviour change, the term 'lifestyle' is used to describe large groups of users, which together with the term Socio-technical systems (STS) helps to explain the dynamics between the material world, social forces and technological organisations through the perception of the individual as a combination of social and technological needs. The three main components influencing energetic behaviour are the relationship between "cognitive norms, energy practices and material culture" (Stephenson, et al., 2010).

1.3 Service design and design-based thinking in government and public sector

The dominant model of today's electric systems is a legacy based centralised system (Tayal, 2017; Kinn, 2016). Furthermore, public-utility considered enterprises (Castaneda et al., 2015) and government regulation systems, define the government and public sectors as central fields for this research. Design-based thinking has the potential to decrease the delivery-gap[2] (Allan, Reichheld, Hamilton & Markey, 2005) between governments and their users: citizens (Mintrom & Luetjens, 2016). It can reflect the government's policy intent, turn strategy to action (Body, 2008), and re-orient government and public services around people (Junginger, 2017). Governments and government organisations have complexed areas of activity and decision-making processes that are sometimes combined with tangled bureaucracy and a shortage of implementation tools. Additionally, they are facing a constant decline in public trust (Allio, 2014), A survey published in 2014 by McKinsey showed that the 'customer experience' is usually better than the 'citizen experience' (Baig, Dau & Riefberg, 2014). Despite the complexity, the government and public sector sectors have the ability, power, and experience (Farrel & Goodman, 2013) with providing public services and products for the greater good (Garner & Merwe, 2016).

1.4 Electricity as a product

Electricity, like other infrastructure services and public goods, is difficult to perceive as a product. Paying taxes, for example, is no different than purchasing other services or products, but the connection between the payment and the products and services received in return, is less direct than with most transactions that users make, and yet they feel differently about it (Body, 2008). Due to the dominant traditional utility business model, tariff is accordingly designed in a traditional form of price per kilowatt hour (Tayal, 2017). The tariff is set by a complex methodology taking into consideration various elements and influences pertaining to revenues, production costs, making payments, and more (Dixit et al., 2014). The characteristics of the tariff determination process include: the tariff's stability, striking a balance between necessary use and wasteful use, fairness in reflecting the needs of all users, preventing discrimination, convenience of payment, understandability and public acceptability (Bonbright, Danielsen & Kamerschen, 1988). The complexity of the subject makes it difficult for users, to fully understand the kilowatt hour basis

[2] A term describing the gap between the providers and the customers perception about a delivered service

terminology (Quesnelle, 2004) and perceive electricity as a product, even though they pay for it as such.

1.5 Prepayment for electricity consumption

Prepayment for electricity consumption is a model that has been around for over 80 years. The literature outlines both the advantages and disadvantages of this model. The advantages for users include: accessibility to information about electricity consumed, a convenient basis for understanding consumption and planning based on a 'unit of time' as well as creating real-time awareness, which results in the ability to manage consumption based on knowledge and avoid 'bill shock' when receiving a high account. Moreover, the users' early information about the cost of their consumption helps to prevent the accumulation of debt, which does not necessarily stem from the price but rather from budgetary management (O'Sullivan et al., 2014; Quesnelle, 2004). However, when connected to energy poverty and low-income users, who sometimes use the required minimum to begin with, the advantage of conscious consumption is not achieved (O'Sullivan et al., 2010). Another problem is the need to make a purchase, which may entail going to a point of sale. Low-income or mobility-restricted users are essentially discriminated against and they incur additional expenses. The benefit for the provider is not only in being paid in advance (Colton, 2001), but the perception of 'self-disconnection': It becomes the user's responsibility when the meter disconnects if not charged.

In the literature, then, there is no unequivocal answer regarding the preference of prepayment over post-payment, but the method has several principles whose redesign may yield advantages and encourage conscious and sustainable consumption.

1.6 Feedback on electricity consumption, smart metering and demand-side management

One of the advantages of the prepayment method as described in the previous paragraph, is feedback on electricity consumption. Feedback has been identified as a key to success of behavioural intervention (Aloise-Young at al., 2016). The 'Prius Effect' concept was coined when Toyota presented its Prius model, giving drivers real-time feedback on their gas consumption, and subsequently changing how they drove (Seele, 2016). Smart meters are a two-way communication device between the elements of the smart grid and among its goals is to empower consumers through enhanced information accessibility; however, it is not always the consumer's perception, since smart meters provide information to the provider but not automatically to the consumer (Aloise-Young el al., 2016). Similarly, demand-side management have characteristics that reflect the focus of the system: from a firm capacity to a voluntary and educational focus for increasing consumer's choice, (AEG, 2017). In-Home Displays (IHD) are information mediators that were found effective in encouraging reduction in energy consumption, in the range of 7.6% – 20% rates, depending on the design characteristics of the feedback (Shimada et al., 2014; Faruqui, Sergicy & Sharif, 2009) including: direct/indirect feedback, temporal proximity to consumption, clarity of language, compatibility to the consumer, consistency, and the option for comparison. The literature review on IHD raised a question about the term "home" as a place that display devices are in. The 'homes without boundaries' trend presented in the Fjord 2017 Trend Report[3], suggests that the smart and connected home require seamless experiences and smart services and devices such as various live-monitoring gadgets, monitoring via cell phones, and domestic controllers already available.

2 Methodology

A mixed-method process was constructed based on qualitative methods such as semi-structured in-depth interviews, open interviews, and observation, together with design research, such as 'bill Un-

[3]An annual trend report by Fjord design and innovation from Accenture Interactive

Enveloping" interviews[4], Prototype design, testing Affinity Diagram[5]and trend research (Martin & Hanington, 2012).

Research was conducted in three parts: In the first part, through a 'Customer Journey Mapping' opportunities were identified and the premises about the users' actions, perceptions, feelings, and 'pain points' were determined. This method promoted a wider perspective on the context in which electricity is consumed (Martin & Hanington, 2012, p.439). The second part focused on identifying the causes and user's response to the problems. The third part focused on translation of opportunities into ideas that may solve the problems that emerged through users' feedback to purposed prototype.

2.1 The research population

The research population is domestic electricity consumers. Within this broad population, two target audiences were studied (see Table 2):

- Users that, did not pay their bills on time and therefor became candidates for having their electricity cut off or had a prepayment meter installed in their home.
- Young urban apartment renters ages 23-38 as a case study. This population was identified as vulnerable to the complexity of the relationship with the electricity provider, in light of frequently moving apartments, and growing trends of unsupervised rentals and the overall challenges of urbanisation growth described in the UN New Urban Agenda, 2016.

Table 2 Research design

Research Participants	Characterization / Line of Business	Method	Number of Research Actions
Domestic electricity consumer users	General population	In-depth interview Un-enveloping interview	10
Domestic electricity consumer users	Candidates for disconnection and prepayment meter users	Interview Observation Observation combined with interview	7
Domestic electricity consumer users	Young urban apartment tenants	Interviews Quick prototype	5
Service providers	Customer service Money collection	In-depth interview	4
Combined	Service providers and recipients	Observation	5
Experts	Assistance to families in financial straits	In-depth interview	2
Experts	Smart stock	In-depth interview	2

3 The Research Findings

The field research focused on forming insights about how users perceive their electricity consumption, mapping the relationship between the users and the provider, and on analyzing the motives and implications of the problems identified. The insights were translated into opportunities for development in the spirit of sustainable development. The main opportunities were chosen according to 3 main measures:

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[4] The method is called as such after the "Unboxing" video clips that document a consumer's first encounter with a product, when they open the box the product was sent in.

[5] A method for managing knowledge and ideas, which is used, among other things, in design thinking process.

- Significant improvement of the user's experience in defined markers, such as: trust between the user and the provider, number of complaints, reducing the number and duration of actions.
- Influencing as many stakeholders as possible and taking the Eco-System rule into consideration.
- The option of combining possible solutions to one inclusive solution that addresses the entire user experience with regards to his relationship with the provider.

3.1 Findings from the Field

The main opportunities that were identified in the user research addressed the following issues:

1. **The problem of readability with the existing interfaces**: The research examined the users' opinions of two main interfaces: the meter and the bill and the connection between them. The meter is a technological instrument that went from an analogue one-way transmitting device to smart and connected in the IOT world. The research showed that more than half of users neither read nor understand the language of the meter. One third of the interviewees do not even know where the meter is placed in their home and do not perceive it as an interface than can work for them.

   While the meter is a technological product that is not always accessible physically, the electricity bill is a familiar document, written in a formal and seemingly satisfactory language, containing all the information required for the users to understand how the bill was calculated and what they are paying for. Most users settle for reading the amount due and are not at all aware of what else appears on the bill. Even though all the users expressed a desire to know more about their electricity consumption, the language the bill is written in and the general perception of a monopolist provider, that leaves the user no choice but to consume from, minimise their ability and confidence in their ability to understand the bill. The research identified a gap between the users and the provider's service representatives, which as opposed to the users, understand the information that the bills provide and the way the electricity consumption is reflected in the meter reading and in the bill. Furthermore, the provider representatives do not feel the lack of trust and fairness about the bills, as the users express.

   The users were also asked whether and how the payment due date written on the bill, affects the actual payment date. While opening the bill, one of the interviewees said "now I put the bill on some shelf, with all the other bills…I pay when a few bills pile up". One of the answers to the question "do you go over the entire bill" was: "Why bother? What's written there anyway?" This, then, exposes the redundancy of the bill as an interface that precedes timely payment, or as an effective source of information for the users.

   Aside from the meter and bill being tools to convey information from the provider to the user, managing the interfaces incurs a cost. The production, printing, sending, digital signing, and other actions pertaining to the bill, as well as installing a meter, replacing it, reading it, checking its integrity and more, are products that are meant to "work" for the supplier and for the users, which will justify their cost.

2. **Frustration, feeling a lack of control, and the user's lack of trust in the provider and his interfaces due to fluctuations in the amount due**. The bulk of the electricity bills among the research participants, is payment for electricity consumption with the addition of fixed payment components and various charges. The amount due changes with each bill, depending on the actual use during the billing period. The users' frustration with the fluctuations in the bill stem primarily from the difficulty in planning expenses, since the amount due may doubles throughout the year, which causes distress and uncertainty

regarding the amount due in the next bill. Secondly, due to the difficulty in quantifying electricity consumption, the users perceive the anticipated amount due as arbitrary.

The existing interfaces, as described, are not understandable to the users, and consequently, the "bottom line" of the bill is perceived as an unclear "fate". Since the research was conducted in a place where the is a monopolist vertical integration structured provider, who not only compiles the bill but also counts the kilowatts and owns the meter, the more unclear and fluctuating the amount due, the more the trust between the users and the supplier is damaged, which can lead to complains from the users, unwillingness to pay and increasing a sense of unfairness.

3. **Difficulty quantifying electricity consumption during the billing period.** The readability of the supplier's interfaces that were described at the beginning of the chapter is especially significant because 'electricity as a product' is difficult to quantify. The reasons for the difficulty, as the users pointed out include:
    - Electricity has concrete manifestations in the form of light, cold, sound, etc., but in general it is not felt by the users on a continuous basis.
    - The various devices have different power supplies and different operating systems.
    - Units of measurement are not easily convertible.[6]
    - Receiving a bill long after use. The bill refers to a lengthy period of use. All the interviewees excluding prepayment meter users, get the bill every 60 days.
    - In some cases, there is more than one user in a residence.

    During the interviews, the users were asked what they thought their bill was composed of. The responses reflected feelings and interpreted behaviours: "I think the air conditioner uses the most, something like 50 percent of the bill" or "my husband never turns off the lights". Other similar responses demonstrated that the interviewees do not have tools to quantify their electricity consumption in order to understand, analyse, and control it.
4. **Frustration due to lack of a reference point regarding electricity consumption** One trend that has already become an accepted standard in purchasing and consuming products and services, is the option of conducting comparisons and the transparency of analysed and catalogued information. The comparison with other users may help save time and money, encourage use or rejection of a product or service and contribute to a sense of belonging and community, when the information refers to users with similar profiles. Based on the difficulty in quantifying electricity consumption and the lack of readability of the existing interfaces, the users expressed a desire to learn about their electricity consumption using a comparison to others or to themselves. One interviewee reported that she compares the current bill to her previous bill: "I check and if I get a lower bill, I feel like I've been a 'good girl'". Even though she knows that the previous bill referred to a different period of the year, where electricity usage differed, she perceives a lower amount due as an expression of her ability to save money and control her domestic consumption.

5. **A complicated process of registering or transferring the right to receive electricity services when moving into or out of an apartment**. With the focus on the population of young urban tenants, a problem emerged that was relevant to the general population but is felt more strongly among the research population: the registration process or transferring the right to receive electricity services when moving apartments is complicated and cumbersome, and it requires the cooperation of additional stakeholders, like the landlord and previous or future tenants. The research population of users move apartments on average once every 27 months, and therefore are required to go through this process frequently, both at the apartment they are leaving and the one they are moving into. All the case study interviewees reported at least one instance where they were required to invest time and

[6] Sample units of measurement in the energy sector: kilowatt-hour, watt, ampere, horse-power, joule

effort in order to prove or repudiate a connection to the electricity bill. The cumbersome process of registering or transferring the right to receive electricity services, and the dependence on others combined with the feeling of transiency in their residence, impacted the young urban tenants' motivation to transfer the electricity contract to their name, and they avoided it, exposing themselves to disconnections due to others' debts.

6. **The prepayment method as an opportunity for control, independence and saving.** In various places worldwide, electricity can be consumed using a prepayment meter voluntarily at the user's request, or at the request of the landlord. In this research, the electricity provider installs a prepayment meter at users that tend not to pay their bills on time for various reasons, to the point that they are candidates for being cut off or have already been cut off. The prepayment meter thus acts as a payment enforcement method that collects previous debts and prevents the accumulation of future debts. Alongside the difficulty in operating the prepayment meter, and its perception as punishment when it is installed at the provider's discretion, one third of the interviewees, using a prepayment meter, expressed satisfaction from using it. The main cause of the users' satisfaction is their high rates of control over their electricity consumption expenses. In addition, the users were pleased that they no longer got into debt for consuming electricity they could not pay for post factum. One of the interviewees reported that he used to forget to pay bills and got into debt, which eventually led to his electricity being cut off. He said about himself "I don't have a problem with money, each time I buy 1200 NIS [7]worth of electricity. My problem is that I constantly have expenses and I used to put all the bills aside and they would pile up." Another interviewee that uses the prepayment meter reported that even though she already paid the debt for which her prepayment meter was installed, she continues to use it because: "that's how I control the electricity rather than it controlling me." All the prepayment meter users, that were interviewed demonstrated a high awareness of their electricity consumption, an understanding of the time they had left to use electricity relative to the amount they had prepaid on the meter, thereby being able to adjust their consumption accordingly.

3.2 Young Urban Apartment Tenants Case Study

Young urban apartment tenants were identified as vulnerable to the complex relations with the electricity provider and as a suitable population for early adaptors[8] of new services that are accessible via digital platforms. Touchpoints [9]between the user and the provider were identified through a 'customer Journey Mapping' as opportunities for a positive or negative experience. Opportunities to form a perception of fairness, trust and confidence, or to create confusion, hopelessness and frustration. The relationship between the case research users and the IEC is characterised by aspects that are relevant to their own unique context: frequent moves, every 27 months on average. The moves affect:

- Perception about the relationship with the electricity supplier, like with other service providers that the users have to be in contact with by law or due to the apartment's geographical location.
- Low motivation to deal with the bureaucracy of arranging the contract with the provider due to the brief or uncertain duration in the place of residence.

[7] Approximately 535 USD

[8] Early adaptors are users that tend to precede the average user in consumption of new products and services and are perceived as open to innovation and trend leaders.

[9] The touchpoints that were studied do not include contact with the IEC on technical issues such as malfunctions, handling the size of the connection, etc.

- Generally, the status of tenants in an unregulated rental market is relatively inferior to the landlord's status.
- Dependence on additional stakeholders such as previous tenants, the current landlord, the landlord in the previous apartment, new tenants, and so forth.

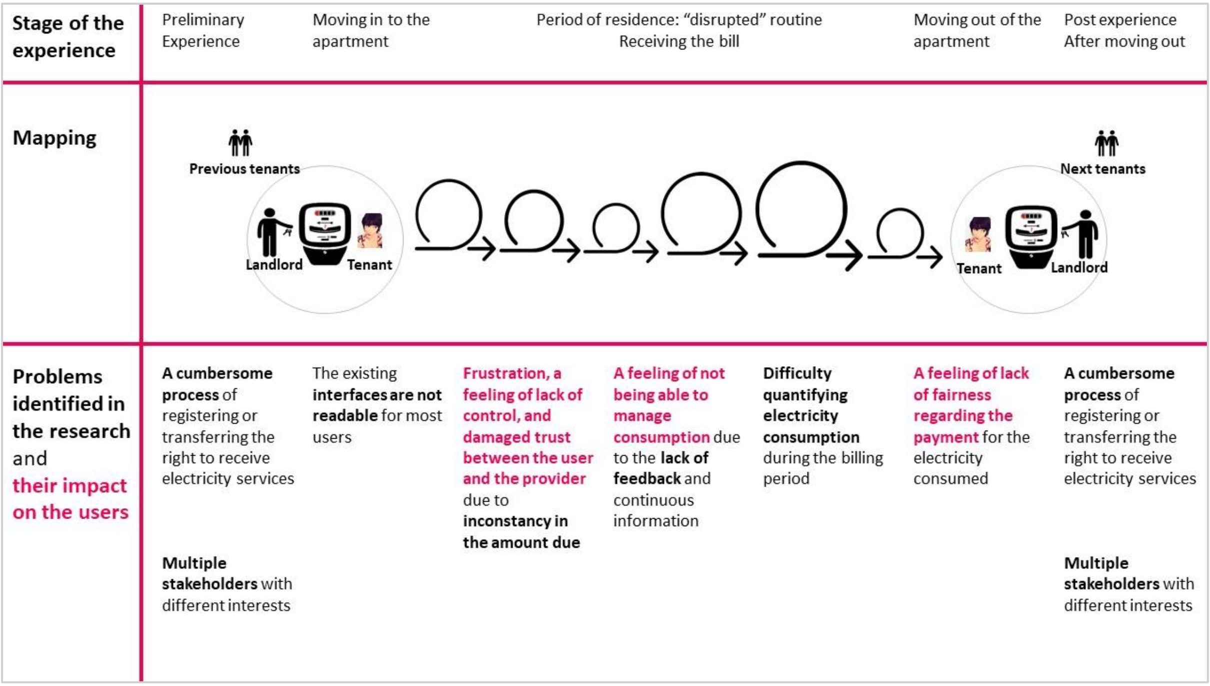

Figure 2. Young urban apartment tenants Journey Mapping

Due to the case research users' frequent moves, the 'moving in' and 'moving out' stages stood out as the 'critical-route' - a move that has a significant impact on the entire experience. Among the 'pain points' that were identified on the 'customer Journey Mapping': lack of control, trust and fairness, that even if they characterise the general population's relationship with the provider, are intensified by changes in payment patterns that may stem from differences in apartment sizes, the tenant mix, type and number of electrical appliances in the apartment, and so on. Moreover, the users find it difficult to follow usage patterns and payment, especially when the bills are not even registered in their name. Furthermore, there is a disparity between the manner of consumption of digital services, to which the case research users are accustomed, and the complicated and bureaucratic manner of how the IEC operates.

The picture of the hopeless and passive user due to a lack of tools, which was depicted in the research of the general population, was reinforced in the case study.

3.3 *Summary of the Research Findings*

The research identified a gamut of missing values in the user-electricity supplier relationship, which create frustration in light of the asymmetry between the "all-knowing" provider, and the users, who were depicted as hopeless, lacking control, and with no tools for understanding and changing their electricity consumption. The problems that were identified were translated into opportunities to develop a domestic electricity consumption management system, which will place the users at the centre and be designed in a user-friendly manner.

4 Results and Discussion

Combining results from the literature review and design research resulted in an inclusive design of a new service proposal, which offers a radical change of existing electricity consumption paradigms, by addressing the asymmetry between the user and the provider through a domestic electricity consumption management system. The system connects existing models and new applications, generating a whole that is larger than the sum of its parts, in the sense of empowering users by transferring knowledge and responsibility to them, thus increasing the possibility for sustainable consumption. Since the system is directed at a high degree of feasibility and applicability, it contains benefits for other stakeholders including: the landlord and the provider.

The following discussion is presented through the description of the five parts of the domestic electricity consumption management system:

4.1 Personalised electricity account- New management system

The proposal enables users a feeling of control and accessibility to information at all times and neutralises the dependency on the provider's interfaces. The goal of managing consumption with the individualised bill, similar to bills that are used for purchases at cellular shops or to store information on the Cloud, is to be based on a familiar format, to enable an adjustment to personal preferences, to generate a feeling of ownership, and to simplify processes. The proposed future development will make quick "check-in/check-out" possible for the consumption of electricity services. Similar to the consumption of hospitality services at a hotel or parking services, payment for consumption of the product and service will apply and will stop when usage actually begins and ends. The user's independent navigation of the digital platform will simplify the cumbersome process and ensure accurate charge and prevent debt accumulation.

4.2 'Electricity Package' at a predetermined sum - transferring control of payment to the user

This section, like its predecessor, deals with increasing the users' control of their electricity consumption rates and expenses. The proposal aims to solve users' frustration in light of the fluctuations in payment and to minimise the lack of trust in the provider and his interfaces. The option of choosing the amount due will help users avoid "surprises" in their changing electricity bill and to conduct themselves financially based on a convenient comparison of usage time versus cost and enable a distribution of electricity consumption costs in a convenient manner perceived as fair payment.

4.3 Feedback on electricity consumption - Democratisation of information to encourage conscious consumption, control, and saving

The need for feedback on electricity consumption emerged from the user's study and led to a literature review on the efficacy of feedback in raising awareness of consumption in general and electricity consumption in particular. The literature review validated the hypothesis that feedback is not only a "service-oriented" tool for users but a savings tool in consumption and expenses and thus the solution resonates with the principles of sustainable development.

4.4 A comparison based on sharing information among users - processing information and making it accessible to encourage conscious consumption

The implementation deals with dismantling the monopoly of knowledge and transferring power and control to the users. The research literature revealed, in this context, the complexity in the comparison of electricity as a product. While the field research found that the users base the amount of electricity they consume on feelings and estimations, as they understand it, since the quantitative comparison between electricity consumption of users takes numerous variables into consideration, such as: the power of the electrical appliances, the size of the space, the number of users, insulation, outdoor weather, and more. This is where technology can give a precise solution to a comparison between users and the design can make the information accessible to encourage savings in consumption and expenses.

Figure 3. Diagram of the electricity consumption management system

4.5 Moving to a prepayment method to encourage a sense of ownership and responsibility of the electricity purchased

Choosing the prepayment method as part of the proposed solution combines the theory that emerged from the field and the literature. In both fields, polarised approaches were identified: On the one hand, the method was perceived as "punishment" for users, and as a consumption management and control tool, on the other hand. This polarisation presents the challenge in "dismantling" the method and analysing it, using management and design methods in order to redesign it as a tool that enables sustainable consumption. Changing the method's outlook, refining its advantages and neutralising its inherent "punishment" in the form of 'self-disconnection' is consistent with consumer trends and with contemporary technological possibilities.

5 Developing a Solution

Aiming to develop a solution based on the research findings, an exploratory research began to by presenting the research findings to the case study population. This stage of the research addressed several questions that will be presented below.

5.1 *Where will the solution be implemented?*

The research about In-Home Displays raised the question of what the case research users actually consider a "home". When they were asked for their opinion about an in-home display, the interviewees responded: "Why do we need another object at home? It's better if the alerts are sent directly to my mobile phone" (A, 30, subject 1) and "I don't want another object that I'll have to schlep with me from one apartment to another" (A, 43). Their responses made it clear that in their opinion, a home does not lie in the walls or the objects in it. The frequent moves from one apartment to another make the interviewees' and subjects' attitudes more extreme regarding the basic redundancy in owning objects, making the home an abstract concept. The answer lies with trends such as homes without boundaries and a screen-less world, which deals with physical manifestations of objects and applications that change as a result of technological progress and encourage a critical and balanced perspective between the virtual and physical in the development of products and services.

5.2 *What technologies are relevant to a solution?*

Since the project aims to find a technological solution to the users' needs for the next few years, adjustments rather than new developments are suggested. The following technologies were reviewed:

PLC - Power Line Carrier - An existing technology where information is transmitted on the electricity grid using signal modulation. MDM - Meter Data Management - An existing technology that uses a SIM card to read a meter or a meter coordinator as part of the Smart Grid. In addition, the option was raised to use Optical Character Recognition technology to read meters for the purpose of photographing the IEC meter and decoding a photo of the numbers in order to quantify electricity consumption. The technology is used, for example, to identify car license plate numbers to charge for driving on toll roads or to charge for parking in lots. One of the advantages of this technology is its compatibility with reading the IEC meter.

5.3 *Who owns the solution?*

In the research about In-Home Displays, which were found to contribute to saving, the question of ownership, installation, and maintenance, became important. In a project of this type, ownership does not only pertain to the physical device that does the job in one of the existing technologies, but to ownership of the information stored using these technologies. Since electricity is one of the most important civilian infrastructures, the solution must be developed on the principles of Democratisation of information while taking data protection and personal privacy into consideration to avoid a situation where ownership is only a question of cost and who can pay for it.

6 Summary

The research began with determining that electricity is not strictly a technological or engineering domain, but the basis for equal social opportunities. Accessibility to electricity is not only a physical connection to the electricity grid, but much more. It is the ability to pay for the electricity consumed and accessibility to information about it. The research was conducted using a human-based approach and thus consistently aimed to elevate the status of the electricity domestic user, who is currently at the bottom of the electricity chain, trying to navigate a way through a variety of technological, engineering, political, and other constraints. The new electricity consumption management system presented in this paper is designed to utilise existing technologies and make it possible for the user to manage his own consumption, give a sense of fairness in paying for the consumed electricity, and enable conscious and efficient consumption.

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Designing with Meaningful Data: *Deep personalisation* in the air travel context

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Data and artificial intelligence (AI) are revolutionising the way customers interface with organisations and vice versa. However, there is limited knowledge regarding how data and AI are used as material during the design process. It is to this practice-research gap that this paper responds, by providing practical insight into a project between a Dutch airline, named *AirlineX* for the purpose of this paper, and a university-based design team. The project let to the development of a principle for personality-driven design that deeply personalises digital touchpoints within AirlineX's operations. This principle is informed by 'big five' personality theory from the field of psychology. Further, a framework for incorporating AI and data as meaningful subject matter into the design process is presented. This framework assists organisations to develop dialogue with customers beyond the purchase point through personal data, representing a democratisation of the traditional business to customer (B2C) perspective. The paper concludes with directions for future research that point toward the growing need for ethical discourse regarding technology, design and society.

personalisation, customer data, psychology, big five, use case

1 Introduction

Understanding a single customer's personality provides the opportunity to adapt to that individual's concerns and interests during (B2C) engagements. This is the essence of personalisation and the key to customer loyalty (Coelho & Henseler, 2012). Airlines connect with millions of passengers annually under strict regulations, thus the challenge to personalise operations faces difficulties. Where some airlines choose to compete on product leadership (for example Emirates), or cost leadership (for example Air Asia), other airlines choose to lead in the area of customer intimacy (AirlineX). This strategy entails emphasis on the delivery of excellent customer experience through offline and online B2C interactions. However, as customer expectations rise in this digital age, so must organisations consider deepening the possibilities of personalisation.

Like many organisations, AirlineX views data and AI as potential opportunities to enrich their relationship with customers. But like many organisations, an all too common challenge is encountered; how to incorporate seemingly limitless technologies into operations in a meaningful way? A technology-push into the market carries the risk of failed adoption (Verganti, 2009). This practical challenge carries great relevance and significance to the design research community – as AI and data are becoming increasingly common subject matter in this digital age. Therefore, the purpose of this paper is to explore AI and data as the subject matter of design by presenting a research through design project titled *deep personalisation*. The project occurred over a period of eight months and led to the realisation of a proof-of-concept for AirlineX which will be being scaled across current operations.

The paper will now proceed as follows; first establishing the concept of data, AI, and the big five personality theory as core content of the paper. Second, the design project is introduced. Emphasis will be placed on how data collection and analysis via AI was made meaningful, by incorporating the big five personality theory. At this point, the paper will present a set of personality-driven design principles that guided humanising data and subsequent ideation within the project. Third, a discussion will occur, with reflection upon the strengths and weaknesses of the project taking place. The paper concludes with implications for practitioners and academics, and guidance for future research. This paper contributes novel knowledge regarding the integration of AI and data into the design process via personality-driven design as both a guiding principle and set of actionable tools.

2 Data and AI

Design-led organisations also outperform peers by identifying and leveraging latent needs (Rae, 2016). Data-driven organisations are also effective performers (Redman, 2013). Data is information that represents an event – for example the number of heart beats a minute can be represented as 60 beats/minute; or the number of times a product is sold, 78.29 million iPhones in Q1 of 2017 (Apple, 2017). This data is stored in raw form in a database. However, the sheer scale of *data* (drawn from online behaviour) determines that there is no immediate action that can be planned or executed after engaging with a database. For example, Wal-Mart adds a billion rows of point of sale data (POS) every day with rows relating to product type, location of purchase, time of purchase and so on (Menon & Sarker, 2016). However, what conceivable action would a manger take when viewing a billion new rows of sales data each day.

Data analysis provides a gateway to action. Data that is analysed can support strategic and operational decisions. AI[1] is a form of computing whereby the machine learns overtime based on feedback from the user and the broader system. Instead of a human entering an algorithm, the machine learns from available data and writes its own algorithms based on patterns and insights. The more data processed, the more accurate the machine can become in analysis and prediction. In such an arrangement, AI is the enabling cognition for processing data like that of Wal-Mart, who are now able to predict based on POS data when a consumer is likely to have a mid-life crisis (Menon & Sarker, 2016). There is possibility in near future that AI will also extend to abductive reasoning – the potential to creative leap. For the time being, AI provides a black box of tools, ranging from descriptive to predictive analysis (Mckinsey Global Institute, 2017). The role designers play in ensuring there is beneficial translation of technologies of this magnitude into valuable products and services is yet to be fully determined.

3 The 'Big Five' Theory as Gateway to Action

In the English language, more than 15,000 words describe personality (Principles of Management, 2013). Goldberg (1990) identifies that many different themes point to a single dimension of personality and so formulated five main dimensions of personality; openness, conscientiousness, extroversion, neuroticism and agreeableness. The big five theory does not imply that personality differences can be reduced to only five traits. Rather, these five dimensions represent personality at the broadest level of abstraction, and each dimension summarises a large number of distinct, more

[1] There are two forms of AI. Weak AI acts upon and is bound by the rules imposed on it by the user. Strong AI is 'born' and grows like a human through autonomous learning (UC Berkeley, 2017).

specific personality characteristics. A basic description of each dimension is provided in Table 1. Currently, the *big five personality theory* is the most validated and commonly used personality model in research (McRae & Torbert, 2016). For example, research has investigates the big five in the different disciplines; economics (Borghans, Duckworth, Heckman, & Weel, 2006); education (Swanberg & Martinsen, 2010); health (Smith & Williams, 1992), and; social resources (Headey, Muffels, & Wagner, 2010). These studies sought to advance each discipline through application of the big five theory.

In the context of this study, the big five personality theory offers a criteria through which to analyse a POS database. For example the attributes of frequent flyers of AirlineX can be analysed to determine personal characteristics that may then guide the design of services and products. Similarly, in research by Kosinki, Stillwell and Graepel (2013), Facebook likes were analysed using AI to determine personality traits and attributes of individual users. The results were that AI was able to describe someone's personality to a higher degree of accuracy than that of family members, colleagues and friends – but not spouses. Further, this principle has been used to increase the voter turnout in the 2017 US elections via platforms such as Cambridge Analytica and Strategic Communication Laboratories Group, UK. However, there is no precedent for similar use of data, AI and the big five theory in enriching B2C interactions – and more specifically the influence of these concepts within the design process. This is the practice research gap to which this paper responds.

Table 1 An alternative 'description of personality' – (Goldberg, 1990)

Trait	**Description**
Openness	Curious, original, intellectual, creative and open to new ideas
Conscientiousness	Organised, systematic, punctual, achievement orientated and dependable
Extraversion	Outgoing, talkative, sociable and enjoys being in social situations
Agreeableness	Affable, tolerant, sensitive, trusting, kind and warm
Neuroticism	Anxious, irritable, temperamental and moody

4 Methodology: Research through Design

To address the aforementioned practice-research gap, a research through design approach (Stappers & Giaccardi, 2017) is applied to report upon a design project that occurred over a period of eight months. The project involved the partnership between AirlineX and a design team based at the Delft University of Technology. The brief for the project was formulated by the client, AirlineX and challenged the design team to address the following line of inquiry: how can customer intimacy be enhanced using data and AI? A research through design methodology involving six design cycles was undertaken to respond to the brief.

4.1 Design Cycle 1: Generative Workshops to Reframe the 'Big Five' in the Aviation Context

The first moment in the design project brought together participants from AirlineX and the design team. Three generative design-led workshops (3 hours in duration each) were completed in order to reframe the big five theory to the travel context as a set of expected behaviours by passengers (See Figure 1). Literature was used to inform these workshops, for example, participants were informed how recent research showed that complimenting high conscientiousness people for their accuracy, completeness, adherence to procedures, and attention to detail positively contributed to their well-being (Rothmann & Coetzer, 2003). Similar opportunities were identified that were specifically related to the travel context, for example - passengers who score high in conscientiousness might expect appreciation for checking-in on time. Two themes from the workshops were identified. First, identifying a set of needs was vital. Second, the resulting interaction quality to meet those needs was a further means for personalisation, drawing similarities to the product focused work of Desmet, Nicolas and Schoormans (2008). These insights were carried into the following design cycle.

Figure 1. Generative workshop to reframe 'big five' into aviation context as passenger needs and interests

4.2 Design Cycle 2: Exploring personality related concerns and interests with passengers

The objective of this design cycle was to explore personality-based concerns and interests established during cycle one with passengers in context. Eleven (11) AirlineX passengers who were waiting for their flights at the *X Gates*[2] were selected in random order as participants. The participants were five male and six female of nationalities from Denmark, US, Canada, Scotland, NL and Turkey. Ages varied from 20 to 50 years of age. A set of design interventions were tested with passengers to explore the potential relationship between personality and travel preferences (Price & Wrigley, 2016). These interventions were based on assumptions formulated in design cycle 1 – for example the following assumption was evaluated; passengers with low conscientiousness tend to delay the preparation process and forget to check details. Another example of an assumption tested was that passengers of high openness would like to explore the airport while waiting for their flight. After the passenger answered ten questions to determine personality (see Figure 2), interventions were then introduced using a tablet to demonstrate potential services and products that explored the stated assumptions. These interventions took between 20 and 30 minutes per passenger with feedback recorded upon consent from passengers. These interventions found that personality indeed plays a role in passenger's preferences, however, there are additional factors such as trip goal and mood that influence experience. Furthermore, passengers tended to oppose change that forced certain behaviours. Any solution that captures customer data would need to provide an opt-in for the passenger to ensure they have the ultimate right to have services customised based on personal data.

[2] X Gates is a fully operational airport gate at Amsterdam Airport Schiphol where AirlineX conduct innovation related prototyping with real passengers

Figure 2. An intervention example tested at X Gates. Personalised bag tags to help encourage high openness, high extrovert passengers to meet

4.3 Design Cycle 3: Developing the Personality-Driven Design Principle

Based on the insights obtained from design cycle 1 and 2, the main concerns of passengers with particular personality traits, needs and interests were summarised. This summary took form through a set of physical cards that visualized a design principle (see Figure 3). Each card contained the type of passenger based on personality, their concerns, interests, needs and the interaction quality desired. Furthermore, every trait started with a symbolic statement that was encountered when working with passengers in design cycle 2. These cards together with a set of design requirements which were translated from the brief were used to develop the personality-driven design principle.

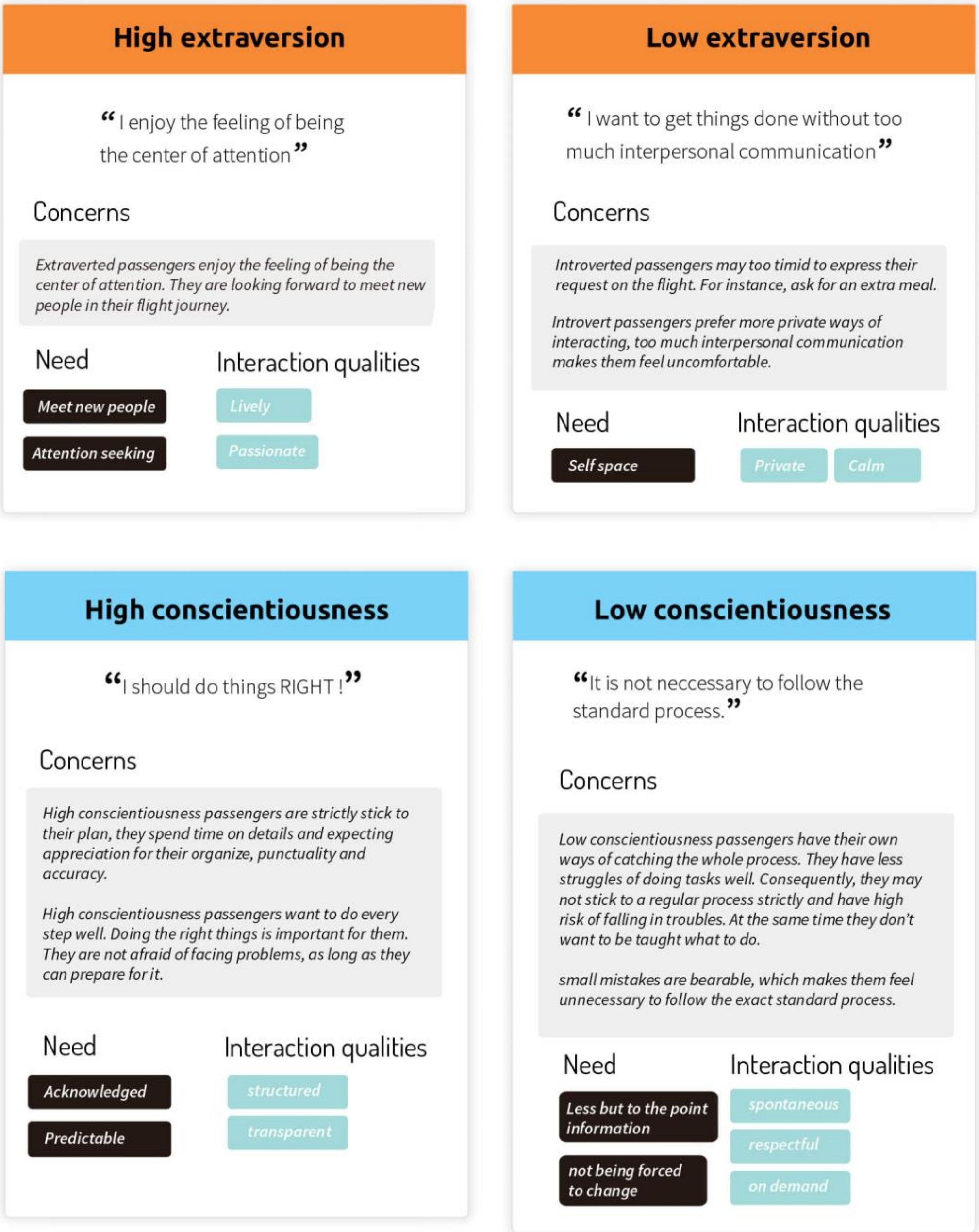

Figure 3. Personality-driven-design principle cards for extraversion and conscientiousness – a tool for designers – Available in larger size Appendix A and B

4.4 Design Cycle 4: Ideation via H2s Method

‘How to’ (H2s) is a design method that supports ideation (Boeijen, Daalhauizen & Zijlstra, 2014). In this case, the method was deployed to assist the design team to approach defined problems and opportunities informed by the earlier cycles of the design process. There were two phases within each H2 question, first to question the needs of a particular personality type, second to envision an ideal interaction quality based on personality characteristics. For instance, according to the personality-driven principle, people who score high in conscientiousness want to be appreciated for their preparation and punctuality. A H2 question can be reframed, ‘How to show appreciation to the high conscientious while they are making travel preparations?’ By answering this H2 question, new ideas were considered. The second set of H2 questions queried the desired interaction qualities. In this scenario, H2 questions can be reframed as, ‘How to show the destination information in a structured way for people with high conscientiousness?' Similarly, 'How to show the destination information in a spontaneous way for people low in conscientiousness?' By answering these H2 questions, new AirlineX services and products could be conceptualised.

4.5 Design Cycle 5: Designing a Use Case for AirlineX Flight Guide

To test the concept, the POS of was considered as an ideal scope for testing the concept. Flight Guide is an existing product in AirlineX that gives important flight information and possible relevant recommendations for passengers before a trip starts. Currently, the Flight Guide uses a rudimentary platform to convey information to passengers with no personalisation. By applying the personality-driven design principle – a set of tailored set of interfaces were proposed to the organisation. The concept begins with collecting new customer data related to personality type through ten questions designed to be playful (see figure 4 as an example). Based on the response to these questions, the approximate personality type of a customer could then be determined and catered to through the online touchpoints of AirlineX. This principle could be scaled across an operations, however, the design team chose to focus on online B2C interactions as a starting point. Figure 5 and 6 further communicate the type of personalisation conceptualised.

Figure 4. Example interface – Gathering data at POS. This customer data is then stored and analysed using AI to determine the personality of an individual passenger. Deeper personalisation of touchpoints can then be developed based on identified personality type

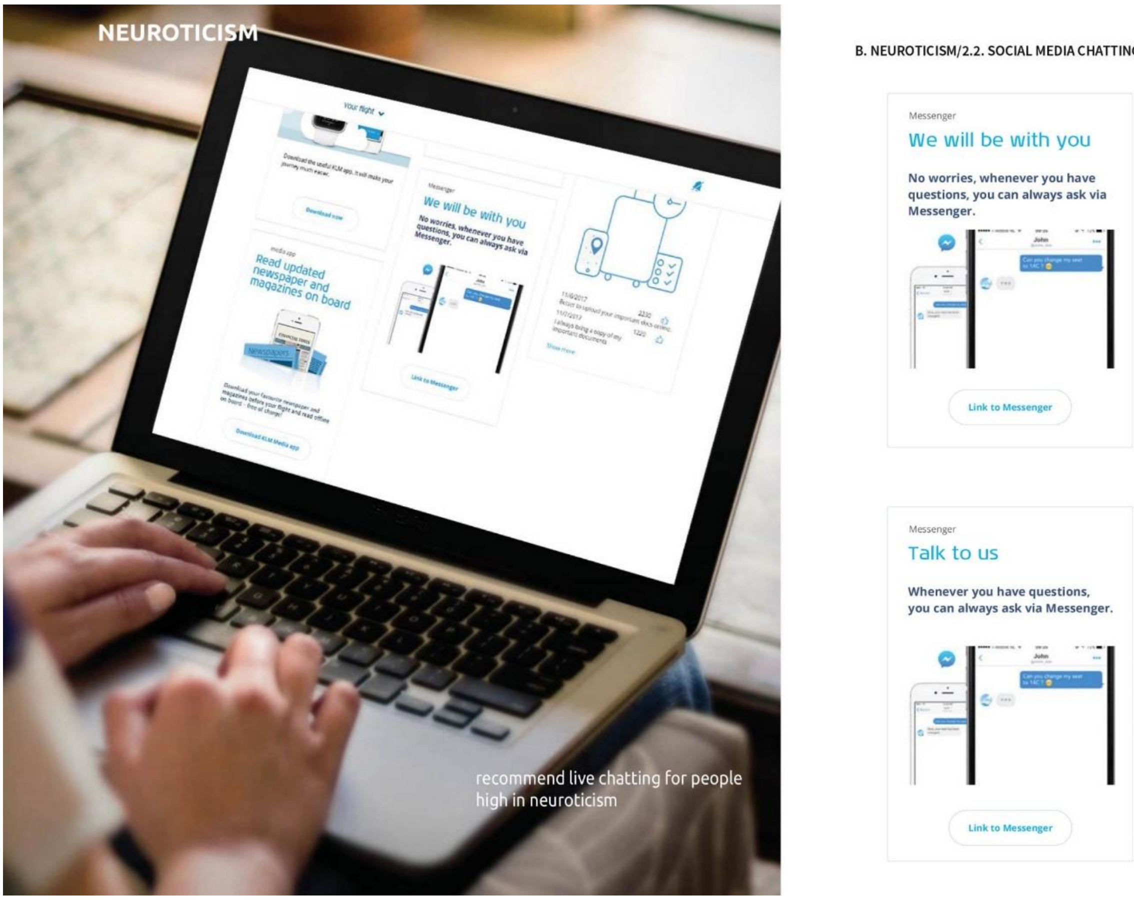

Figure 5. Example interface for passenger with a personality score indicating neuroticism. The airline will be 'with you' during your journey. Research shows that the computer can be an effective mediator people who are shy (Strizke, Nguyen & Durkin, 2004). Other touchpoints where the passenger interfaces with the airline can also be adapted to support the neurotic flyer – for example passengers can be guided through security by ground crew at unfamiliar airports

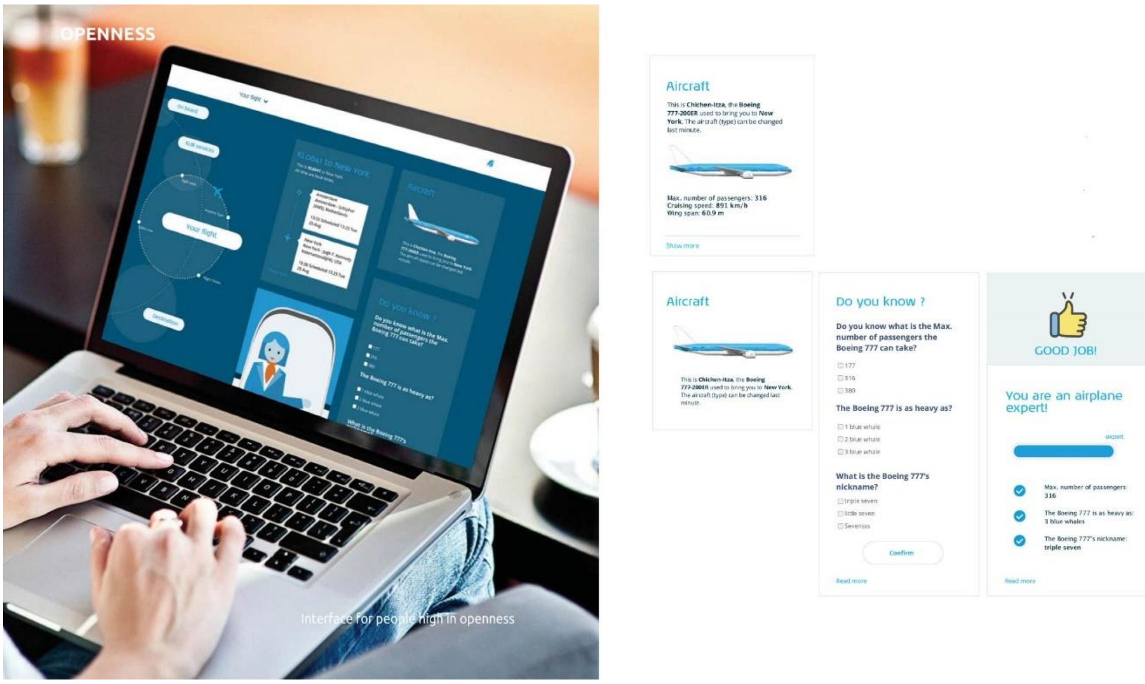

Figure 6. Example interface for passenger with a personality score indicating openness. The passenger is able to explore, learn new things about aviation and be rewarded. Other touchpoints where the passenger interfaces with the airline can also be adapted – for example a business class passenger could be served a surprise meal that contains their favourite ingredients or flavour.

4.6 Design Cycle 6: Evaluating the principle with real customers

The final design cycle of the project evaluated the concept with passengers. The evaluation approach involved 20 AirlineX passengers waiting at the X-Gates lounge at Amsterdam Airport Schiphol for departing flights. 20 semi-structured interviews were completed, each taking a duration of approximately 30 minutes. The evaluation began with ten personality-related questions that were used to determine an approximate personality type. There is a practicality-accuracy trade-off of using 20 questions only. Certain questionnaires to determine personality can be up to 60 questions long. In this instance, the questionnaire looked to identify strong indicative traits of personality only. Given the live environment, this is considered a limitation of working with the big-five theory and must be factored into future research.

Passengers were then involved in A-B testing of existing and new personality-driven Flight Guide services. Nine out of twenty passengers were high in conscientiousness and showed consistent preferences to the high conscientiousness-oriented interface design. For extraversion traits, five out of six of passengers high in extraversion appreciated the high extraversion-oriented welcoming banner. Extraversion played a role in passenger preferences. For Openness, twelve out of twenty passengers consistently responded positively to the personality specific version of Flight Guide. Openness also played a role in passengers' preferences. In conclusion, the personality-driven design of Flight Guide was positively received. According to the results, openness, extraversion and conscientiousness play a role in influencing preferences. Passengers were more likely to choose a design that matched with their personality. This result suggests that services taking personality into consideration can positively influence customer experience in air travel context.

4.7 Implementation

This paper only considered the design of Flight Guide, which is the primary digital channel of AirlineX. Opportunities to design based on personality at various touchpoints within the travel journey are being pursued in further design projects. However, based on the learning present within this project, there are five notable design requirements that must be considered when attempting to design based on personality. These requirements are presented in Table 2.

Table 2. Design intervention details

Design requirement	Description
1. The personality-based interaction should not influence the satisfaction of basic needs	The fulfilment of the personality-oriented needs and preferences should not influence the fulfilment of the basic needs. For instance, people high in openness may prefer a more explorative way of viewing information. However, the fulfilment of this preference should not influence the information clarity, which is a basic need
2. The personality-based interaction for one customer should not influence the experience of other customers	People high in extraversion may tend to express their extraverted nature. Services for this group of people should not influence the experience of others who may be introverted or low in openness. Careful consideration of how these services are implemented is required
3. The goal of travel should be taken into account	According to the design practice results, passengers with high extraversion may look forward to meeting new people in their waiting time. But if he or she is traveling for a business purpose, the most important need while waiting would be a good place to work. Consequently, the trip goal should be taken into consideration while tailoring the service and product based on personality in this situation. Other factors, for instance, mood, and who you are traveling with may also influence the needs in a specific moment.
4. New interactions should also be able to reflect the brand image of the business	The personalised design should not lose the brand identity of the business which is represents
5. Support, rather than force change	Personality driven design should encourage behaviour that assists a customer to engage with a business – rather than force certain behaviours through exclusive design

5 Discussion

5.1 *Making Data Meaningful*

To scale this concept up, passenger data would be analysed, using an algorithm underpinning AI to determine the personality of AirlineX passengers based on all operational data. AI as a cognitive machine can then humanise customer data by determining the big five personality traits. This phase of analysis becomes the initial exploration witnessed in a design process – often through design methods such as persona design or observation. What AI and data provides is a mechanism to vastly scale the exploration capabilities of the designer. Consequently, the principle is a base, it is a starting point to consider a system that collects and translates data into meaningful design material. The design team can then ideate to develop unique and deeply personal brand experiences based on personality type. This is the essence of personality-driven design using data and AI as a design material. Further, through collection of customer data and subsequent adaption of services to the individual, a living dialogue between business and customer can be developed. A visualisation of this process is presented in Figure 7.

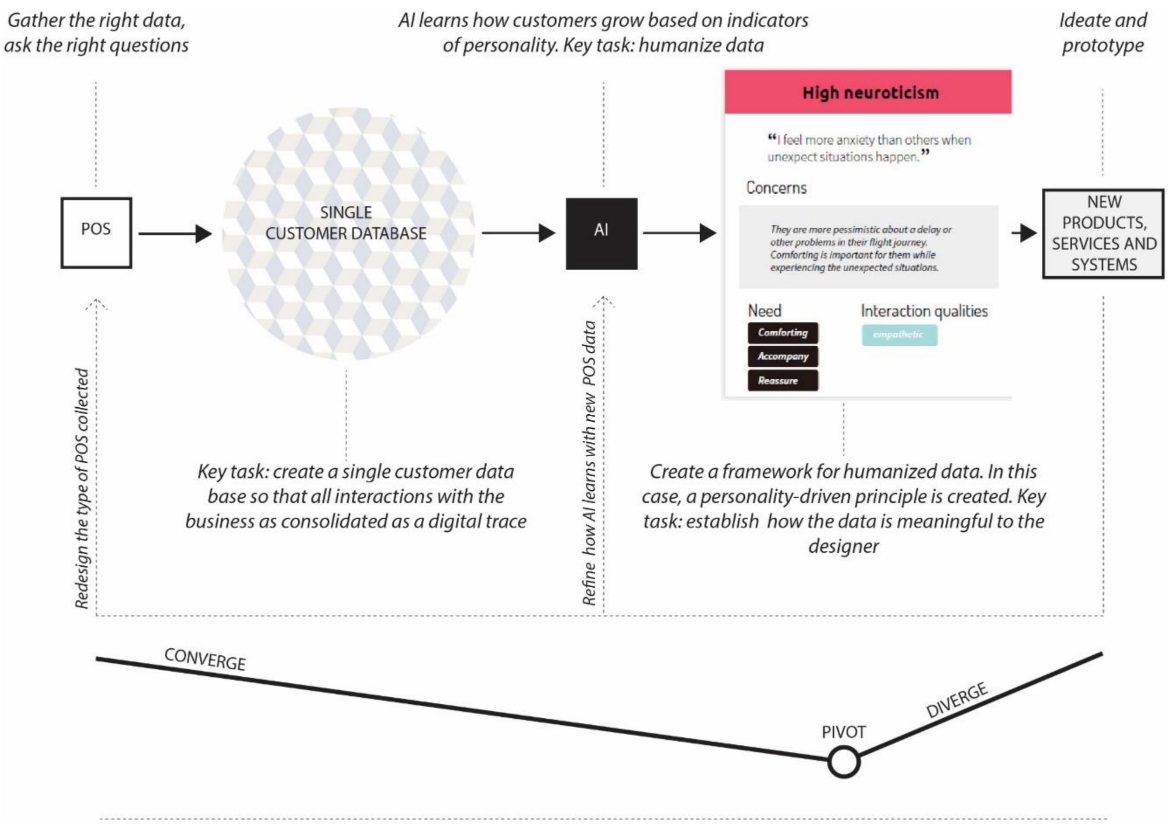

Figure 7. A framework for using Data and AI as design material. When the principle is automated into an operating system, then a set of services and processes can be adapted according to passenger personality type at any touchpoint. This framework assists organizations to develop dialogue with customers beyond the purchase point through data, representing a democratisation of the traditional B2C perspective. The new perspective becomes B2C2B – a closed loop of dialogue between customer and business that leads to improved value creation and capture for both parties

5.2 *Combining the Strength of Designer and AI*

Data-driven organisations are efficient performers (Redman, 2013). Design-led organisations also outperform peers by identifying and leveraging latent needs (Rae, 2016). When AI is paired with data of a person's digital trace (from social media for example), the machine will find correlations, identify patterns and make predictions of possible needs and preferences for future. AI when partnered with a principle for processing data is able to perform a form of exploration. The scale of this exploration is something that the designer is not able to mimic. Critically, what the designer can do is take the result of AI exploration and translate this into the design of products, servicesand systems. In this case, we have shown that the designer asked AI to identify the personality traits of passengers in order to provide an opportunity for deeper personalisation of online AirlineX services. Therefore, AI offers a powerful design tool for the designer in a digital economy – particularly to allow designers to turn ubiquitous data into meaningful material for designing. For the time being, the designer will be to able direct AI, however, this may not always be the case. Therefore, the possibilities of AI and data must remain a prominent discourse of the design community.

5.3 Learning on the Job with AI

Learning on the job is the notion that an organisation can learn and grow as its customer also grow in life. Collecting data by asking explicit questions to passengers during every POS business interaction is not a sustainable approach. The passenger may like to ‘skip’ such questions or even become frustrated with the service and choose another. In order to make data collection resonate with lean or agile businesses, the process must be less disruptive to B2C relationships. Learning on the job is the strength of AI will enable an organisation to grow with customers by tracking online behaviour – with privacy protocol in place.

This way of measuring personality is less disruptive to the passenger, and also more accurate in a sense that the results are based on behaviour, rather than how a customer describes themselves. However, such a concept requires further research to overcome privacy constraints. The ethics of data use are ever-current. Greater transparency regarding how data is collected and used is required to educate consumers. Designing services and products that explicitly show consumers how data is collected , held privately and used to benefit their experience has been the approach throughout this project. A lead user group who actively contribute data might be one way of testing a prototype for this service.

6 Conclusion and Implications

The proposed personality-driven design principle derived from literature review and design practices is just one suggestion to humanise data using AI. The original big five personality research (Goldberg, 1990) and personality related research was extended to the aviation context. A relationship was found between customer’s personality and their preferences in their flight journey, which suggests the value of taking personality into account for personalisation. For an airline, or any organisation pursuing a personalisation based strategy, this design principle when partnered with data and AI can enable services and products to be tailored to the individual. AirlineX competes on customer intimacy by providing exceptional customer experience through its frontline staff – notably its cabin crew. However, now the airline can also compete through deeper personalisation of products and services that adapt to passengers overtime. This carries great implications for considered the business model as a dynamic entity – capable of shifting form in response to personal preferences. The implications of this project for designers are identified:

- The ‘big five’ translates to a set of needs and interaction qualities that are aviation specific;
- The designer can plan what type of data is collected from customers by asking the right questions;
- AI provides the cognition to analyse data, but still requires a set of design-principles to add meaningfulness in the form of humanization;
- Humanised data is meaningful data for the designer.

7 Future Research

For all of the technology advancements since the creation of the internet, the infant stages of a true digital economy are only yet being realised. A fundamental shift in the way that society operates is approaching with consequences for the design research and practice. What must be avoided, is an organic explosion of possibilities such that was witnessed with the internet - given the ethical complexity of AI and data. Therefore, future research must focus on the role of the designer as a translator of technology into life. More particularly, research must address the responsibility of designers as developers of ethical frameworks for technology as additions to society.

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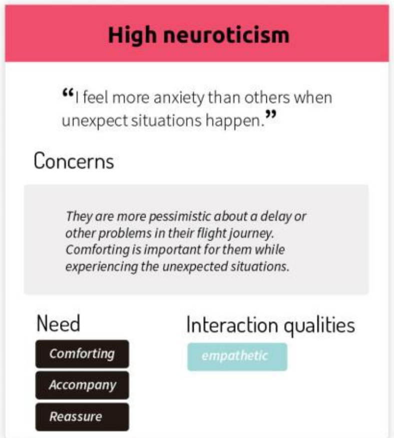
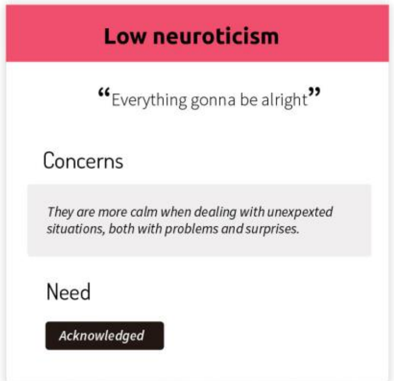
9 Appendix A – 8 Personality Cards

10 Appendix B – 2 Personality Cards Continued and Interaction Qualities

Traits	Needs	Interaction qualities
High Extraversion	Meet new people, Attention seeking	Passionated, Animated
Low Extraversion	Self space	Private, Calm
High Consciousness	Acknowledged, Predictable	transparent, structured
Low Consciousness	Less but to the point information, Not being forced to change	on demand, spontaneous, respectful
Low Agreeableness	Less disturbed by other people	
High Agreeableness	Acknowledged, Enable to help others	warm
High Neuroticism	Comforting, Reassure, Accompany	reliable
Low Neuroticism	Acknowledged	
High Openness	New options, Creativity, Surprise	explorative, Inspired
Low Openness	Routine	concrete





Section 13.

The (Act of) Drawing in Design

Editorial: Drawing as a Powerful Catalyst for Design Driven Research and Creation

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KU Leuven
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Drawing is one of the most important activities of a designer, who draws with different media ranging from the pencil to the computer mouse. The act of drawing is a multi-layered, multi-sensorial activity with a significant impact on creativity, creative output and knowledge production. It is above all an act with a long tradition related to many disciplines that adopt the map, the sketch, the plan, the section, the detail and relate them to their discipline-specific acts of drawing. All this includes a mental relationship between the outcome and the first sketch. In our current age, gurdominated by multi-media and digital alternatives, we look at possible (re)- interpretations of this activity and productions. How is the (act of) drawing connected with design, designing, design research, interaction design, pedagogy, geography …?

The question of space appears to come back time and again in the course of human history, that proves we can re-think and re-design space through the transformation of immaterial and mental aspects into tangible space (so-called analogous spaces), opening new avenues to innovation and reflection, and to debates on political and social topics. There are numerous strategies to be investigated here, ranging from the transformation of immaterial and mental aspects in tangible space (so-called analogous spaces) to looking at old masters who focused on how space is related to mental aspects such as thinking, reflecting and understanding the world. But most of these strategies strongly rely on drawing as the eidetic act of transformation between the immaterial and the tangible world.

Drawing and space share a common history, and all along these historical lines—that reach as far as today—strong dependencies between the drawing and the space exist, which appear to make them inseparable, both in the conception and in the observation and understanding of space. In designing, looked at from a historical perspective, space is often that which drives designers to drawing, whereas drawing is often that which leads to new spaces. Innovative ways of drawing have led to innovative concepts of space. The urge for the latter has often instigated the quest for the former, and the other way around.

This co-existence of both entities—the drawing and the space—generates fruitful crosspollinations, and this forms the base of this research environment. We believe that bringing these together may deeply change our view on this research landscape, and further expand it.

The further development of the architectural drawing and the analogous space is key to the discipline of architecture. Both track chairs of this conference track have erected the research group *The Drawing and The Space* (http://www.thedrawingandthespace.info, https://architectuur.kuleuven.be/departementarchitectuur/english/research/onderzoeksgroepen/the-drawing-and-the-space) at KU Leuven Faculty/Department of Architecture, with the explicit ambition to investigate the potential of the intersections between Drawing and Space for the discipline of architecture

The Design Research Society 2018 conference offers an opportunity to map and discuss interests between design research, and current professional, educational and research practices that all seem to revolve around the act of drawing as a powerful catalyst for design driven research and creation.

The scope of the theme The (Act of) Drawing in Design (Research) is twofold. Firstly, it will be a meeting point for researchers from a variety of backgrounds to jointly share and discuss their insights and ideas. Secondly, we aim to explore the meaning and values of the (act of) drawing in the light of design driven research and creation as a whole.

As a result of the call of our DRS conference track we received a set of submissions that, altogether, appear to cover a range of subjects and topics that widely benefit from the drawing as a powerful catalyst for design driven research and creation. These subjects and topics range from (1) anthropological approaches and (2) computational and robotical interests over (3) sculptural and artistic processes of knowledge production and (4) the physical gesture of drawing as a generator of memories to (5) notionality and inscription of verbalization to make tacit knowledge explicit and (6) analogous drawings of speculative architectural designs as forms of knowledge production in the field of architecture.

Here occurs the tight correlation between the architectural drawing and the analogous space. It is clear that each of the contributions to our DRS conference track demonstrate ways of drawing as descriptors and initiators of particular spatialities: (1) the mental and physical space of aboriginals, (2) robotical versus analogous space, (3) abstract sculpturalities that describe space through spatial occupation, (4) physical human gestures of drawing that make ‘memory’ tangible and translate it into space, (5) imagineering space through close observation of innovative ways of drawing and (6) space making through the embodiment of ‘landscape’ (fragile topographies) by deep and intense processes of drawing.

The themes and outcome of this conference may help to further investigate the aforementioned themes, and the submitted contributions prove that these themes need to be further investigated. We are very grateful that the Design Research Society is offering platforms from which this content can be further discussed, shared and disseminated. Hence the chairs of this conference track wish to expand and strengthen this community in collaboration with the DRS and the researchers and designers who have showed their interest through the contributions they have submitted.

The Search of the Unpredictable – the Process of Drawing

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With the aim of shedding light on practical procedures of imagination, this paper is focusing on the analysis of experimental drawing processes. They were conducted in order to provide a basis for the discussion of the relationship between the gesture of drawing and the dispositions of the designer formed by inherited conditions, the socio-cultural framework and individual experiences (Damasio, 1999). With this approach of *practice-led iconic research*, it is not the goal to develop generalized descriptions for any innovation process as the Design Methods Movement of the 1960s once proposed, but to differentiate between conditions supporting or inhibiting the development of surprising and intriguing images for various contexts. The drawing experiments and their discussion provide insights into the workshop of imagination.

gesture of drawing, disposition, imagination, practice-led iconic research

1 Positioning the Inquiry into Design Processes after the Iconic Turn

“If I knew where my ideas come from, I‘d go there”[1] was the title of Thomas Demand’s lecture on *Imagination* at a conference in Basel in the autumn of 2010. At first glance, this may sound tongue-in-cheek, but it reminds us that this inquiry into the processes of visual innovation is not going to be unveiled by mere formulas. The core of creating new images is elusive (Derrida, 2007, 3). While contemporary aesthetic practice hesitates to reflect on its processes on a scientific level and, therefore, fails to explain its impact, the history of Western thought offers a number of descriptions directly related to the creative process. The idea of an individual’s talent or disposition being responsible for the creative capacity reappears in different contexts. In these descriptions, the faculty of an individual’s imagination is either a result of godly influence (Assmann, 2003, 21 – 36), of genius (Kant, 1790, § 46), or of social interaction (Latour, 2005, 46 – 50, Renner, 2014, 69 – 84), depending on the status of the individual in respect to divine powers, to an autonomous constitution, or social interaction. Instead of elaborating the numerous references

[1] Demand, T. (2910) Lecture title. Conference Imagination. Suchen und Finden, eikones, Swiss National Center of Competence in Iconic Research, October 19th, 2010. Programme available online: https://archiv.eikones.ch/nc/veranstaltungen/detail/?tx_cheikonesevent_pi1%5Buid%5D=142&cHash=b8746393b5b3fcec6ca49824678fb040 (last visited November 10th, 2017).

the humanities provide for a discussion of imagination[2], my contribution will start with a prominent attempt to reflect the processes of design in the middle of the 20th century.

In the Design Methods Movement, which was founded at a conference at the London Imperial College held from September 19th till September 21st, 1962, an interdisciplinary field of inquiry into the processes of design was initiated. The protagonists of the movement intended the extension of the field of design, from a process of aesthetic decision-making to a science of decision-making for the development of a better future of society. The aim was to bring together a variety of scientific disciplines such as engineering, architecture, urban planning, and design in order to describe their processes of invention (Mareis, 2011, 38). This often led to flow chart-like descriptions of generalized problem-solving processes intended to provide a guideline for systematic steps of planning. In retrospect, we can state that – for the sake of being scientific in the post-war context of economic growth and optimism – the intuitive search for an unknown visual solution was neglected (Langrish, 2016, 51 – 64). Even the founders of the movement critically commented on the outcome of their previous intentions. The following statement of 1971 by Christopher Alexander, one of the founders of the Design Methods Movement, can be used in support of the analysis of practical design processes but also to critically assess the proposed analysis of design processes in the following part of this contribution:

> *"Since the book was published [in 1963], a whole academic field has grown up around the idea of the leading exponents of these so-called design methods. I am very sorry this has happened and want to state publically that I reject the whole idea of design methods as a subject of study, since I think it is absurd to separate the study of designing from the practice of design."*
> *(Alexander, 1972)*

We may argue that the proposed field of inquiry into the design processes in the context of *practice-led iconic research* (Renner, 2010, 2017/2018) is an attempt to involve the existing competence of the practice in order to avoid a discourse detached from the practice of visual communication. On the other hand, we may also interpret Alexander's statement as a statement against any kind of scientific reflection on design processes and on design in general. The inquiry into design processes by the Design Methods Movement of 1962 has been characterized by three layers which, according to John Langrish, have all failed:

> *"1. A general all-purpose optimistic* zeitgeist *that saw the world as getting better than it had been.*
> *2. A belief that the process of designing had an important part to play in this 'getting better'.*
> *3. A belief that the design process could itself be made better through becoming more scientific."*
> *(Langrish, 2016, 55)*

[2] It is not possible to go into all the details of these theories here. Terms such as "abduction" (Pierce), "impulsion" (Dewey), "tacit knowing" (Polanyi), and "serendipity" (Rheinberger) could be considered here as well.

In opposition to the above-described aims of the Design Methods Movement, this contribution and its analysis of image generation avoids these pitfalls in the following manner:

1. Only in one respect does the inquiry into the design process after the iconic turn[3] attempt to "change the world" by implying that the understanding of images is a crucial part of information dissemination in a society which is based on democratic principles.
2. The importance of design in improving the world is shared until this day, but, following the iconic turn, the inquiry into the design process aims, more than anything else, at providing evidence that the practice of design actually does have an impact on society.
3. At their core, practical design processes will not be improved by means of scientific inquiry. But research will provide the means to conceptually frame the processes in new ways and help to further develop the design practice, the educational design principles, and the knowledge about images.

In due consideration of the declared differences from the Design Methods Movement, the inquiry into the design process suggested by *practice-led iconic research* places the practical procedures of image generation at the centre of its attention.

If we return now to the humanities and their discourse on imagination, we can start with the etymological aspect and emphasize the close relationship between the term of "image" and that of "imagination". As the term suggests, imagination is closely related to images and consists of the ability to form new ones (Boehm, Aloa, Budelacci & Wildgruber, 2014, 8 – 11). Kant has described the necessity of imagination to form sensuous experiences out of a schema and sensuous stimuli. To him, everybody has the faculty of imagination, but only a genius is able to use it to achieve beauty in art[4].

In opposition to the faculty of imagination, there is the idea that nothing is truly new. All that we hold to be new can be either something that may already exist but of which we are simply not aware, or something which is the result of a re-configuration of existing elements. An early source of this position can be found in Plato's *Meno* (Plato, 380 B.C.E.). In their dialogue, Meno and Socrates declare that any inquiry into a subject is merely pure recollection. Beyond this view, the terminology of figuration grants the existence of new occurrences but only under the aspect of a reconfiguration of existing elements. While imagination is closely related to the processes of an emerging image and, therefore, to experience, configuration is related to the processes of conceptual abstraction through words in language (Mersch, 2006, 79 – 91).

[3] The terms "Iconic Turn" (Boehm 1994) and "Pictorial Turn" (Mitchell 1995) were coined in the middle of the 1990s in the context of art history in order to describe the observation of a flood-like increase of image production and dissemination caused by digitalization. Both authors claimed the lack of scientific knowledge on how images generate meaning in comparison to language, which has been a topic of critical reflection since antiquity. Boehm, G. (1994). Die Wiederkehr der Bilder. In: Was ist ein Bild? 2nd ed.; Boehm, G. (ed.), Paderborn, Germany: Wilhelm Fink Verlag. Mitchell, T. W. J. The Pictorial Turn. In: Picture Theory, Essays on Verbal and Visual Representation. Mitchell, T. W. J., 2nd (ed.), Chicago, USA: Chicago University Press.

[4] "Genius is the talent (or natural gift) which gives the rule to Art. Since talent, as the innate productive faculty of the artist, belongs itself to Nature, we may express the matter thus: Genius is the innate mental disposition (ingenium) through which Nature gives the rule to Art." Kant, I. (1790). The Critique of Judgment, § 46. Available online: http://denisdutton.com/kant_third_critique.htm (last visited on September 10th, 2017).

In accordance with the philosophical debate on the *schema*[5] (Heidegger, 2010) and the use of the term of *image schema*[6] in the cognitive sciences (Lakoff & Johnson, 1999; Johnson, 2008; Fauconnier & Turner, 2002), the concept prevails that our memory holds condensed and generalized records of past experiences – the dispositional space – which are constantly interacting with the signals perceived by our senses – the image space. Based on Antonio Damasio's understanding of the dispositional space, we can infer its responsibility for the quality of a gestural movement.

> *"The image space is that in which images of all sensory types occur explicitly. [...] The dispositional space is that in which dispositions contain the knowledge base and the mechanisms with which images can be constructed from recall, with which movements can be generated, and with which the processing of images can be facilitated." (Damasio, 1999, 331)*

With this structure in mind, the creation of images and their perception depends on the memorized experiences of their designers as well as their beholders. Both hold an archive of images and their generalization in their mind. Yet, every image we perceive can be seen as a constant reconfiguration of the rules defining a class of memorized experiences in a condensed form and below the threshold of consciousness.

In contrast to the philosophical positions addressed above, the main focus of this paper is based on the analysis of the outcome generated by practical and experimental design processes. In order to avoid any misunderstanding, it is important to declare that the outcome of the experiments which will be discussed do not strive to be understood in the context of art. The experiments are conducted to provide evidence in the form of image variation. They are discussed, but not replaced by language, in order to contribute to the understanding of how images generate meaning in the context of communication, design, architecture, science, education, art etc. Aware of the blurred borders, the approach of *practice-led iconic research* tries to avoid the confusion between the preconditions and hidden forces of the art context with the aim of a scientific discourse often encountered in *artistic research*.

Following the dichotomy of *imagination* and *configuration*, the starting point of the following experiments could be the analysis of the processes of collage, exploring the combination of existing image elements in order to understand processes of figuration. However, in this paper I shall focus on the analysis of experimental drawing processes that are directly related to the concept of imagination.

We can argue for this practice-led approach referring to theoretical positions pointing at their own limits. The analysis of gestures in general, and gestures of image creation in particular, was already described by Vilém Flusser. He emphasized the necessity to engage in gestures in order to understand them. "To analyze the gesture of painting with the intention of understanding it, one must engage with it oneself (Flusser, (1994) 2014, 66)." Also, Heidegger's description of

[5] Martin Heidegger describes the Schema in reference to Kant's metaphysics as the rule derived from a generalization of experiences. The Schema-Bild is the generalized image attached to the Schema: Heidegger, M ((1929) 2010) Kant und das Problem der Metaphysik. In: Martin Heidegger Gesamtausgabe, I. Abteilung: Veröffentlichte Schriften 1910 – 1976. 2nd ed.; Frankfurt am Main, Germany: Friedrich-Wilhelm von Herrmann, Ed., Vol. 3, Vittorio Klostermann Verlag, § 19 – 21, 90 – 101. Heidegger refers with his explanation to Kant's Critique of Pure Reason: Kant, I. ((1781/1787) 2003) The Critique of Pure Reason, translated by Meiklejohn, J. M. D. Available online: www.gutenberg.org, [EBook #1177], (last visited on September 18th, 2017).

[6] The term of Image Schema again appears in recent philosophical positions informed by cognitive science: "An Image Schema is a dynamic, recurring pattern of organism-environment interactions. As such, it will reveal itself in the contours of our basic sensorimotor experience. Consequently, one way to begin to survey the range of image schemas is via a phenomenological description of the most basic structures of all human bodily experience." Johnson, M. (2008). The Meaning of the Body. Aesthetics of the Human Mind. 1st ed.; Chicago, USA: Chicago University Press, 136.

Zuhandenheit can be addressed in order to firmly embed practice-led methodology in the limitations of a purely theoretical approach (Heidegger, 2006, 69).

2 The Training of the Hand – on Shaping Dispositions

The potential of the hand in relation to imagination has been described in a variety of contexts. Sociologist Richard Sennet, e.g., discusses a variety of phenomena encompassed by the training of the hand in music, cooking or a craft such as glass blowing (Sennet, 2008, 149 – 178). In the critical analysis of the Suzuki method to learn how to play the violin he states:

> *"This [the removing of the tapes] is therefore also the moment when error becomes clear to the musician. As a performer, at my fingertips I experience error — error that I will seek to correct. I have a standard for what should be, but my truthfulness resides in the simple recognition that I make mistakes. Sometimes in discussions of science this recognition is reduced to the cliché of "learning from one's mistakes." Musical technique shows that the matter is not so simple. I have to be willing to commit error, to play wrong notes, in order eventually to get them right. This is the commitment to truthfulness that the young musician makes by removing the Suzuki tapes." (Sennet, 2008, 159)*

The necessary acceptance of making mistakes in playing a musical instrument can be directly transferred to the act of drawing. Besides, in drawing it is impossible to be successful if we think that every line set on paper has to be perfect. It is exactly in the process of finding a definite line – executed as a physical reaction to a change in the environment before a conscious decision has been made – that an unpredictable shift can happen which is not accessible through a conscious inference. But this does not mean that the result of a successful drawing is achieved by chance. Depending on the drawing tool, the search for a definite line happens on one sheet of paper in the process of drawing by starting with a tentative composition, which is continuously revised until the drawing is considered to be finished. Or, since the tool does not allow any alteration, the drawing has to happen in one go and, therefore, the improvement of the drawing is achieved through the repetition of the drawing from scratch on separate sheets of paper.

In reference to the above-described influence of dispositions, the gesture of the hand in the act of drawing is influenced by the individual's dispositional space formed by condensed memories below the threshold of consciousness. This conglomerate of traits is formed by inherited conditions and early childhood experiences, and continuously transformed by new experiences (Damasio, 1999, 222/223). A training in drawing can be understood as a deliberate influencing of the dispositional space. This can be done by various approaches presented in the following experiments. The first drawing experiment that indicates the qualities of the sensory/motor apparatus and its concealed decisions consists of two series of nature studies produced under varying degrees of time pressure. The drawings were made on large sheets of paper (50 x 70 cm) mounted on the drawing board of an easel in order to make generous gestures necessary. In the first series, the drawings were produced in decreasing time spans of 30 minutes, 10 minutes, one minute, and 10 seconds, with the goal of representing the object as it is perceived [Figure 1].

Figure 1 Sequence of drawings made in decreasing time spans. Example from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

The series makes clear how the shortening of the time span available for drawing impacts the abstractness of the resulting image. In the shortest time span, decisions have to be made under high pressure and reflex-like movements, involving the entire arm. In the second series, five drawings are made in different time spans established in advance, with the goal of representing the object as it is perceived. The first 10-second drawing requires that the designer takes fast, basic steps to abstract the form [Figure 2]. The next three drawings were produced in longer time spans of one minute, 10 minutes and 30 minutes and, therefore, enabled a more profound interaction with the object and its translation into a drawing [Figure 3]. The spatiality, contrast, and composition of the area surrounding the object, etc., could be investigated at leisure in these drawings.
Again, produced in a time span of 10 seconds, the fifth drawing shows, in comparison with the first, distinct differences in the translation of the represented object [Figure 4]. From the unspecific interpretation of the first drawing, which follows the silhouette of the object, another drawing is produced that is equally reduced, but is an improvement in the representation of the very essence of the object. The drawn exposition of the interior form, with the suggestion of individual blossoms and their rhythmic repetition, is directly derived from the designer's experience with the more detailed drawing. Even though I only present the drawings of one person from this experiment, the results are similar if we conduct this exercise with a group of designers or students.

One reason why the result may not be evident with approximately 10% to 20% of the participants, is when the person conducting the experiment is afraid to fail, or to be unable to fulfil expectations and, therefore, to make a mistake. The series of drawings presented above show how the translation of an object in a fast drawing process, which necessarily relies on unconscious decisions guided by our dispositions, depends on the designer's experience with the object. The sequence proves that the careful observation in the long drawing processes shows its effect clearly in the second 10-seconds drawing. Although the unconscious decisions made in the drawing process can scarcely be verbalized, they can be influenced by drawing exercises and the visual study of the object to be depicted. Along with the designer's experience, the interaction with the object of representation influences the records in the dispositional space. Since practicing to draw is just one specific experience influencing a designer's or an artist's dispositions, we may ask if we can differentiate other frameworks of experiences affecting the decisions concealed below the threshold of consciousness. The following experiment is another inquiry into the experiences shaping the traits that guide the gestures of drawing.

Figure 2 Example of the first 10-second drawing by participant A. Example from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

Figure 3 the 1-minute, 10-minutes, and 30-minutes drawings by participant A. Example from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

Figure 1 cf. above

Figure 4 the 1-minute, 10-minutes, and 30-minutes drawings by participant A. Example from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

3 Reflecting Collective and Individual Influences on Dispositions by Drawing

The following drawing experiment was conducted with ten participants, all Master's students in Visual Communication, though with different cultural backgrounds. They were asked to draw compositions of horizontal and vertical lines using ink and brush on large sheets of paper mounted on the drawing board of an easel. The goal consisted in achieving an interesting or aesthetically pleasing result. The participants in the experiment had plenty of time to engage in this search for a favourable composition. After many attempts had been made, approximately after one hour, the students were asked to select and mark their two favourite examples. The selected image pairs [Figure 5] by six participants [Figure 5, left to right, participants A, B, C, D, and E] of the experiment

show a variety of individual approaches. They range from compositions following a predetermined strategy of dividing a plane [Figure 5, left column, participant A] to a planned use of the tool and its ability to hold ink [Figure 5, right column, participant E]. On the opposite side of the spectrum, there are compositions which are the result of a process that is not preconceived, but a sequence of actions following the setting of the first stroke [Figure 5, middle column, participant C]. In a second task, the participants were asked to draw objects such as pumpkins and lilies

with brush and ink. The idea of a predetermined strategy, e.g., is recognizable in the representation of the still life by participant A, especially in the forceful generalization of the flowers using straight lines [Figure 6]. The ink-wash approach and the bold composition by participant B is consistently applied across all her drawings. The inclusion of controlled accidents in the drawing process by letting ink and water converge on the paper results in a textural quality triggering the imagination of the beholder [Figure 7]. Participant C creates tension by a playful and intuitive placement of dark spots in relation to fine lines. The rhythm of the gesture representing the flowers is imitating the observed rhythm of leaves and segments of the stalk [Figure 8]. The painterly development of grey values through a nervous gesture in the abstract compositions and the representation of the pumpkin lead to a realistic representation of light and shadow [Figure 9]. And the conceptual idea of demonstrating the material quality of brush and ink by setting a repetitive stroke on the paper until the ink runs out, is mirrored in representing the linear and spatial principle of the pumpkin [Figure 10].

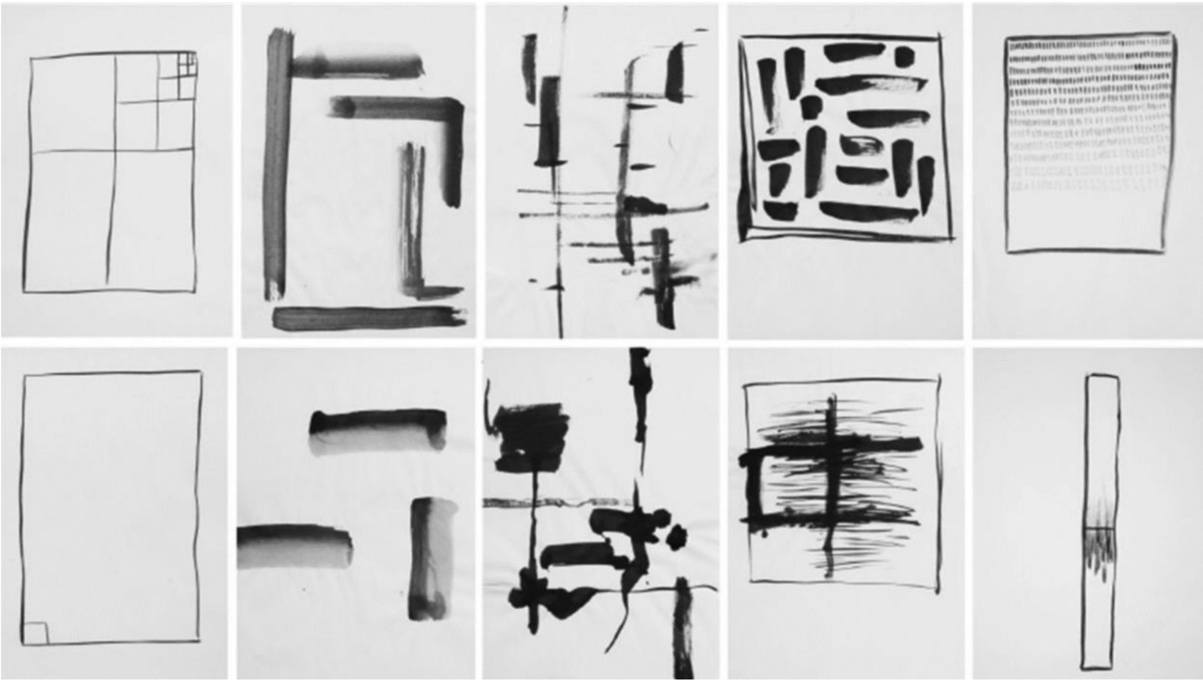

Figure 5 two favoured compositions by 5 participants. Examples from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

Figure 6 the two favourite abstract compositions and the two favourite drawing of lilies by participant A. Examples from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

Figure 7 the two favourite abstract compositions and the two favourite drawing of lilies by participant B. Examples from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

Figure 8 the two favourite abstract compositions and the two favourite drawings of lilies by participant C. Examples from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

Figure 9 the two favourite abstract compositions and the two favourite drawings of pumpkins by participant D. Examples from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW.

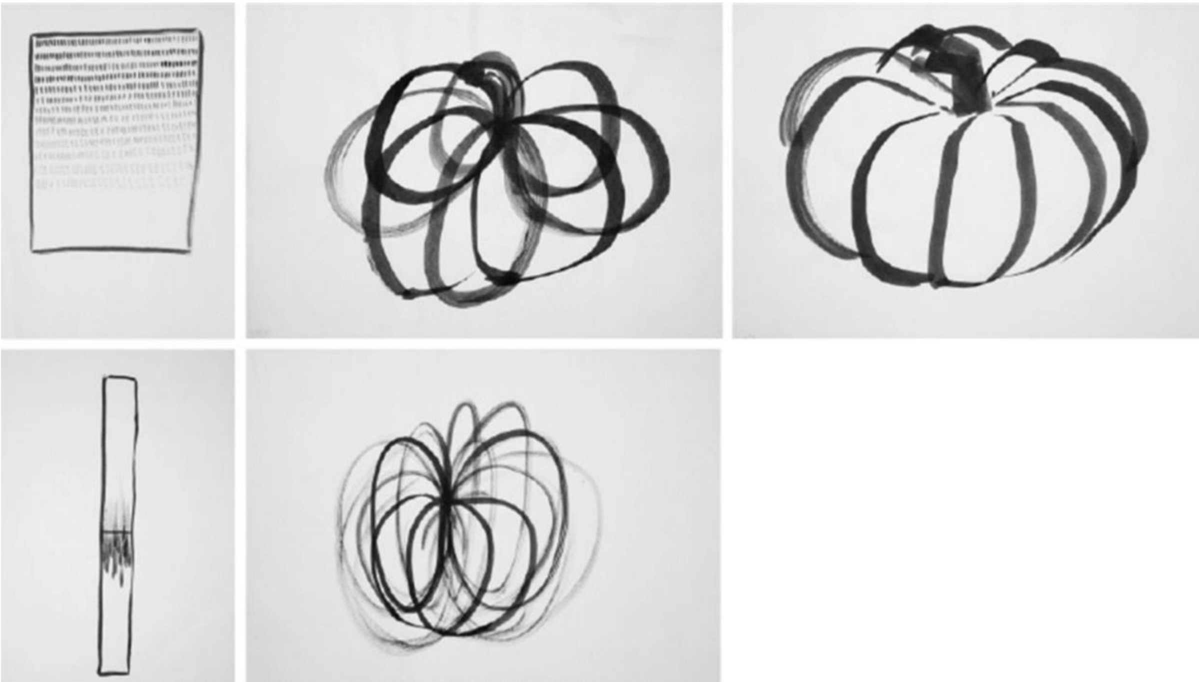

*Figure 10 the two favourite abstract compositions and the two favourite drawings of pumpkins by participant D. Examples from a class project conducted by the author from 2010 onwards at the Visual Communication Institute, The Basel School of Design HGK FHNW***.**

After a short analysis of a selection of results generated in the above described experiment, we can return to the question of what influences the disposition of the gesture of drawing. In view of the diversity of the results discussed, we can infer different aspects leading to an individual specificity of the drawing process.

A strong influence on the gesture of drawing can be attributed to a preconceived conceptual framework that exists or does not exist as a verbally accessible idea before the first stroke is set on paper. As we have seen in the results of participant C [Figure 8], the process is not following a rule which could be described before the act of drawing is executed. In opposition to the results of participants A [Figure 6] and E [Figure 19], relying on a concept, the drawing of participant C is the result of a series of gestures, reacting to the traces created just before.

We can also describe the diversity of the results according to the different ways the participants use the drawing tool. Either the brush is used to invent the elements of the drawing (participant B [Figure 7], participant C, [Figure 8] and participant D [Figure 9), or the brush is considered a means to execute an idea and could also be replaced by any other tool (participant A [Figure 6] and participant E [Figure 10]). Again, the described diversity of approaches can be attributed to different levels of confidence. On the level of individual experiences, everybody had either been told that he or she was able to make nice drawings or was not able to draw well. In addition to such individual experiences, there also seems to be a strong collective influence on a cultural level in regard to what is considered a successful drawing, the use of the tool and the role of a physical gesture in a specific society. The Asian cultural background of participant B (South Korea) and participant C (Taiwan) can be held responsible for a framework which allows an intuitive and sensuous approach using brush and ink. Whereas the reliance on a conceptual framework was preferred by the participants from a Western industrialized culture – i.e. participant A (USA) and participant E (Switzerland). Even though the number of examples discussed does not allow a statistical verification, we can formulate the hypothesis, that the socio-cultural background acts as a framework of individual experiences and, thus, has a significant influence on the dispositions of a designer. They become apparent in the individual aesthetic preferences of drawings, displaying collective and individual influences on a dispositional space and, thus, on the gestural movement in the act of drawing.

4 The Dispositional Space and Its Hierarchy

In the following drawing experiment, twenty participants were presented with nine non-figurative images [Figure 11]. They were then asked to draw the mental images triggered by the visual stimuli on top of the samples.

The results allow us to infer general observations. Once again participants rely on an intuitive method to define the imagination in the process of drawing or use a conceptual approach with gestures executing a preconceived idea, as described in the experiment in section 3. But beyond this observation, we can describe other aspects in view of the results of the survey. The rather ambiguous stimuli can be described, for instance, as a trigger to project images stored in the beholders' dispositional space. They vary in their success to activate the beholders' imagination. The clearly outlined but ambiguous form, e.g. [Figure 12], has sparked more associations than the photographic image [Figure 11, bottom right]. The photograph, as soon as it was recognized as a representation of gravel, put an end to the process of imagination. Neither with a clearly outlined but ambiguous shape, nor with textural stimuli, the beholder is able to immediately find a congruence with a schema stored in his/her dispositions. Therefore, the search is extended and leads to a wider range of associations or to a richer aesthetic experience (Dewey, 1934, 52 – 53). In reference to the described survey, the image schemas residing in the dispositional space appear to be organized by categories that are not equal in their likelihood to be recalled and enter into the realm of consciousness. In respect to the representation of faces, at least 50% of the resulting drawings of the survey described above show a human or animal face in a frontal representation indicated by a silhouette line specified by eyes and mouth [Figure 13]. We can use this outcome as an argument for the dominant position the image schema of the face, specifically its frontal view, holds within the dormant records stored in our memory.

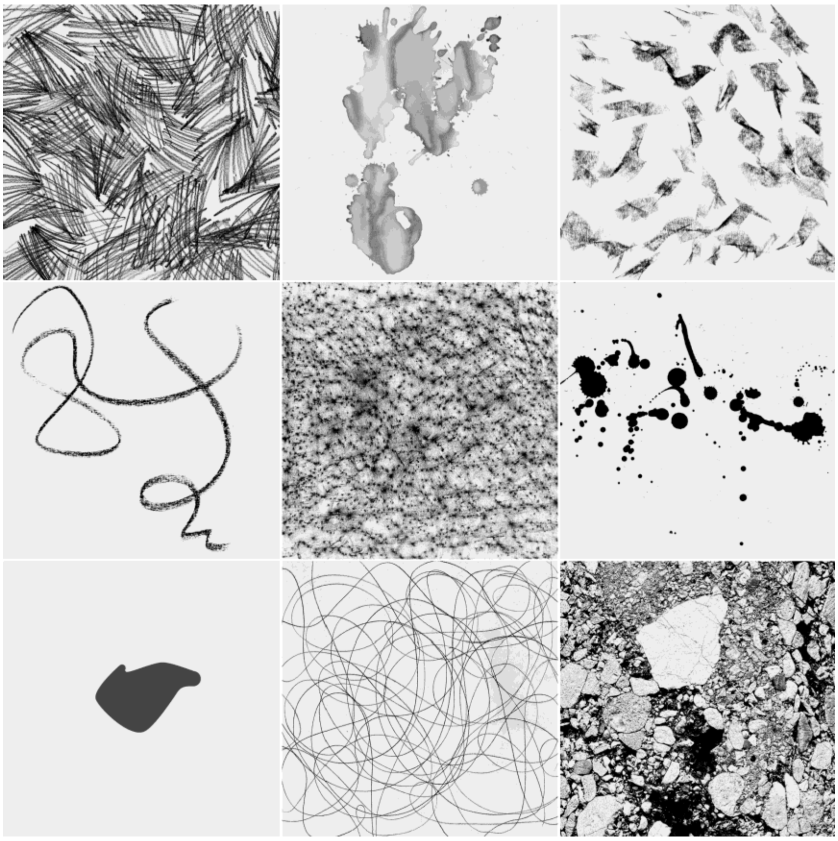

Figure 11 Indre Grumbinaite, Drawing as Cognitive Act, 2011. Eight visual stimuli as a starting point of the experiment. Master Thesis Project at the Visual Communication Institute, The Basel School of Design HGK FHNW.

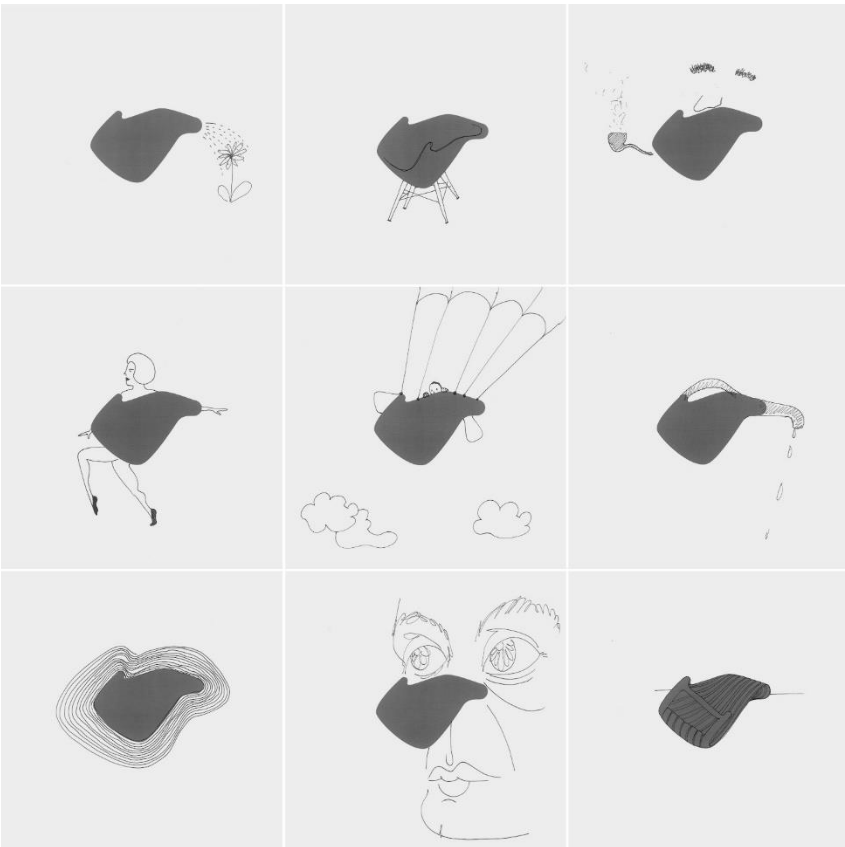

Figure 12 Indre Grumbinaite, Drawing as Cognitive Act, 2011. A selection of nine imaginations by participants of the survey. Master Thesis Project at the Visual Communication Institute, The Basel School of Design HGK FHNW.

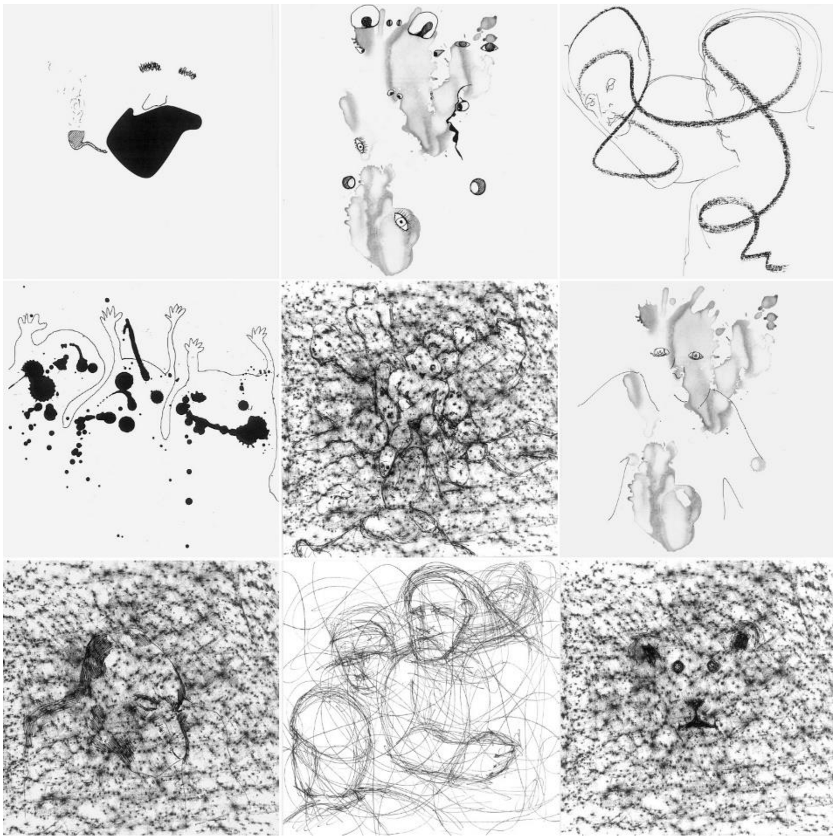

Figure 13 Indre Grumbinaite, Drawing as Cognitive Act, 2011. More than 50% of the results of the survey show faces. Master Thesis Project at the Visual Communication Institute, The Basel School of Design HGK FHNW.

5 Conclusion

If we now return to Thomas Demand's a priori position quoted at the beginning of this paper, we still cannot say where our ideas come from. But we can assess more precisely the dependence of the gesture of drawing on past experiences memorized in the dispositional space. These records – which are held responsible for the trait of movement and, thus, also for the trait of a drawn trace – are composed by many influences. Three of them have been addressed with the experiments presented. We can claim that finding the dominant position of the facial schema is based on the necessity to recognize and read faces for survival. This ability is, therefore, framed by an inherited disposition. The traits to use brush and ink in an abstract composition and in representing objects however depend on a socio-cultural framework consisting of individual variations formed by individual experiences such as a certain training in the technique of drawing. Imagination, in opposition to figuration, can be described as employing the individual setting
of dispositions to create unseen images. The conceptually framed processes of drawing – when a preconceived idea is executed restricting the gesture of drawing – does not take advantage of the concealed dispositions of the designer in the same way. These conceptual drawing processes are closer to the mechanisms of figuration. In these processes attributed to collage and language, the unexpected is achieved rather through a poetic approach arranging conventional elements in an unexpected manner.

We may ask now what these findings mean for aesthetic practice. It would probably be most inhibiting if we should try and analyze all dispositions responsible for the individual traits of a designer while he or she is drawing. The recognition of one's own aesthetic preferences, displayed in drawings, allows us to either develop them further or counteract them in order to avoid a narrowing path of expressions. For the education of designers and artists, it is crucial to understand design methods suited to a search of the unpredictable. The gesture of drawing is not only a method to achieve intriguing and surprising images but also a means to inquire into the processes of imagination.

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Drawing as Notational Thinking in Architectural Design

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In view of a renewed interest in *notationality* as central concept in design theory, the aim of this paper is to rethink of the concept of notationality as developed by Nelson Goodman in order to conceptualize the link between notational practices and their role as epistemic procedures in architectural design in a way that is tailored to the discipline. In-between the radical ambiguity of early sketches and the determined, anatomical character of the final drawings of an architectural design process exists a conceptual twilight zone in which various types of visuals overlap and interact, and in which the practice of drawing plays a pivotal, developmental role. The epistemic potentials of these practices are dependent on purposive notation. We develop two concise themes here: first, the relation between notation, iterability and signs; second, notation and the experimental 'space of formalization' it provides.

architectural drawing; notationality; design process; inscription

1 Introduction

The traces and marks left by pencils and styluses (and more recently on computer screens) play instrumental, operative roles in architectural design processes. Drawing serves to develop architectural ideas, forming an indispensable part of architectural thinking processes (Edwards 2008, pp. 12–13; Geer 2011, p. 45; Pallasmaa 2015, p. 92).

Some forms of drawing are forms of notating that exhibits potentials as cornerstones of design-based thinking. Their potential is inextricably bound to notating. Their usage as design tool for developing ideas cannot be decoupled from the fact that it is a practice of materializing thoughts through the practice of purposive notation, of inscribing traces on a surface in a directed, cognitive process that is intrinsically entangled with its object (Schurk 2013, p. 538; Van Den Berghe 2013, p. 667).

Given this reliance on notation, the aim of this paper will be an attempt to rethink of the concept of *notationality* as developed by Goodman (Goodman 1968) in order to conceptualize the link between notating and its role in knowledge production in architectural drawing in a way that is *tailored to the discipline*. This seems necessary in view of two developments. First, a renewed interest in notationality in conjunction with the idea of *operativity* in design processes. (Ammon 2013, Krämer 2009) Second, because Goodman had many worthwhile things to say about notational practices, yet left the topic of notation in architectural design processes largely undeveloped.

By explicating how Goodman conceived the relation between idea and notation, followed by a proposal to rethink the concept of notationality in a new direction, the case is made that architectural design is a form of thinking that is closely bound to notational practices, yet in a broader sense than Goodman imagined. Moreover, the case is made that Goodman overlooked precisely those aspects that make notationality important for contemporary architectural practices. This claim is substantiated by a recourse to works by Zumthor (2014), De Certeau (1988) and Krämer (2009).

2 Notationality: the relation of idea to notation

The concept of notationality as discussed here derives from the aesthetic theory of Nelson Goodman. (Goodman 1968, pp. 127–156) Informally, the term refers to the degree to which artistic performances can be noted down in a notational scheme with a high degree of exactitude. Thus, a score of a Bach cantata or the written choreography of a dance is notational: it can be expressed on paper and read afterwards; it can be performed multiple times by referring to the written sequence of signs. Each time the cantata or dance is performed is an instantiation of the score or choreography.

Put differently, the score or choreography is a type that determines which performances are tokens of the instructions set down in writing. A performance that misses essential features cannot be said to be that specific cantata or this specific dance. (Miller 2017) The score thus determines how we should judge the performance – if the gap between instruction and instantiation becomes too wide, the relationship between the two is obliterated. Originally, Goodman introduced the concept of notationality to distinguish between autographic and allographic works of art, shifting the emphasis of the discussion towards the relation between the type (the original) and the token (its performance or instantiation) (D'Cruz and Magnus 2014, pp. 2–4).

More formally, the term notationality is a stringent condition for symbol systems or schemes. The aim of this condition is to specify precisely how a notational scheme or system might be translated to a performance and back. (Goel 1991) Thus, a set of symbols that possesses perfect notationality can be used as basis for a performance (for example, as a cantata). Conversely, the performance can be used for writing a series of symbols that allows for a second, qualitatively identical performance. Goodman applied this distinction to architectural design, leading to the question to what degree drawings or sketches could be understood as a token of an original thought.

Goodman held that notationality applied not only to performances that can be readily described by notational schemes or systems, such as scores or choreographies, but that it also could apply to sketches and paintings. Of course, he remarked that sketches are different and less defined than musical scores:

> *Thus, whereas a true score picks out a class of performances that are the equal and only instances of a musical work, a sketch does not determine a class of objects that are the equal and only instances of a work of painting. Unlike the score, the sketch does not define a work (…) but rather is one (Goodman 1968, p. 193).*

This discussion of the sketch is closely aligned with Goodman's discussion of painting, where the same problem surfaces: the musical score or the choreography is an ideal example, and is expressed in a clear, symbolic language. Although the score does not determine everything about the performance (its expressiveness, for example, is more hinted at than completely described), its formal appearance and the use of individual symbols is unambiguous. Notes are notes, and steps are steps in these ideal languages. Visual language is in this sense more complex: it does not consist of discrete units (like notes, letters or symbols), and while Goodman discusses how one may consider a painting as a class on its own, the original problem remains: there is a fundamental ambiguity regarding the notation and the work in painting.

The problem is one of identity: the painting does not refer to a prior score or script, and each attempt to remake it does not rest on the interpretation of a symbolic language, but on a direct performance. One has to paint to replicate a painting, while someone does not have to compose in order to re-perform a cantata.

When we consider sketches in the context of an architectural design process, the problem introduced by Goodman deepens. First, many sketches are not clear, unambiguous instructions in a predefined visual language. Second, there is no formal condition that states that a visual language is structurally akin to a verbal language. Third, architectural design processes are comprised of multiple visual languages superimposed on each other. Quick scribbles and thoughts that are jotted down may be a-temporal, even a-spatial ideas (Graves 1977). They are ambiguous in character, making it hard to consider them as a score, script or choreography.

Conversely, the contents of a technical drawing are fully determined. It is composed of technical, symbolic languages to clearly and unambiguously communicate its meaning. Dimensions, materials, and symbols play utilitarian, practical roles in such drawings. On the level of notation, technical drawings used to realize architectural objects have more in common with a script or a musical score than the conceptual drawings early in the design process:

> *In that architecture has a reasonably appropriate notational system and that some of its works are unmistakably allographic, the art is allographic. But insofar as its notational language has not acquire full authority to divorce identity of work in all cases from particular production, architecture is a mixed and transitional case (Goodman 1968, p. 221).*

It is here that Goodman skips a step here as it were, leaving the variety and different roles of architectural drawings largely undiscussed, calling architecture broadly 'mixed and transitional', while abstaining from clarifying how different media, notational systems and performance are distributed in architectural design processes. Exactly this gap in Goodman's provides an opportunity to reflect on the role of notations in architectural representations, and to augment them to suit architectural practice.

In-between the radical ambiguity of early sketches and the determined, anatomical character of the final drawings of an architectural design process exists a conceptual twilight zone in which various types of visuals overlap and interact, and in which the practice of drawing plays a pivotal, developmental role. In a sense then, architectural drawing is a form of notation, but it is a vastly different form than the script or the musical score. Instead, in architectural design processes different forms of notation come together and overlap.

The question that Goodman poses ('is a work repeatable by relying on its notation?') is thus not directly applicable (or even relevant) to architectural practice. Instead, the drawing is an integral part of the creative process that gives rise to realized architecture. Although it is possible to build the same building twice, it does not follow that therefore every architectural drawing is a kind of musical score to which Goodman's criteria of notationality must apply, nor is it the case that an autographic work should be a one-off affair. Instead, the situation is often the other way around: drawings deal with a specific context and a specific architectural assignment that cannot be divorced from the final, built result (D'Cruz and Magnus 2014, pp. 10–11).

To do justice to architectural drawings the relation between the notation and the built (or even unbuilt) result needs a different account in order to be applicable to architectural design processes. Two main reasons can be noted for this necessity; first, architectural drawings, models and artefacts are not only intended as instructions for realization. Second, they contain a multitude of insights that are not reducible to linguistic structures, and cannot be judged solely as series of symbols – although such symbols form much of the content of the drawing. If Goodman's account should be criticized on fundamentals, his reliance on symbol systems and their semantic and syntactic properties to clarify processes in domains where these properties have limited applicability should be considered as a prime candidate. The linguistic model works well for certain symbol sets and applications (for example, mathematical symbols or the alphabet), but only limited in the case of drawings and images in a broader sense. It is at this point that we may need to leave Goodman's approach behind, and look for different ways to augment his argumentation with regards to images and drawings.

Therefore, the next section discusses how the notational systems are utilized during architectural design processes in ways that are indeed notational, yet of a broader character not entirely reducible to Goodman's model. In turn, the epistemic potentials of such systems are dependent on such purposive notation. We develop two concise themes here: first, the relation between notation, iterability and signs; second, notation and the experimental space it provides. These themes allow us to augment and complement the useful features of Goodman's account with selected concepts to make the concept of notationality relevant to contemporary architectural practice.

3 Notation, iterability and signs

When one draws to design something, either a building, neighbourhood or logo, one is confronted with absence: the object under construction exists only as a promise, as a vague mental image maybe. Although it is absent in its physical form, it structures the inquiry. The absence of the object is not just a simple lacking, a generic non-presence. It is an absence of a specific type:

> *Since every absence, whether in the language of action or in articulated language (…) presupposes a certain absence (to be determined), the absence within the particular field of writing will have to be of an original type if one intends to grant any specificity whatsoever to the written sign (Derrida 1988, p. 7).*

Derrida's claim here is very precise: the signs and traces that emerge as reaction to an absence match it, like a puzzle piece that matches an empty slot. If we apply this thought to architectural design, the drawing process is not just a matter of imitation, of denoting a mental image, but it is a precise response to a precise absence. The first conclusion to be drawn here is that denotation is not the goal of a representative process: the idea is explicitly *not* to create images that resemble a ready-made 'image in the head'. Instead, the precise absence forces designers to respond in ways that are clearly matched and oriented towards the subject matter.

Drawing is a way to represent various qualities and properties of the absent object, hauling it step by step into the physical world. While it is certainly true that architectural drawings can be used to 'test' or 'refine' the properties of the object in the real world, such an account would be overtly reductive. (Edwards 2008, pp. 12–13) Drawing is as much constitutive as it is explicatory. It materializes an idea, instead of merely externalizing a ready-made mental version of it. (Dernie 2013, p. 10) Here, then, is a first reason to regard drawing as an explicit notational form of thinking – the developmental potential of architectural thinking is embodied in its drawing practices.

Architectural objects are materialized through notation (or, alternatively, inscription or tracing). In design processes, such acts of notation manifest through drawing or modelling. The qualities that are being drawn or the objects that are being modelled do not pre-exist somewhere, waiting to be released. Instead, their qualities have to be uncovered and created at the same time. This process rests on a very specific type of repetition that works through notation. Sketches and ideas are reworked over and over again, re-iterating a concept, thought or idea.

An example of this practice can be found in the work of UNStudio. Van Berkel and Bos utilized diagrams that described the structure of design proposals on a very general level. These diagrams condense information in an organized, yet flexible manner. Van Berkel and Bos note that even before thinking of practicalities, the diagram shows what is happening at a certain location. (Van Berkel & Bos 2006, p. 15)

Since every architectural project is embedded in its own, singular context, UNStudio developed customized diagrams that were tailored to the needs of individual projects. They noted that after a few years, certain diagrams re-appeared, and that this repetition led to a more precise and focused level of inventiveness. This type of repetition is different from just replicating the same solution in a different situation. Each repetition is simultaneously a further developmental stage of an existing knowledge base and a new adaptation to a unique architectural context.

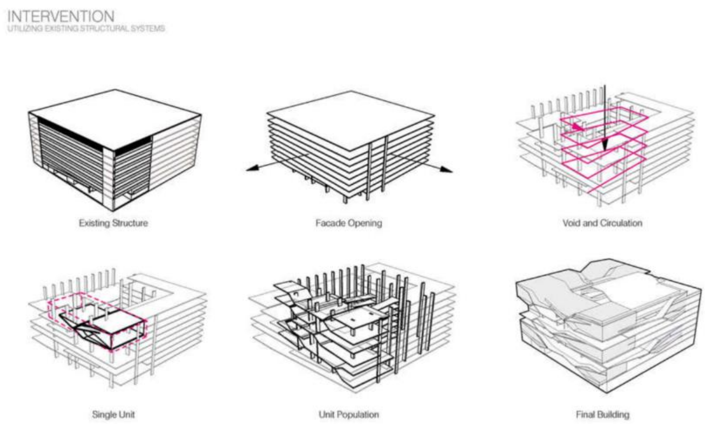

Figure 1 UNStudio diagram; each phase highlights an individual design decision, limiting what is depicted in each step. Source: UNStudio

Diagrams unite serial production and combinatorial freedom. Each diagram is uniquely tailored, yet linked to its predecessor and to its descendant. Yet, by combining and recombining elements in the diagrams, something genuinely new emerges through re-iterating a similar methodological gesture.

The concept of iteration is closely related to the theme of re-performing: iterability connects repetition to alterity, and similarity to novelty. (Derrida 1988, p. 7) Every form of notation has this potential to some degree. Both in reading and writing, generative repetition occurs. Every time a sign is written or a drawing is made, something genuinely new emerges. Such repetition is needed to reach alterity at all. It is the necessary condition for emerging novelty. Naturally, this introduces the question why this should be so.

First, we should therefore note that the repetition we encounter here is not necessarily the same as in the case of performing the same cantata or dance twice – the performance is not a token of an ideal type. (Parsons 2016, p. 16) The repetition in architectural design processes is of a different character. The reason of why this is possible may be sought in the signs it utilizes, and the role that these signs play in the thinking process.

The individual signs that constitute drawings are peculiar elements in the sense that they combine seemingly paradoxical and contradictory qualities. They are highly abstract, depicting the bare minimum of an idea, sometimes only alluding to some of its qualities. The sketches of Frank Gehry come to mind – a few lines depict a general compositional principle, the details of which are not directly derivable from the drawing itself.

Yet, these lines catch an architectural essence with minimal means – they serve as a point of reference for reasoning and further development during subsequent design steps. A different form of abstracting can be found in Ludwig Hilberseimer's 1927 plans for a *Großstadtarchitektur*, his 1944 proposals for a 'New City', or O. M. Ungers' 1977 *Die Stadt in der Stadt*, although in this case it is an abstraction with regards to level of detail, not so much with regards to spatial composition in the narrow sense. (Anderson 2016; Hilberseimer 1944; Ungers 1977) The organization and spatial configuration is there, but it lacks an element of how it functions in everyday life. Yet, these images evoke a feeling of 'indeed, it could work like this', adding plausibility to a possible future, what De Jong calls the creation of 'necessary conditions for existence'. (De Jong 1992, p. 10)

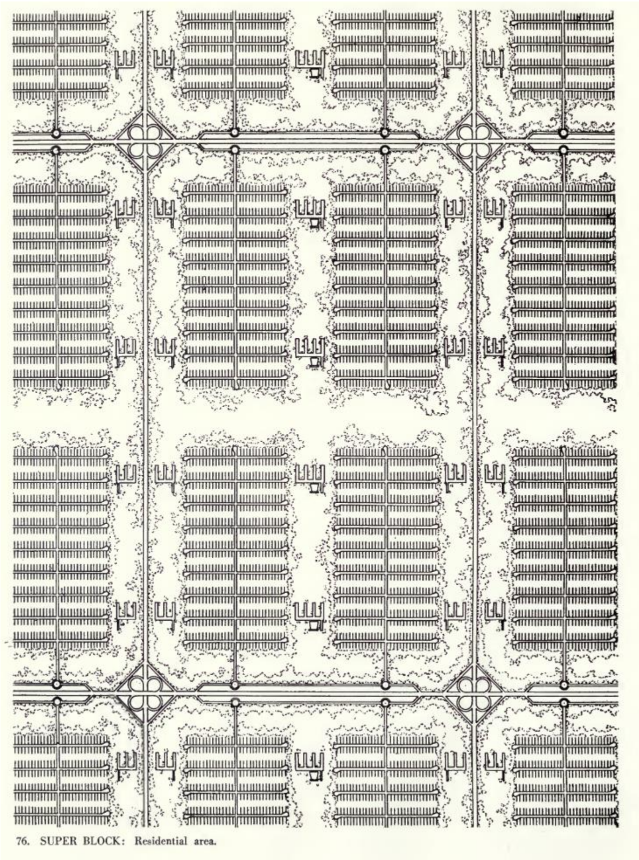

Figure 2 Abstraction in the representation of a planned settlement. Some elements are worked out in detail, while other are left open. Source: Hilberseimer 1944

Put differently, architectural drawings combine the formal and symbolic qualities of notational systems with the allusive power of artistic expression. Nevertheless, the lines, shapes and planes of architectural drawings have an abstractive quality much like musical scores.

This abstractive quality allows one to understand the architectural object *as* an object with a certain agency – i.e. the capacity to actively guide and direct thinking processes. There is a certain holistic quality to early process sketches that is only accessible, it seems, by a lack of presence: in such sketches, many qualities of architectural objects are hinted at or suggested, but not spelled out. Yet, they are strangely enough also present, drawing the observer into the drawing, encouraging him to form associations in his mind. Again, the concept of iterability surfaces, although not in a strictly linguistic form. It is as if drawings encourage a mental, generative iterability with regards to their contents. In a precise analysis from Emma Cocker, this iterability can be seen at work as a critical and creative faculty:

> *(…) the hypothesis emerges as autonomous critical activity, no longer bound by the repetitious cycles of testing and validation to which is it subjected in other fields. Its mere conjecture is rescued from the pejorative, recast as the pleasurable reverie of the thinking mind engaged in nascent speculation. Released from the stranglehold of teleological knowledge production, it is possible to discern specific properties or characteristics within the hypothesis that, in turn, point to certain critical operations at play within the practice of drawing. (Cocker 2017, p. 98)*

Zumthor spoke in this regard of the drawing as an entity shot through with gaps in which the imagination can wander. (Zumthor 2014, p. 13) The essentially incomplete, allusive character of architectural notation actively encourages the mind to wander around in it, to inhabit the drawing in thought and to postulate hypotheses about the blanks. Some sixty years earlier, Polanyi already formulated a similar idea, stating that meaning emerged once an author 'dwells in' an object, interiorizes its features and regards it as a world on its own, a conceptual microcosm to be inhabited and explored. (Polanyi 2009, pp. 17–18) It is through such indwelling that meaning emerges: once the object is viewed from an internal viewpoint, certain features light up and becomes the carriers of meaning, inspirations to be explored further, or irritations in need of solution.

The absence of too many particulars focuses the spotlight of attention on what is present or present-in-absence, allowing drawings to develop a 'vector of abstraction', or 'sharp abstract point', as Bachelard called it. (Bachelard 2002, p. 26) He speaks of a 'sharp abstraction', an abstract quality that has nothing to do with being vague or undefined. Instead, it is an abstraction that simultaneously embodies the core of an idea. Even the first sketch is not an arbitrary jumble of loose elements: it points towards the essence of an idea in a purposively deployed, visual idiom. Likewise, architectural diagrams possess a clarity that is a direct result of their abstract nature. They filter all obfuscation out, depicting the bare minimum of an idea in a format that is simplified without being simple; understandable without being unrefined; yet open and inviting of reflection. The sharp abstraction is the means through which the essence of an idea can be grasped, however incompletely. Yet, this first grasp is necessary to set off a process of directed inquiry.

Zumthor emphasizes the necessity of this incompleteness: the drawing or model has to contain blank spaces in which the imagination can enter. The blanks are the niches for something new to be created at all, be it through imagining what should be in the blank, or by considering the elements surrounding it. (Zumthor 2014, p. 13) In this context, he also speaks of the perception as '*Besitzernehmend*', a term that has no English equivalent, but that can be translated as 'taking-in-possession' or along the lines of inhabiting, of moving in. Hence the accurate observation that "each drawing is made from the inside out, leaving a trail for others to follow from the outside in." (Moore 2011, p. 35) The signs that make up the drawing draw the observer in, allowing him to wander around in it, to inhabit the drawing, focusing on different aspects every time a tour is made.

To a degree, the signs of which drawings are made up are not just fixed, rigid inscriptions that can be read in different ways, but are themselves unchangeable. They can be interpreted through a process of endless iteration and re-performance, just as the diagrams of UNStudio allow for endless re-combination and the emergence of new ideas. However, they are themselves also flexible, or 'plastic' in Malabou's sense, allowing them to be shaped and reshaped by the context in which they are applied, but nevertheless retaining an immediate expressiveness. (Malabou 2009, pp. 66–68) Indeed, they have to be – if the lines, points, planes, symbols and coordinates must give rise to something new, if they are to open up 'spaces of alterity' in which different possibilities can be thought by means of repeating the same methodological gesture.

If 'repetition' is a matter of making the same (or nearly same) drawing, then 'novelty' is produced by the space that the signs and their interplay allow. Such signs can be interpreted in different ways, they focus the attention on different aspects of a design when viewed in various combinations, or they form parts of different associative chains, allowing one to apprehend the whole by means of its parts.

4 Notation and its Space

In both its manual and digital forms, drawing shares many characteristics with writing, especially in its reliance on producing inscriptions or traces. Particularly relevant here is De Certeau's conception of notational practices. (De Certeau 1988, pp. 134–135) According to him, such notation takes place in a blank space (*un espace propre*) that is as it were an island, isolated from the outside world as long as it is used for notational practices. The notational character of this space has tangible effects on the outside world: what is written or drawn on this plane affects how the outside world is perceived. This conception of drawing as taking place within a defined space is fully applicable to manual and digital drawing. The virtual space as well as the paper can be understood as clearly marked domains in which experimentation takes place. Admittedly, there are differences in terms of materiality here: drawing on a paper with ink is a clearly different experience than drawing in the phenomenally reductive space of digital production. The act of drawing (or notating) is an act of explorative reasoning and extrapolation. What emerges in the blank space is viewed as a world to be inhabited or as a more abstract representational scheme.

The space for drawing is a space of formalization, a plane where (visual) language and conception are systematized. 'The scriptural enterprise transforms or retains within itself what it receives from the outside and creates internally the instruments for the appropriation of the external space'. (De Certeau 1988, p. 135) What notational practices create, therefore, are not just outcomes, but also effective tools and mechanisms for better thinking and designing – 'the nascent speculation'. If we apply this thought to architectural design, drawing (both digital and manual) is done to develop the properties and qualities of an absent, architectural object – and simultaneously the means to represent it. Thus, architectural drawing creates both the preconditions for representing and realizing its built results. In both instances, thoughts become matter, either in the form of a representation or in the form of a built object, with the notational act of drawing functioning as a bridge between the mental and the material. (Van Den Berghe 2013, p. 667)

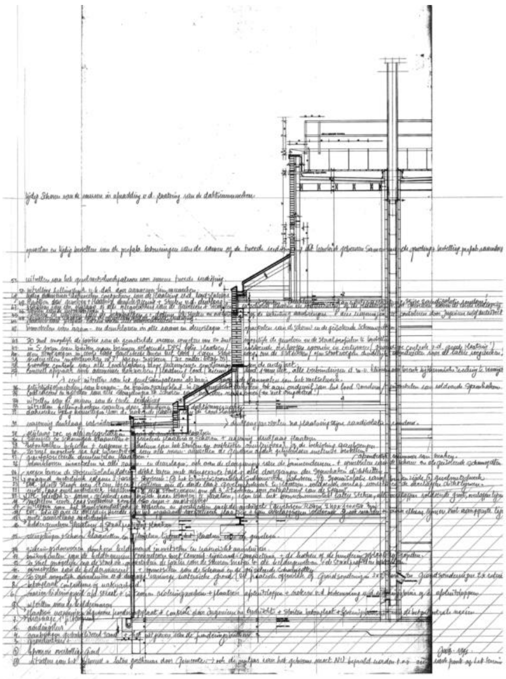

Figure 3 A chronological drawing from Van Den Berghe (2013), the VDV-C House (1990), an annotation of a vertical section - or, a formalization of each step. The drawing overlays different processes that will take place in time, rendering them explicit in the gesture of formalization

The act of formalization is an important feature of drawing, and possibly one that caused Goodman to regard architecture as 'mixed and transitional'. Through formalization, the images that are being produced enter a graphic format, the characteristics of which we will discuss now.

We could say that – in Krämer's terms – images in the broad sense possess a degree of 'operative visuality' *(operative Bildlichkeit).* The question that Krämer raises is what the exact role of images in our contemporary visual culture is – especially when it comes to generating knowledge. Images are not just supports that serve to facilitate the process of putting everything in grammatical terms.

Their existence as visual entities is not reducible to a communicative role. Instead, Krämer raises the question whether knowledge generation should not move from a ‘grammatology’ focused on linguistic structures to a ‘diagrammatology’ focused on the visual potentials of images in conjunction with text. (Krämer 2009) To put it in the terms of this paper: can we move beyond Goodman with the aid of the theory discussed this far?

Krämer identifies a few features of operative visuality that overlap with the account of De Certeau, notably its panoramic character. The eye can receive multiple images at the same time. It can catch the essence of an object literally in a split second, given enough clues and partial representations. The fact that drawings are two-dimensional (even 3D drawings on a screen) allows one to read a drawing, and to give it an orientation. Some of its features are in the foreground; others in the background. Some features occupy the centre; others are peripheral. Still, there is a certain ordering to its elements – an ordering that surpasses Goodman’s concept of notationality, but shares with it the emphasis on reading and the ordered form of notation. As drawings are meant to be read and interpreted, their potential rests in the fact that in them something singular can be seen as something general. A perspective drawing of a certain building in its context may cause one ‘to think of a similar one’, or it may set off a chain of associations. There is a close link to an effect that Schön described as ‘see-as’. (Schön 1983) Designers use drawing not just as a kind of ‘serial problem solving’ aid (Goldtschmidt 1992) but simultaneously as a medium in which recognition and rethinking play a constitutive role through graphic inscriptions.

As such, the drawing is not just a stepping stone in a solving process, but a continuous combination of doing and observing. On this account, Krämer notes that the line as mark is the archetypical act of defining. The distinction or the line marks an asymmetry: an object is inside or outside the boundary; it is well defined by its edges or it is open; it contrasts with its environment or disappears in it. Precisely in this characteristic of the graphic language, Krämer asserts, consists its epistemic potential. Generation of options and possibilities, thinking about the operational constraints and visualizing these options are inextricably intertwined, and mutually necessary to arrive at coherent design proposals at all. (Krämer 2009)

5 Discussion

Summarizing the points discussed above, we can concisely postulate the following assertions: architectural drawing is an explicitly notational practice that is nevertheless not reducible to Goodman’s concept of notationality, although it is similar in some respects. Yet, it is inextricably bound to the act of inscribing, of notating, although the inscription itself plays a very different role than in Goodman’s theory. The signs that are inscribed are themselves open-ended and subject to change. They can be interpreted in different ways, opening up the new possibilities, taking on different roles in different contexts. Therefore, the act of repetitive representation in the context of a directed design process creates a series of objects composed of different layers of meaning.
This richness of meaning allows designers to inhabit or ‘dwell inside’ their objects. Yet, this immersive exercise takes place in a space of formalization, allowing the designer to imbue creative and allusive ideas with a sense of rationality and rigorousness. (Zumthor 2014, pp. 30–33) The formalization is a double one: the drawing is a material trace of the thought, giving it a fixed point in the physical world, and it simultaneously imbues the drawn object with tangible properties like size, material or shape. With drawing, the idea moves from the mental to the discursive – from something that is grasped by the mind to something that can be grasped in natural language.
Taking this into account, we may state that the rigidity of Goodman’s account seems to stem from the fact that architectural images are to a degree pictorial: they can depict life-like the object that is being designed. Yet, they are not necessarily to be read as denoting such an object in the same way that a painting resembles an existing building. Unlike a work of art, the value of architectural notation resides primarily in its abstractive quality, the so-called ‘sharp abstraction’. In that respect, architectural images often resemble maps rather than blueprints, as argued by Miller:

> *By depicting certain properties as highly isomorphic while other details are omitted or stylized, map designers affirm the importance of certain kinds of information and relationships while downplaying other details. It is vital to the success of a map that it be isomorphic in the properties most vital to a map's intended usage. (Miller 2017, p. 6)*

Like every effective representation, the tension between what is depicted and what is omitted determines the room for interpretation. Architectural representations are indeed shot through with perceptual gaps and holes that can be filled by the imagination. Yet, the notational character of sections, plans, perspectives and elevations stems from the fact that there is a tangible and productive tension between what is determined by unambiguous symbols and more evocative, allusive elements of drawings. On one hand, Goodman's idea that symbols allow for the reproduction of a work is to some degree true. On the other hand, architectural drawings are not merely reducible to such elements.

Concluding, and drawing the lines of thought together, architectural design can be seen as continuous, critical performance that utilizes notation, but is not reducible to it. The resulting drawings, models, animations – and eventually buildings and spaces – that emerge from this process are not reducible to a type/token distinction, but escape the idea of narrow teleological knowledge production. Goodman's application of the type/token distinction to architecture does not perform the explanatory work for which it was invented, because the process that is at work in architectural design is not reducible to this distinction at all. First, because the fact that drawings are not composed of notations in a narrow linguistic manner. Second, because the process of architectural drawing does not run unambiguously from undefined to defined, or from abstract to concrete, or from conceptual to practical. The absences and blanks in the drawing serve as spaces for exploration and creative performance. Moreover, the fact that the act of drawing occurs in a space of formalization in which signs are made frees it from mere production of knowledge. Instead, drawing becomes a mode of inquiry, a process of grasping disparate elements of an idea, or of developing certain aspects of it.

Therefore, the notationality at work in architectural design processes is *generative* in its creative and critical potential. It is a necessary condition for architectural thinking, the cognitive process that cannot be thought apart from its artefacts and acts of notation it engenders. The different notations in an architectural design process jointly form a rich system of allusive, metaphorical and technical information, a system which possesses 'operative visuality'. This body of information is too rich to be grasped completely at once, necessitating repetition and layered evaluation, a careful approach that pays attention to those aspects individually and in conjunction with one another. The relative ambiguity of some of the artefacts produced in this process allows the imagination to play a key role through notational practices.

With the emergence of generative design methods, the question of notationality takes on a new urgency. Not all architectural drawings are hand sketches in which there is a direct link between 'doing and observing'. Instead, in many cases the architectural gesture is no longer one of notation in the strict sense. It is as well the definition of limits and constraints within which the computer can generate options. The observation and evaluation takes place on a series of generated options, in which the hand had little role to play. The cognitive link between drawing and seeing is as it were broken. Yet, the images that result from the computing process have certain notational qualities: they too consist of symbols, lines, shapes etc. And they too have to possess a degree of operative visuality. Yet, they seem to affect the mind differently than the hand drawing – and at this point, we might well conclude that the broader concept of Goodman's notationality will need further revisions in the future, if only to better understand the relations between notation, generation and visualization in the age of digital drawing.

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Desert Drawing: from pigment to (*Apple*) pencil

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The ability to digitally draw is ingrained within contemporary visual design practices. Drawing is a way of recording, representing and communicating that reveals the identity and voice of the creator as they design for a communication purpose. This paper presents a case of how a group of young Indigenous students re-interpret traditional culture through the act of drawing, as they move from analogue to digital technologies. Through a series of design workshops, the drawing styles of participants from remote Central Australia were recorded and analyzed. Workshops were based within Youth Participatory Action Research methodologies and embedded within Indigenous pedagogies. Results show the ancestral essence of country, connectedness and story remain ingrained within these new digital forms. Initial findings reveal three core themes; drawing as research practice, drawing as cultural practice and drawing through technology. The ability to draw in a new, digital way can create numerous benefits to developing the creative practices of young Indigenous people, as well as social and economic benefits within remote Australia.

drawing; design; indigenous; aboriginal

Acknowledgement of Country
This project acknowledges the traditional custodians of the land on which this research has been conducted, the Western Arrernte people, and their Elders past and present. This research is grounded in acknowledging and protecting the continuing ownership of traditional knowledge, cultural expressions and intellectual property rights of its participants.

1 Introduction

The ability to digitally draw is ingrained within contemporary visual design practices. This paper presents a case of how a group of young Indigenous students re-interpret traditional culture through the act of drawing, as they move from analogue to digital technologies. Drawing, as an ethnographic exploration, is a way of recording, representing and communicating that reveals the identity and voice of the creator as they design visible objects for a communication purpose. To examine the process of drawing as a meaning-making design activity, I utilise a case of working with Indigenous youth from Ntaria, a remote Aboriginal community in the Central Desert of Australia.

The following questions framed the research; (1) can traditional creative practices adapt to digital ways of working, and (2) do these tools support or erode traditional culture? These inquiries are investigated through a broader research project that is centred on understanding how Indigenous young people reinterpret their traditional culture and creative practices through working with innovative digital design tools.

Australian Indigenous art is the oldest ongoing tradition of art in the world, dating back some 30,000 years. The introduction of post-colonial mediums such as acrylic painting, radio and film have become sites of agency, resistance and self-determination for Aboriginal and Torres Strait Islander People. What happens then when you introduce a new digital creative tool into a community of thousands of years of strong creative traditions, embedded in cultural and spiritual practice?

The importance of this case for the design research community is concerned with what value design can bring to historically marginalized voices, but also what value these voices can bring to design. The Australian design industry has historically had limited understanding and lacked influence from the important creative sources of Indigenous Australia. Through looking at the practice of design through the lens of young people from Ntaria, we can reframe the 'act' of designing in relation to Indigenous ways of being, knowing and doing. Indigenous approaches challenge current Euro-centric understandings of how visual communication design is introduced, taught and practiced within cross-cultural contexts. It is examined here, through the tools and technologies of digital drawing.

This research project employed a methodology informed by decolonising perspectives and Indigenous ways of being, knowing and doing. This allowed for a re-interpretation of design processes and outcomes, as situated and mediated through the physical location of Ntaria. Design researchers in cross-cultural contexts need to be situated, not just as co-designers or co-participants, but also as trusted facilitators, trying to bridge the gap of 'outsider' and reframe power dynamics within design and representation.

Digital drawing was introduced to 20 young Indigenous People in Ntaria through a series of design workshops over 12 weeks. These workshops were based within Youth Participatory Action Research (YPAR) methodologies and informed by Indigenous pedagogies. This was embedded within a framework of creative participation – that through using Indigenous ways of knowing, young people in remote communities can use design (through digital drawing) as a tool of empowerment and positive social change.

Results reveal that Indigenous groups can create and renegotiate interactions with digital drawing technologies. This allows for an exploration of how different knowledge traditions engage with design tools and create new potential sites of innovation. Incorporating Indigenous Knowledge approaches becomes imperative in understanding the capacity in which design tools can take on new meaning within new spaces of engagement. Drawing in a new digital way has the potential to stimulate new visual styles within Indigenous creative practice, while empowering young people to take control over their creative futures.

2 From analogue to digital tools

Drawing represents an on-going process of selection, reflection and change (Stones & Cassidy, 2010). Fish and Scrivener (1990, p.122) discuss how drawing involves both manipulation of mental imagery and perception of external elements in partnership. Tools are also used to externalise ideas and mental images. A drawing tool may then be defined as a 'moving entity whose use is initiated and actively guided by a human being' (McCullough, 1998, p. 68). The specific purpose of the drawing tools in this study, was designing forms of visual communication, as the hand is physically extended by an ability to make external marks, be those on paper or a screen.

Within visual communication, considering and selecting the content, layout and tools to make a drawing is a design process. It is a series of conscious decisions leading to a visible object that fulfils its communication purpose: it tells a story, shows an idea or explains an issue.

The digital design tools within this research refer to iPad-based graphic software, namely working with vector-brushes and digital shapes within the Adobe Draw app. Here, selection and manipulation of pre-defined shapes or freehand lines can occur. Digital drawing (or digital visual communication) is the focus of this paper, as the participants learn to draw in a new digital way for the first time. Yet it is also important to mention traditional cultural uses of drawing within this paper. This provides a context for the introduction of new tools within a specific visual culture; to understand their value and measure their impact.

3 Country as being: the remote desert context

Below the social and historical context of the study are introduced to provide a background to the location and create a sense of identification with the participants and the implications of living within a remote Indigenous community.

Figure 1 Ntaria (Hermannsburg) location (orange dot) in relation to Alice Springs (black dot)

The remote Aboriginal community of Hermannsburg, known locally as Ntaria (see Figure 1), was the physical location of this study. It is located in the traditional lands of the Western Arrernte people, an Indigenous tribe of Central Australia and the custodians of Central Desert country. Believed to have been living on their lands for more than 20,000 years, the Western Arrernte maintain a strong connection with traditional language and culture.

Aboriginal concepts, such as 'relatedness', 'kin' and 'country' are central to Western Arrernte experience, yet hard for non-Indigenous people (such as myself) to describe and understand. 'Country' embraces the people, plants and animals of a place as well as its seasons, stories and creation spirits. Country is not static, but living, a place of belonging, a way of believing and a sense of responsibility (Austin-Broos, 2009). 'Relatedness' is a way to describe social relations in Aboriginal life, where every-day interactions are centered on the maintenance of relationships, from country, kinship and family (Myers 1979, 1991).

Most Arrernte people are economically and socially marginalised in terms of access to governance, services, employment, housing and education (Foster et al., 2005). The cumulative impact of Ntaria's history, like much of Indigenous Central Australians has entrenched many of the Arrernte as a fourth world group[1]. The Western Arrernte are still largely marginalized from engagement with market

[1] The term *Fourth World* traditionally refers to marginalized and oppressed groups such as Indigenous peoples living either in Third World (relatively undeveloped) or First World (developed and capitalist) countries.

society, with a large dependency on welfare. In Western Arrernte life, where connection and relatedness is paramount, the result is seen in emotional tensions within and between genders and generations (Sutton, 2001).

4 Ntaria Mob: The participants

As this study focuses on young people living within remote communities, it is important to mention common social circumstances of living within these contexts.

The common Western trajectory of education leading to employment is not played out in remote Australia. As a consequence, Indigenous youth are struggling with identity. Teenage boys tend to drop out of school after passing through initiation ceremonies around the age of 14 or 15 and show a greater tendency to spiral into substance abuse, anti-social behaviour and incarceration. Poor school attendance, low retention rates and uneven levels of English literacy and numeracy are present across both genders (Kral, 2011).

It is not surprising that research continuously shows remote Indigenous youth struggle to find their place both within their own communities and wider Australian society. Tonkinson points to their capacity to endure hardship, to innovate and be resilient as factors that will ultimately enable young indigenous people 'to forge new and rewarding paths to fulfilment in the greatly changed world they inhabit' (2011, p. 234).

Outside of the school context, Indigenous youth, enabled by wider access to new technologies such as television, video games, digital photography, the internet and mobile phones, are keen consumers of global youth culture. Central Desert youth now 'perform' differently, adapting to contemporary realities (Kral, 2011). There is growing literature supporting that Indigenous children are not just passively receiving culture (LeVine & News, 2008). As Eickelkamp explains, 'children are active learners; they make and remake culture and history – as innovators and keepers of language, certain modes of knowing and bodies of knowledge, artistic practice, moral codes, patterns of behaviour and social norms' (2011, p.2-3).

5 A framework for Indigenous design research

5.1 Indigenous design perspectives

This project is framed through an understanding of design based within visual knowledge, traditional practice and expressions of cultural creativity. Bratteteig et. al explain:

> *'There is knowledge that lives in the design process and is embedded in designed artefacts. There is knowledge we generate as researchers-observers, and knowledge that stems from also being engaged in making digital designs – which sometimes involves making them happen as an occasion for studying them' (2010: 17).*

The Ntaria case study covers this range of design and research practices. Working cross-culturally situates this project within both necessary disciplines - between designerly ways of knowing (Cross, 2001) and Indigenous ways of knowing (Martin, 2009). It is when design knowledge combines with indigenous knowledge that forms this projects core focus.
This research is positioned within the communication design field, as the tools and techniques of digital drawing were introduced from a visual communication perspective. This offers an approach into the relations and interactions between tools and digital expressions where the object of activity is communication, whether narrative or aesthetic.

Akama (2008: 161) asserts that:

"Communication design is a process that is based on how to apply and manifest different kinds of understanding and to explore what designed outcomes could mean for different people. Embracing and acknowledging the diversity and multiplicity of viewpoints of all stakeholders can allow the design process to explore the potential and possibilities of the meaning of different design outcomes"

This framing embraces diversity and difference, based within the processes and outcomes of communication design.

Looking at social-cultural perspectives on communication design, Stuedahl et al. point to the practices and tools of communication design allowing for the emergence of digitally mediated meaning making (2010: 68). That communication design research builds and analyses design for, and communication through, digitally mediated interfaces. This involves the multimodal mixing of cultural, symbolic and mediated materials that entails a complex blending of design practices and user knowledge and experience (Stuedahl et al. 2010: 68).

Different cultures will have different perceptions on what it means to 'do' design and embed their own knowledge within the process and subsequent outcomes. Different cultural representations of design, and their implications remains relatively unexplored within (Western) design literature. This project examines design at the cultural interface; between traditional craft and creativity and Western design & technology.

5.2 Research methodologies

Research on Indigenous issues should be carried out in a manner, which is respectful and ethically sound from an Indigenous perspective. Therefore, the methodological framework is centered within a decolonizing perspective; necessary within Indigenous research given the existing social inequities that Indigenous peoples continue to experience. A decolonizing approach enables a framework that seeks out Indigenous voices and representations within a research field, that has historically marginalized and silenced Indigenous peoples (Smith, 1999). This approach also acts to decolonize Euro-centric design education, principles and practice within Australia.

In discussing the representation of Indigenous knowledge, the work of Smith in *Decolonizing Methodologies* is imperative, as she advocates for methodologies that have the potential to ensure that research with Indigenous peoples can be 'more respectful, ethical, sympathetic and useful' (1999, p. 9).

As a non-Indigenous researcher working within Indigenous research, I needed to ensure the project did more than just follow ethical principles, but that I become a collaborator in projects and processes that respect and promote Indigenous aspirations. Being involved, establishing and maintaining relationships allowed me to better understand participant aspirations and how this research can be both useful and fit within established cultural practice. I have aimed to ground my work and give voice to Western Arrernte identity, values, aspirations, and specifically to give voice to Ntaria design understandings, processes and outcomes.

From a design perspective, collaborative, participatory and action-based research methodologies are generally identified as being compatible with the goals and emerging reform agenda for research involving Indigenous peoples. These methodologies, particularly participatory action approaches are well suited to creative research that requires ongoing participation, collaboration and reflection. As Denzin describes:

> *These are narrative, performative methodologies, research practices that are reflexively consequential, ethical, critical, respectful, and humble. (*Denzin in Denzin, Lincoln & Smith 2008, p.936)

Through there are many approaches to design and participatory research that could have been used to address the complex methodological realities of this project, YPAR was chosen. This approach values the voices and knowledge of youth, challenges the injustices that many marginalized youth experience, and empowers participants to make changes in their communities (Cammarota & Fine, 2008).

YPAR recognizes that young people are often socially constructed in ways that do not match their realities or potential. It allows young people to 'contest, challenge, respond to, and negotiate the use and misuse of power in their lives' (Ginwright & James, 2002, p. 35). Research is therefore conducted *with* youth; around the issues they find most important in their lives.

The YPAR approach places value on creative participation, and the resulting design workshops fostered a collaborative exchange between teaching and learning of digital drawing and traditional culture and beliefs. Research focused on instilling the confidence and the technological knowledge for young people in Ntaria to develop skills and outcomes that utilized their own ways of being, knowing and doing - promoting their traditional creative knowledge within new contexts.

6 The Ntaria approach

The broader research project was designed over numerous months (and many community visits) in conjunction with the students and the wider community. This ensured the voices of the students were privileged, the project was useful to the community and ethical approaches were followed. This extended development period allowed the students to be actively involved in decision making processes and have the opportunity to collaborate on the form and content of their design workshops and subsequent creative outcomes.

Design workshops (Martin & Hanington, 2012) were held with 20 Senior Students at Ntaria School, aged 14-18 over a period of 6 months. With the unpredictability of community life and numerous cultural interruptions to students learning and attendance, the project moulded to fit within its context and the circumstances at Ntaria. This long-time frame was critical to give participants the space, freedom and time to explore, learn, collaborate and share their knowledge.

Design workshops were selected as an appropriate method as they focus on collaboration, the incorporation of academic and community knowledge, and outcomes that can contribute to positive change. The critical features of design workshops are that researchers can stay on track with planned activities/outcomes while remaining adaptable to changing circumstances and group dynamics. Problem solving by design is also exemplified within design workshops and they additionally align with Indigenous pedagogies, Aboriginal Ways of Learning (Yunkaporta & Kirby, 2011) and evidence-based curriculum design.

The design workshops consisted of participatory sessions, and focused on design exercises for an assigned brief. These sessions focused on introducing students to the technical knowledge of digital drawing through working on an iPad and the Adobe range of digital drawing apps, such as *Abode Draw.* The students were introduced to key digital design concepts, such as layering, opacity, replication, and shape creation – not possible with analogue forms of drawing. How they implemented these new possibilities into their work was analysed throughout the project as their skills, competence and experimentations working with the digital drawing tools developed. The design tasks included designing a logo, poster, school signage and t-shirt graphic – all visual tasks based in communication.

There was no visual or process direction given to students, as the research was concerned with if and how the students would embed their traditional creative practices with design tools and ways of working. Workshops were often taken out of the classroom, to gather materials, such as local bushfoods, to photograph, capture, and trace on the iPad, or to photograph the landscape for creative inspiration and colour swatches. This also enabled time to 'be' on 'country', to share stories and local knowledge; for me to learn what was important to them and give context to their stories. This was additionally supported by the mobile technology, allowing students to integrate place, story, culture and knowledge into their creative tasks.

Figure 2 Design workshops in Ntaria, clockwise from top left: Collecting bushfoods, leaves and seeds to use as design inspiration; Walking on country to rock engraving site to tell stories; Collecting bush bananas, a local bush food; Sharing stories and local knowledge. Images authors own, 2017.

7 Drawing as design research

Different cultures will have different perceptions on what it means to draw and to design, as they embed their own knowledge within the process and subsequent outcomes. This research situates the introduction of digital design tools firmly within socio-cultural approaches, as human action, marks and interpretation are ingrained within culture, communication and context.

Questions of culture, through which each of us encounters and makes sense of the world around us, have been recognised as crucial to understandings of design. Indigenous knowledges encourage us to deepen our understandings of the ways in which culture and knowledge are entwined and shape any idea of what 'design' might be. This paper is concerned with Western Arrernte cultural representations of design, specifically through digital drawing. As principals of design practice are predominately Euro-centric, it raises the question of what meanings will be re(produced) in cultures by representations of design? Will the introduction of design tools change the creative practices of young people, or perhaps create a new design language through the introduction of new digital ways of drawing?

7.1 *Colonial encounters*

Drawing has been an integral part of cross-cultural interactions in Australia from the earliest encounters between Aboriginal people and European settlers (Hinkson, 2014). Sayers suggests Aboriginal drawings were collected by Europeans both as sources of information and as evidence of Aborigines' aptitudes and capacities (1994, p. 71). Hinkson suggests another kind of appreciation, 'a fascination with what these pictures could provide by way of unprecedented access to the distinctive ways of seeing, their inner lives, of their producers' (2014, p. 30).

The commissioning of Aboriginal drawings was common practice amongst anthropologists of this period as drawing was a productive means of eliciting information and understanding around Indigenous people's ways of life. These anthropologists claim they did not interfere in the subject matter or style, instead focussing on drawing content. Berndt observed during the 1950s that visual forms in the anthropological works were of marginal interest, due to the apprehension that taking active interest in the forms as 'art' would undermine the objectivity required of the 'scientific approach'. Yet what remained unexplored was the ways in which these drawings became more than just artefacts collected by anthropologists.

The introduction of new drawing tools and mediums, such as pencils and crayons, paper and canvas, required Aboriginal artists to learn to integrate their traditional practices into new forms. The introduction of these apparently benign Western tools significantly impacted on Indigenous creative practice and its outputs. With new tools came new design questions, such as how to use introduced media to best effect, or how to employ a colour palette well beyond the traditional ochre hues. Perhaps one of the most remarkable things to note is the ease in which Indigenous practitioners were able to adopt the newly introduced tools and mediums, immediately seizing upon their potential for new forms of artistic expression.

7.2 *Redrawing the boundaries*

Drawing is a way to understand participants' values, interests and ways of working. Many studies in design have emphasised the importance of drawing, as visual thinking, as a sequence of design moves (Goldschmidt, 1991), 'having a conversation' (Lawson, 1994) or a 'graphical conversation with the materials of design' (Schon, 1992). Western interpretations of design-based drawing generally refer to sketching, modelling and drafting (physically as well as digitally) as a means to generate ideas, explore and communicate design. However, within an Indigenous context, there exists an opportunity to extend this understanding.

Design research within a specific visual culture needs to be characterised as situated and mediated by the physical location in which it is undertaken. Place and country form imperative perspectives for young people living in remote contexts and as such, design needs to analysed from this perspective. Grounding these activities in Ntaria allows us to observe drawing as a meaning-making activity in a modern day cross-cultural context. The outcomes are firmly Ntaria perspectives of design, narrative and story.

Design involves reasoning, making decisions, expressing ideas and taking action. Drawing as a design research tool acts a vehicle to explore students' decision making with digital outcomes. Their pencil drawings may reflect their Indigenous Knowledge, but their digital expressions and the way they transfer that knowledge onto a digital medium is a record of the designer's thinking. How they apply new possibilities, made available by digital tools and programs reveals the adaptability of traditional knowledge, and the capability of the students to engage with design tools.

The design workshops revealed that the Western linear process of design (from design brief, to concepts, refinement and final product) is not mirrored in Western Arrernte ways of working. The Ntaria design process is circular, combining knowledge over generations, finding new ways to share traditional stories. Stories are repeated, danced in ceremony, painted on the body, drawn in the sand, which each new interpretation making them new again. Students' initial drawings or 'sketches' at the beginning of the design process were more about re-enacting these stories, not concept development. Through the process of drawing, their story becomes alive again, it is retold by marks on paper or on digital designs on an iPad. Students innately know these stories and designs – they need no visual research, they are intrinsically part of their family, culture and identity.

This new design practice emerging from Ntaria offers a challenge to our current understandings of communication design education. Although still an evolving practice, design in Ntaria is primarily about communicating, utilising the common tools of the discipline. Yet the values and narratives that it communicates are firmly Ntaria perspectives, enabling a new cultural perspective to the discipline. Communication design within Ntaria can be realised through the interplay of tools and signs with technical and cultural resources. Together these depend on and are constituted by a complex mix of relations (Thackara 2005) between appropriate tools, their introduction, technology access, and how these fit within culture and place. Design offers a way for young Indigenous people to express themselves, to share their knowledge about their country, culture and their place within contemporary society.

8 From sand to screen: Drawing as cultural practice

Indigenous Australian drawing practices, honed over thousands of years, weave art with storytelling. Prior to colonisation, paintings by Aboriginals were drawn on rock walls, carved as petroglyphs, painted on bodies and most significantly drawn in dirt or sand. Sand drawing is an elaborate combination of narration, song, signs, gesture and drawing. As Munn (1986) observes, 'the areas of bare sand characteristic of central Australia provides a natural drawing board permanently at hand.' These markings are a system of 'talk' in an Arrernte manner, and often serve as an iconic system for representing events, in effect, as a graphic written language.

Figure 3 Sand drawing in Ntaria, Central Australia, 2017. Source: Image authors own.

In Ntaria adults still tell stories about the land and ancestors through sand drawing. These stories are sometimes mythical or 'dreamtime stories', about how people, animals and the land were created, but also about journeys and hunting trips and contain information about where to find water, food, how to hunt animals and so on. As they tell these stories, they illustrate the events in the sand using traditional symbols. For example, concentric circles may be a meeting place, camp, a watering hole; a wavy line might be a track, a river or snake. The stories often involve a journey and the combination of story and drawing is required to extract it's meaning.

Students are still using these same symbols today and the traditional practice of sand drawing is being re-interpreted with new technology. Working digitally, the iPad allows for a re-imagining of drawing practice. Instead of drawing with their fingers in the sand, students swap this for the screen, effectively creating a new contemporary reinterpretation of cultural practice.

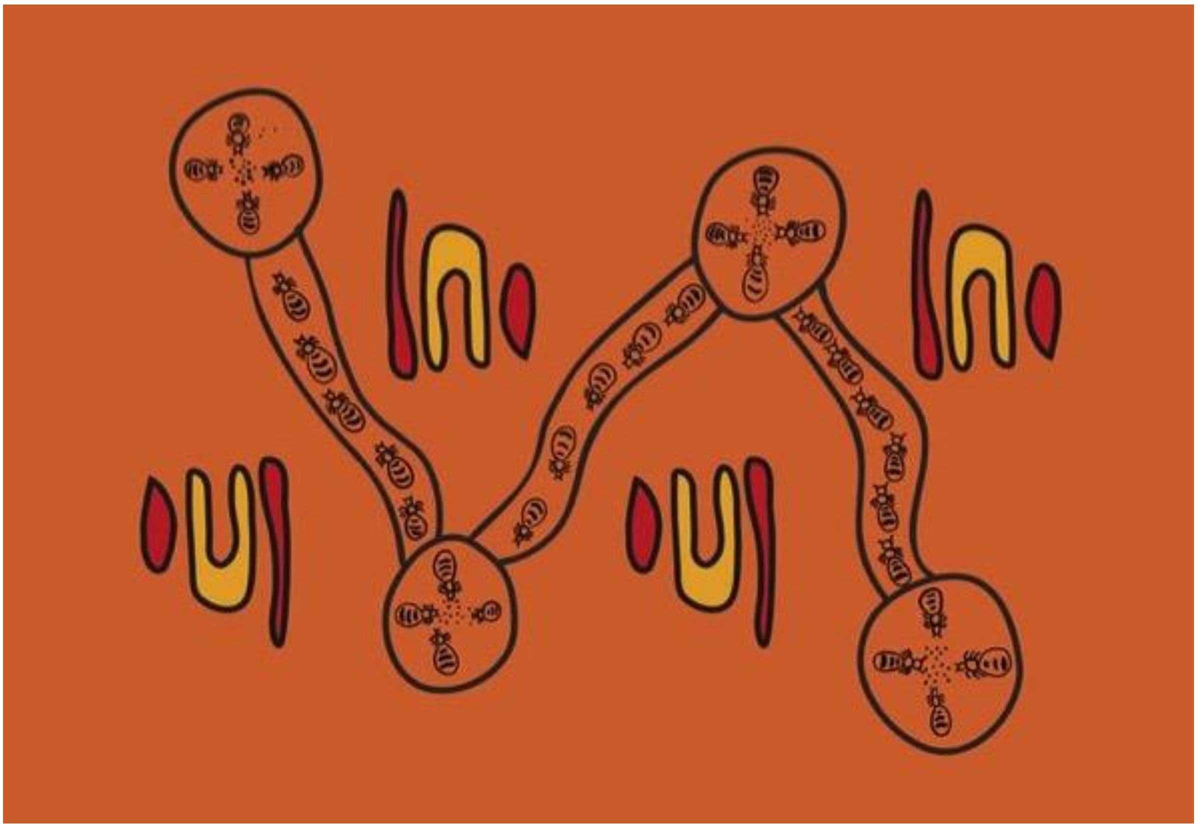

Figure 4 Participant 1. Age 14. Honey Ant Story, Digital Drawing, 2017

Figure 4 depicts a Honey Ant story, a common dreamtime story from the Central Desert area and a traditional bush food. You find their 'houses' or 'camps' as described by Participant 1. The honey is then sucked from the ants.

> *This is a design of people sitting down digging for honey ants. The ants are going to their houses and finding which place they are going to camp. Honey ants are important because they are good bush tucker. They are good to eat! (Participant 1)*

Depicted in the drawing are four women sitting, digging into the honey ant tunnels with their digging sticks to collect the honey ants. The woman is shown by the 'U' shape with the digging stick and coolamon beside her, common tools in collecting bush foods. The drawing effectively acts as a story on how to collect the honey ants, and where to find them buried in their 'houses'. It reveals the participant's knowledge of this cultural tradition.

It is through the use of symbols, now created on an iPad through duplicated bold coloured shapes, that the participant has used contemporary technology to tell traditional stories in a new way. The importance of the content cannot be underestimated. Although exposed to Western media and culture, participants chose to depict traditional knowledge. With a wealth of accessible images of global youth culture at their fingertips, the students fashion and music choices influenced by American rap and R&B culture, it is significant the students draw upon cultural stories.

Cultural identity remains a large part of community life for young people in Ntaria. With Indigenous language and cultural practices becoming eroded and disappearing at alarming rates, it positions design as a contemporary way to reinvigorate culture for young people. The majority of the students' drawings depict events and stories of ancestral creation and traditional understanding. Digital drawings give a new shape, form and colour to Western Arrernte ritual knowledge.

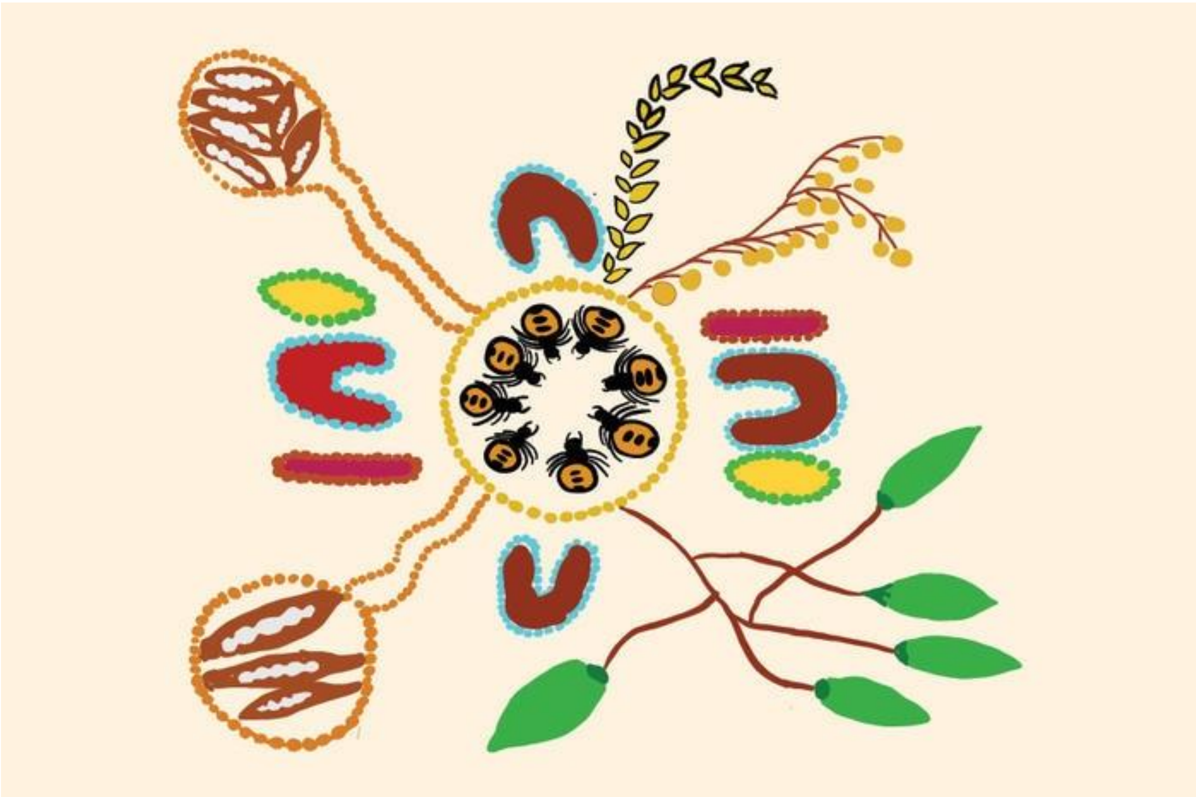

Figure 5 Participant 3. Age 14. Bush Tucker Story, Digital Drawing, 2017

Figure 5 shows a family collecting local bushfoods. It highlights how forms of drawing are critical in intergenerational knowledge transfer within Indigenous communities. In the participant's words:

> *My favourite things to do are sharing stories, going hunting, looking for bush tuckers. My ideas come from the bush. From going out hunting and my Grandparents talking about stories. (Participant 3)*

These results also highlight how design fits within a broader socio-cultural framework. The outcomes are less about style, form and function, but about cultural meaning, identity and storytelling. Designs are about caring for country, respect for culture and traditional knowledge. The drawings act a prism through which to explore Western Arrernte experience and reveal how young people from Ntaria see their place in the world.

9 Drawing through technology

Developments in technology have radically changed many aspects of the professional practice of design, including approaches to drawing. There is relatively little information available on how young people in remote Indigenous Australia are shaping the creative, cultural and communication uses of these new technologies. This is supported by Kral, who notes 'accounts in public or policy discourse tend not to portray the creativity and agentive participation of remote Indigenous Australian youth in new forms of cultural practice and production' (2011, p. 6). Young people continually show themselves to be adept at integrating cultural forms into new technology. They perceive significant differences, but also continuities, between digital and traditional modes of communication and, for the most part, are keen to incorporate the new technology into their lives.

Students had no experience creating on digital devices before the workshop program began. This was their first introduction to drawing on a screen and working digitally. Students drew their images using the *Adobe Draw* app on the iPad, with some students preferring the use of the *Apple Pencil*, while others worked with their hands. The pencil provided an intuitive tool to transition students from working on pen/paper to the digital context. Some students preferred to draw by hand first, before creating their design on the iPads. But they did not see the pencil drawings as 'early sketches' but as a means of storytelling.

> *I draw the stories first on paper and then I make them on the iPad. With design, you use different shapes and there are different names for things. (Participant 3)*

Some students preferred to directly 'trace' their pencil drawings on the iPad, by photographing the image, creating a new layer and then directly re-creating it digitally. Others however utilized the potential of the technology, creating innovative aesthetics through the digital tool kit at hand.

As shown in Figure 6, the pencil drawing of the Waterhole story is re-invented through the use of digital drawing tools. It is an intrinsically digital image, utilizing new approaches, particularly to colour and new techniques, such as the use of perfect circular 'shapes' made possible through the digital format. It is also worth noting colour has only been added digitally; colouring by hand is a labour-intensive method in comparison to the quick application of colour on its digital counterpart. These design decisions made by the student allow us to analyse the use of digital tools and how this impacts on creativity, creative output and knowledge production.

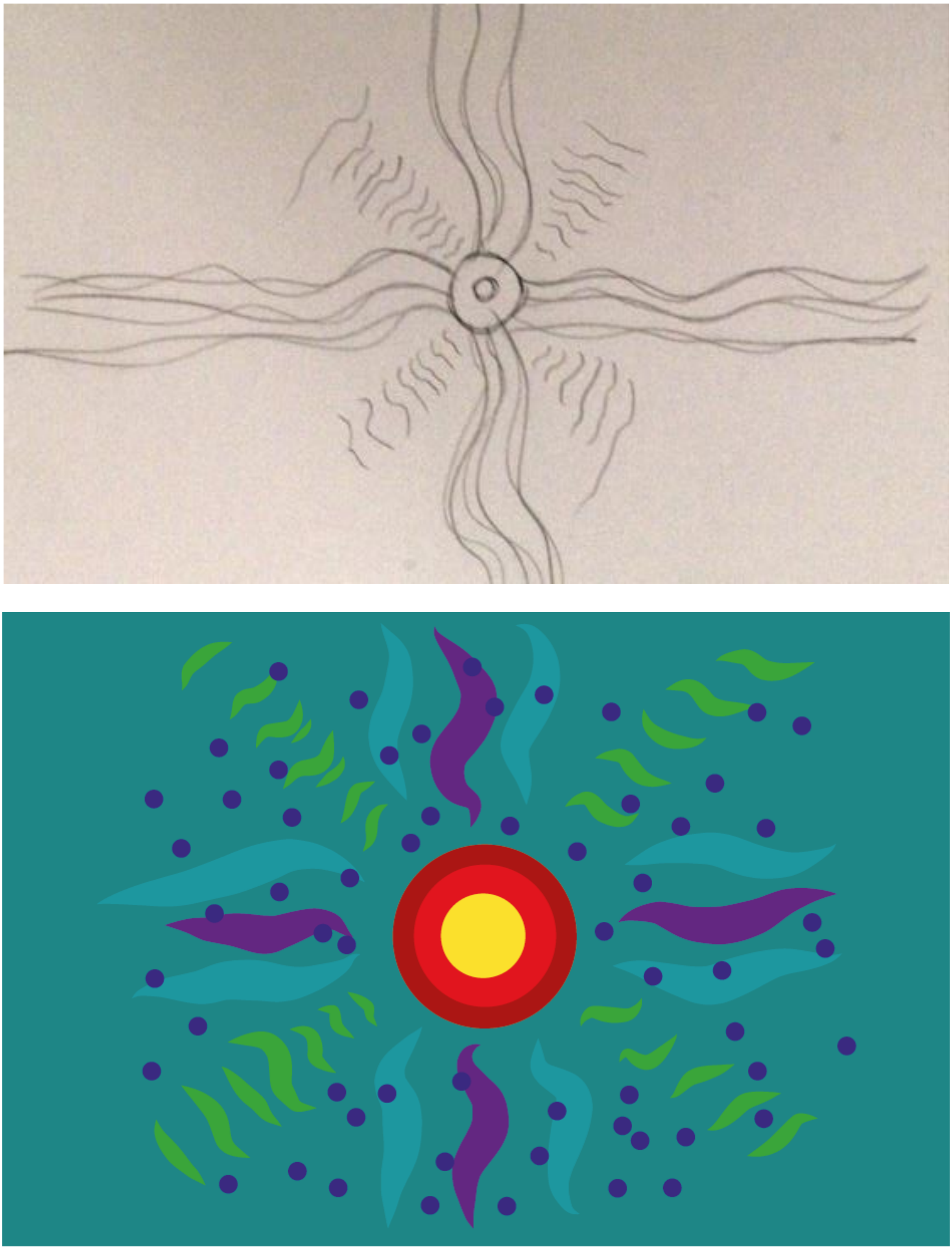

Figure 6 Participant 4. Age 15. Above: pencil drawing of waterhole story, in comparison to digital interpretation. Below: Waterhole story, Digital Drawing, 2017.

As these students were working for the first time in a new medium, it presented opportunities for aesthetic innovation and experimentation. They found inventive ways to use the technology, drawing on different techniques to create straight lines depending on their knowledge of the application (See Figure 7) or to achieve a traditional dot painting effect with digital drawing (See Figure 8).

Figure 7 Students draw a straight line on the iPad using different tools. Left: Student uses a ruler to draw a line with the Apple pencil. Right: Student uses the digital ruler tool to draw a straight line on the iPad. Source: Images authors own, 2017.

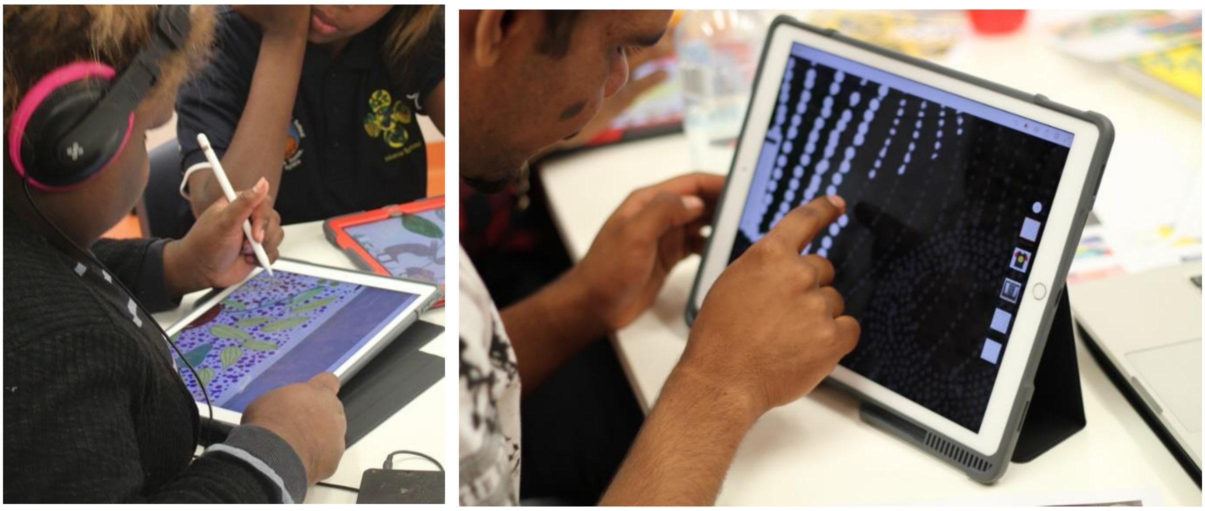

Figure 8 Students use different methods to create traditional dot drawings. Left: Student uses the Apple pencil directly onto the screen to create the dot effect. Right: Student traces dots from a drawing using his hands. Source: images authors own, 2017.

The digital drawings that emerged from the workshops exemplified the existing creative skills of the students, particularly in applying their cultural knowledge to new digital media. Through the digital format students were also able to share their design with family, friends and the community, creating and sustaining new and unforeseen meanings, connections and impacts.

10 Implications for design and for Ntaria

What does this case then reveal to us as communication designers and design researchers? This project was a two-way teaching/learning exercise. It questioned what can we, as design researchers, learn from Indigenous approaches to the discipline? And what value can design bring to Indigenous youth living in remote communities?

From these results we can conclude that young people from Ntaria can adapt traditional creative practices to digital ways of working, and these tools support traditional culture and give voice to Ntaria youth.

The implications of this case begin with expanding our current understanding of cross-cultural communication design and positioning it *within* specific visual cultures. Design in Ntaria highlights design processes do not necessarily translate across culture. When working cross-culturally, researchers cannot merely overlay the common Western trajectories associated with design processes. Cultural meaning and social purpose are imperative here. Introducing new tools and design processes need to fit within place-based understandings of country and relatedness.

Therefore, cross-cultural approaches to design must be situated and mediated from a specific cultural context. There is no pan-Aboriginal, or Indigenous approach. A reimagining of communication design from a specific remote desert community, would contribute to our understandings of the social, cultural and economic dimensions of design. Creative research outcomes could facilitate the natural evolution and contemporary relevance of Indigenous visual culture in Australia. It also contributes to the recognition of Indigenous Australia as a fertile and important place for the fostering of design practices.

In terms of what value design can bring to remote communities, drawing enabled young people to express their identities in contemporary ways, giving a historically marginalised and silenced group a voice and sense of agency.

Learning to draw in a new digital way can both stimulate new forms of creativity and expand the scope and outcomes of Indigenous creative development. The nature of digital drawing tools allows students to leverage their basic knowledge and apply it to a range of fields and outcomes. These digital forms are where the potential for innovation lies, as new sites of capacity building, enterprise development and sustainable livelihoods.

Maximising the creative and technological capabilities of any culture is vital to producing the factors conducive to developing innovation through design. It was clear the outcomes of the design workshops had potential market currency: students were able to digitally print their design work on a range of materials and sell them within the community. These outcomes also held social currency within the school, as younger students were keen and eager to participate, and older community members were interested in what the students were designing. Strong culture is fundamental to Indigenous wellbeing, and such support for Indigenous culture through new creative mediums provides a solid foundation to enable outcomes and economic participation in remote communities.

Although in its early stages, this research also hopes to address the chronic under-representation of Indigenous Australians in the technical design professions, such as communication design, product/industrial design and digital media design, by making their tools of use more relevant and accessible to Indigenous Australians. Drawing here is the foundational knowledge necessary for design. Learning to draw in a digital way has the potential to create meaningful employment opportunities within design professions whilst maintaining cultural integrity.

11 Conclusion

Through the prism of these drawings, we can see an affirmation of Indigenous culture through digital drawing. The drawings reveal that young people in Ntaria are visually connected to their traditional imagery and iconography, despite the introduction of a new digital technology. It is through new tools that young people can reinvent their cultural knowledge to suit a contemporary aesthetic. Highlighted here is an inextricable relationship between the past and the present, the richness and beauty of their cultural heritage, but also the uncertainty of their future.

While it is impossible to quantify the long-term impacts at this early stage, it is hoped that this paper will contribute to a broader discussion and understanding of design, one that seeks to incorporate

Indigenous perspective of process and outcomes, which will ultimately benefit design and expand the scope of the industry.

The designs that are emerging from Ntaria, and the use of drawings as research tool, is a highly fertile ground for the investigation of creativity, the role of new technologies and the incorporation of Indigenous Knowledge within design. It is hoped these new perspectives open the door to developing new approaches and techniques, within remote Australia and the wider design industry.

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On Connecting Form: explorations of a drawing method

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In this paper I will reflect on how my pencil tracing drawings of second-hand furniture parts inspire to investigate the newly created form connections in these drawings. The reflections are based on the tacit knowledge that was established during the long process of developing a specific drawing method. I will elaborate on my explorations of the qualities of the forms of these objects, the compositions I make with the pencil tracings, the texture of the drawings, the specific size of the drawings and the referential qualities of the forms in the drawings. The drawing method is all about a succession of acts. I apply pencil tracing, hatching, cutting, painting and folding acts. Through association I want to look deeper into the drawing method and more specific into the inherent level of abstraction. I will reflect on the sculptural quality of the 2-dimensional drawing and elaborate on how the scale 1/1 aspect of the drawings and the connecting of the forms through tracings generate imagination of and associations with three-dimensional space. I ask myself the question how the drawing method can bring me further in the creation of new spatial entities (on the a imagined level, and on a three dimensional level) and how eventually these drawings relate back to design?

drawing act; reflection, connecting form; abstraction, space.

1 Introduction

In this paper I will give a reflective account of how I developed a method of drawing over the past few years as part of my artistic practice. It's a method that is based on the act of tracing second hand furniture parts with a pencil and where I then start a creative process by adding other drawing acts. The reflective nature of this account is about looking deeper into the formal mechanisms of these different drawing acts, and about what I'm looking for through drawing in this way. Through reflection on this method I look for a new understanding of the phenomenon produced by the generative quality of the drawing method.

> *The practitioner allows himself to experience surprise, puzzlement, or confusion in a situation which he finds uncertain or unique. He reflects on the phenomenon before him, and on the prior understandings which have been implicit in his behaviour. He carries*

out an experiment which serves to generate both a new understanding of the phenomenon and a change in the situation. (D. Schön, The Reflective Practitioner: How Professionals Think in Action, New York, Basic Books, 1983)

The red line through the paper is about a particular quality of the tracing drawings that has to do with the connecting of forms that appear in the tracing process. I will investigate the character of the qualities of these connections. Next to that I look into how to connect the drawing method to space. During the process of elaborating on the drawing method the importance of abstraction will also be underlined. Here the role of the imagination of different notions of space is examined. In addition to my work with drawings, my fascination with furniture parts has led me to make videos and installations, based on the question of how to give these two-dimensional furniture parts a new spatial quality, and how we can understand the forms, materiality and sizes of these ordinary objects.

2 Compositions with furniture parts

In 2009 I was invited to participate in an art project called *Kunst en Zwalm*. In the courtyard of a mansion house I showed a collection of parts of second-hand furniture and old mirrors (figure 1). The installation was called *Collection*. On a wooden platform, I installed marble, glass and different styles of mirror in a clear composition. The size of the platform corresponded to the size of a small (living) room. The fragments of the furniture were put together in a composition to create an overall reflective surface. I'm fascinated by these ordinary objects because they are remains of middle-class chic; they carry some kind of middle-class memory with them. I am particularly interested in the form and in the materiality of these objects when using them in compositions. This installation has been (and still is) a source of inspiration for me on a range of projects where the specific formal qualities of the furniture parts are used to make drawings and sculptures.

Figure 1 Collection, Kunst & Zwalm, Zwalm, Belgium, 2009.

2.1 *Placing and re-placing*

The composition of the installation *Collection* was achieved following a process of carefully looking for interesting positions by placing and *re-placing* the objects. It was a search for clear relationships between form and matter. I experienced the placing and *re-placing* of the objects as interesting acts. Handling these heavy but also fragile objects on the wooden platform felt like performing a choreography and composing a sculptural installation at the same time. I investigated this performing and composing act again in my studio by having a camera take a picture every 30 seconds while I placed and *re-placed* furniture parts, in the search for challenging compositions. I made a stop motion film of it, where the static quality of the composition is a nice counterpart to the spatial and physical handlings. My figure negotiates the composition through the handling of the objects (figure 2).

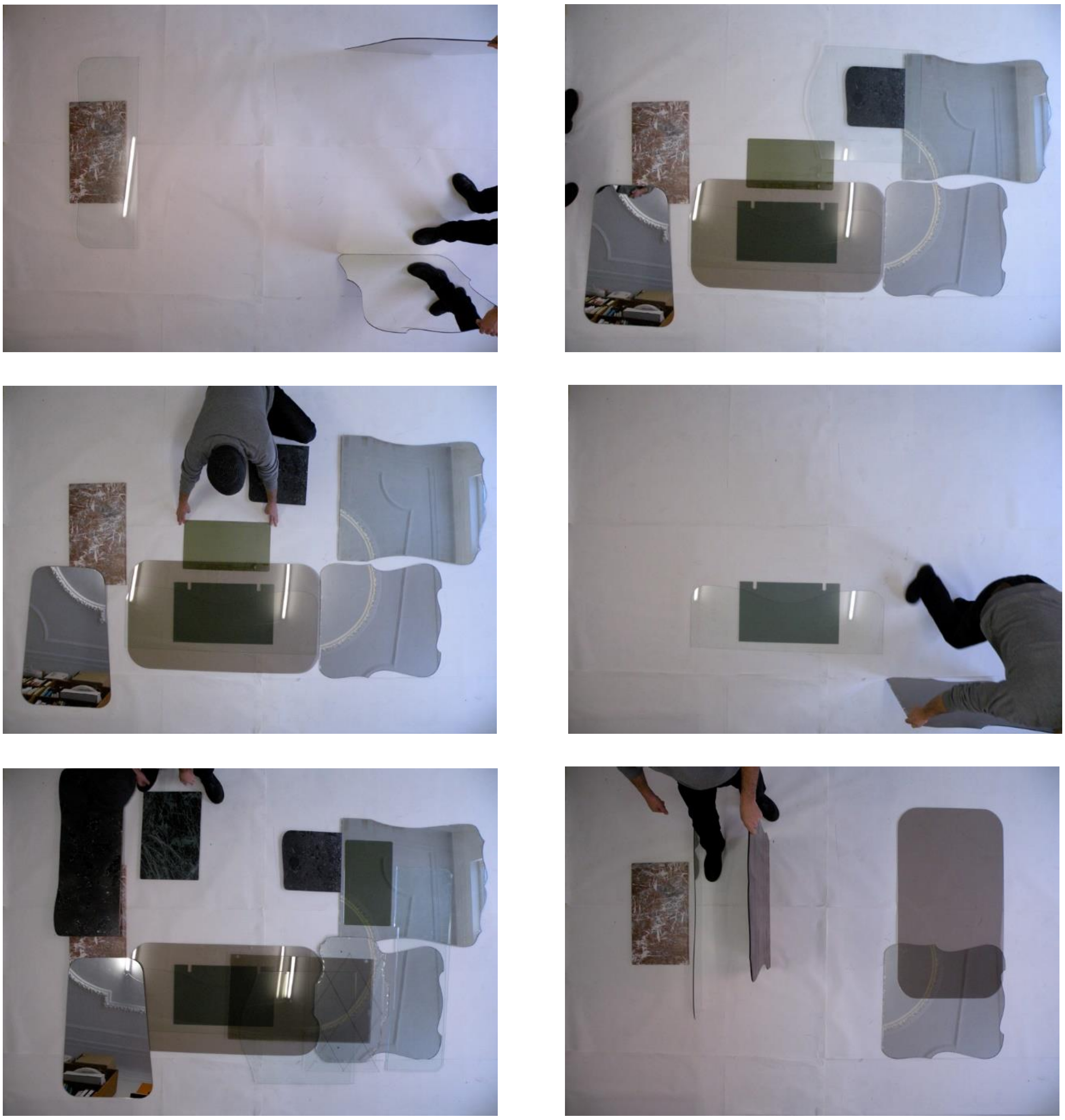

Figure 2 Placing – Re-placing, stop motion, 3', 2010.

To be able to remember the position of some of the objects, I started to trace them with a pencil. Very quickly, I began to appreciate the formal qualities of these line drawings (figure 3). I investigated the forms of the furniture objects in relation to the forms of the tracings of those objects. I was particularly interested in the transparency of some of the glass objects, where the curves of the forms are more visible. The glass objects established a nice dialogue between each other and in relation to the lines of the tracings, revealing new information about their forms.

Figure 3 Placing – Replacing with Tracings, stop motion, 3', 2010.

3 Exploring qualities of the tracings

I extensively explored the qualities of the tracings of the furniture parts by making multiple series of drawings. In the first series, I looked into the quality of the traced pencil lines. I reflect on the thickness and the hardness of the lines and their quality of tension. I also investigated the way the lines interact with each other when different tracings overlap. I made complex, dynamic and optical line drawings. Given the size of the furniture parts, I decided to use big drawing paper, to make the spatial impact of the flowing lines as strong as possible (figure 4).

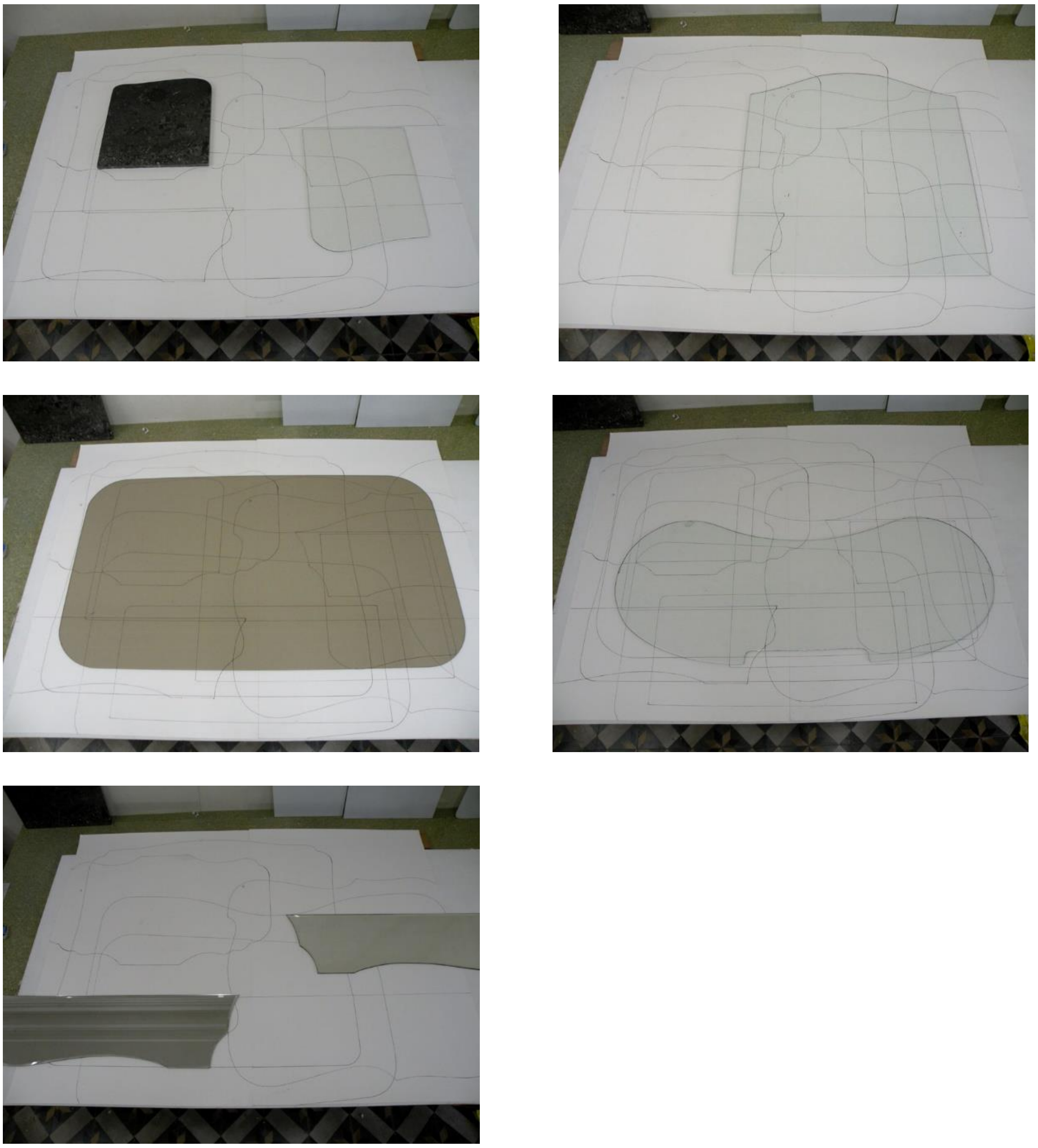

Figure 4 Try-outs for tracing project, 2009.

Coincidence plays a part when making the drawings, because I hardly have an idea of what the formal result will be when I'm tracing the objects. When the furniture part is traced and removed, the traced form shows itself, and the impact on other tracings becomes visible (Figure 5). The drawings are made horizontally. When they are hung vertically on the wall one can take more distance whereby the overall composition is more visible. In some cases, traces of dirt and old paint from the furniture parts is present.

3.1 Referential forms

In the tracing drawings one can recognize the origin of the forms; one can recognize the mirrors and furniture parts through the sizes of the forms and the specific curve of the lines. But the flowing lines interact with each other when they overlap; they seem to be connected and to create new forms. In some drawings, the overlap creates excessive fragmentation. Most of the forms that are created by the (overlapping) tracings are symmetrical and consist of tight, curved lines. The abstracted forms can elicit associations with things other than furniture parts and mirrors, such as a top view of an imaginative car (figure 5).

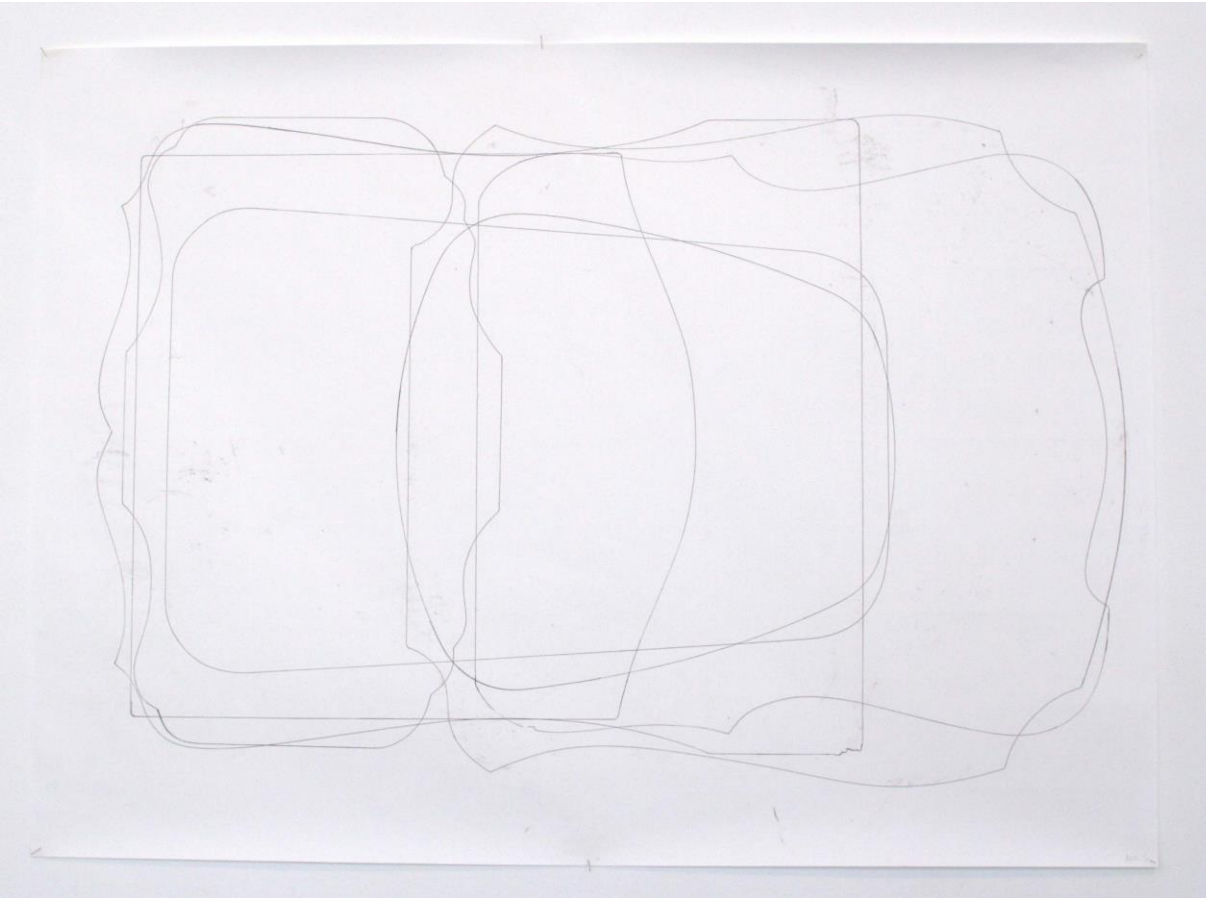

Figure 5 Tracing Form, pencil on paper, 110 cm x 150 cm, 2011.

4 The sculptural in the tracing drawings

4.1 Exploring qualities of form

In the past, I made sculptures consisting of boxed-in objects where only a fragment was still visible through a customised hole (figure 7). In the same spirit of boxing-in, I started to cover up part of old mirrors and furniture parts with white glossy lacquer (figure 6).

The white lacquer highlights the curves of the sheets and the unlacquered parts give identity to the minimal forms. As with the boxing-in of a lampshade, here too I had to look for a challenging balance between the covered (hidden) and uncovered (visible) part of the object. But differently to boxing-in, in this case the lacquer transformed the material appearance of the furniture parts. They are partly dematerialised forms. The strength, weight, colour and fragility of the objects is difficult to grasp. As with the tracing drawings, it is a search for the pure formal qualities of the ordinary objects. Through the abstraction, the typology of the objects surfaces, and at the same time a designerly aspect speaks through it.

Figure 6 Reflective Shapes, lacquer on marble and glass, 2008.

Figure 7 Boxed Hanging Lamp, mixed-media, 29cm x 31cm x h 42cm, 2013.

4.2 Tracing form and tracing space

When I'm boxing in an object, I'm somehow tracing the spatiality of that object. It's as if I'm scanning the object by means of the box. With the work *Boxed Hanging lamp* (figure 7), for example, before making the box in wood, I investigated how much of the object's form should stick out of the box, such as to enable a new reading and understanding of that object. I wanted to accentuate a fragile and sensual quality of the ordinary glass hanging lamp. Like a scanner, I pass along the object with the cardboard until I can see something new is happening in between the visible fragment, the materiality and the opening in the box (figure 8).

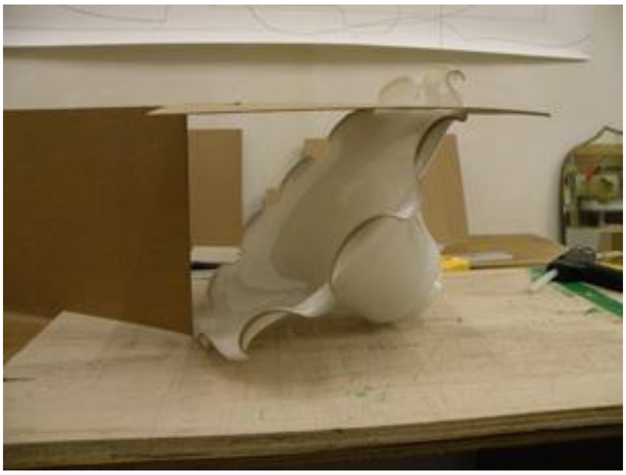

Figure 8 Try out for Boxed Hanging Lamp, 2012.

4.3 Some references from the field of sculpture

The scale 1/1 that is present in all my tracing drawings, originates from my long-lasting interest in the concept that British artist Rachel Whiteread (1963) uses in the making of her sculptures. She casts the negative space of big objects like the sculpture House, 1993 (figure 9) or small objects like the underspace of a chair. All her sculptures take on the size of the negative space of the object that is casted. In a similar way the objects I use determine not only the form but also the size of the drawings (and of the objects and the installations) that I make. The tracing drawings are therefor always made on a scale 1/1.

Figure 9 House, Rachel Whiteread, 1993. (photo credits: Sue Omerod)

On the other hand, the variation of form and size of the fragments of secondhand furniture allow for a strong compositional element in my drawings. The work of another British artist namely Tony Cragg (1949) is a reference in that respect. In the early years of his career he used quiet often fragments of everyday and ordinary objects in a process of carefully constructed composition on the ground. He creates a specific momentum of order and stillness with objects that can be considered as waste (figure 10).

Figure 10 Spirale, Tony Cragg, 1983, courtesy collection/M HKA, Antwerp. (photo credits Heirman Grapics)

4.4 Exploring sculptural qualities

Sculptural qualities can be identified in the line drawings. The different, overlapping, thick lines and curved forms seem to have a spatial impact on the white paper. This inspired me to add matter to the tracing drawings to make the forms and the sculpturality of the forms more explicit. I looked back at the sculpture *Plastered Chair* I made some years ago (figure 11).

I smeared three to four thin layers of plaster on an ordinary chair, except for part of the back. I applied the plaster with my hand just before it hardened. This process resulted in an even structure on the fabric like a fragile shell. The chair lost its function; the porous plaster accentuated the forms and made it into a sculpture. In the same spirit I started to colour in the forms of the tracing drawings with a thick orange-brown colouring pencil. I hatched different layers of the same tone until a smooth and equal surface of 'coloured matter' was created (figure 12, 13). The carefully applied shading resulted in a slightly transparent, skin-like structure. As with the plastered chair, the traces of the physical act are not too accentuated.

Figure 11 Plastered Chair, 1996.

Figure 12 Fragment of Tracing Drawing, 2009.

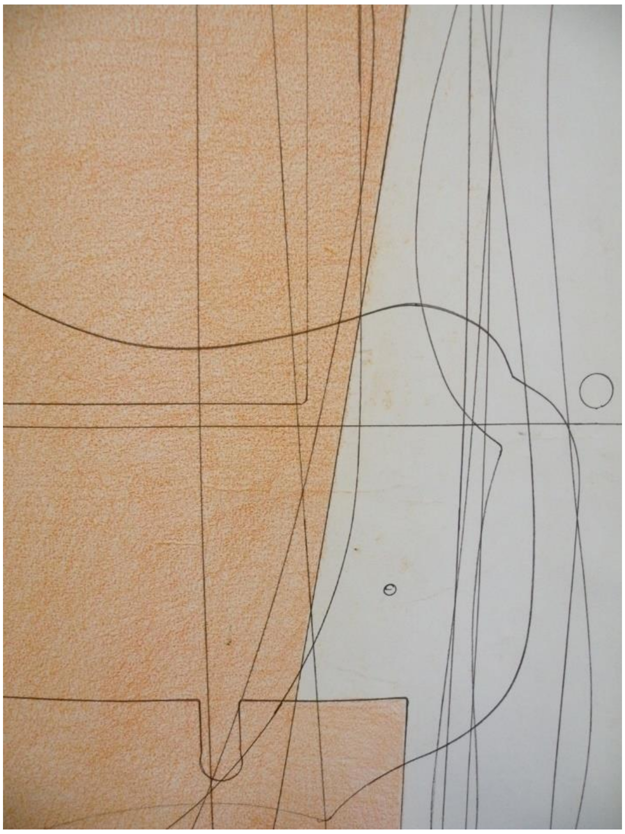

Figure 13 Fragment of Tracing Drawing, 2009

The hatching is intensive. There are different tonalities that are intensified by the thick grain of the paper. Filling in forms in the drawing accentuates their concave and convex characters. In some drawings, the hatching establishes new formal relationships with all sorts of connotations. The forms remind us of enlarged terracotta objects (figure 14).

In addition to the colouring pencils, I started to use a beige, water-based lacquer to paint over some of the hatchings. It's a light and warm background tone that gives a new value to the objects and other colours (figure 15). As a result of applying the lacquer to the drawings, painterly aspects were introduced in the drawing method. It is a satin lacquer, slightly transparent. It leaves a haze of the underlying orange-brown colour. The water-based lacquer makes the drawing paper shrink slightly, causing the drawings to come away from the wall slightly. The skin-like quality then becomes even more present. The combined lacquered forms look like a stiff monumental dress.

In this respect there is a reference to the sculptural work of the Austrian artist Franz West (1947-2012), and more specific in the way he treats the surfaces of his sculptures. He applies fabric, plaster, resin and paint on volumes as if he is pulling a skin around an object, and by doing so introduces a bodily dimension on abstract form.

https://www.muhka.be/nl/collections/artworks/u/item/12044-untitled--188

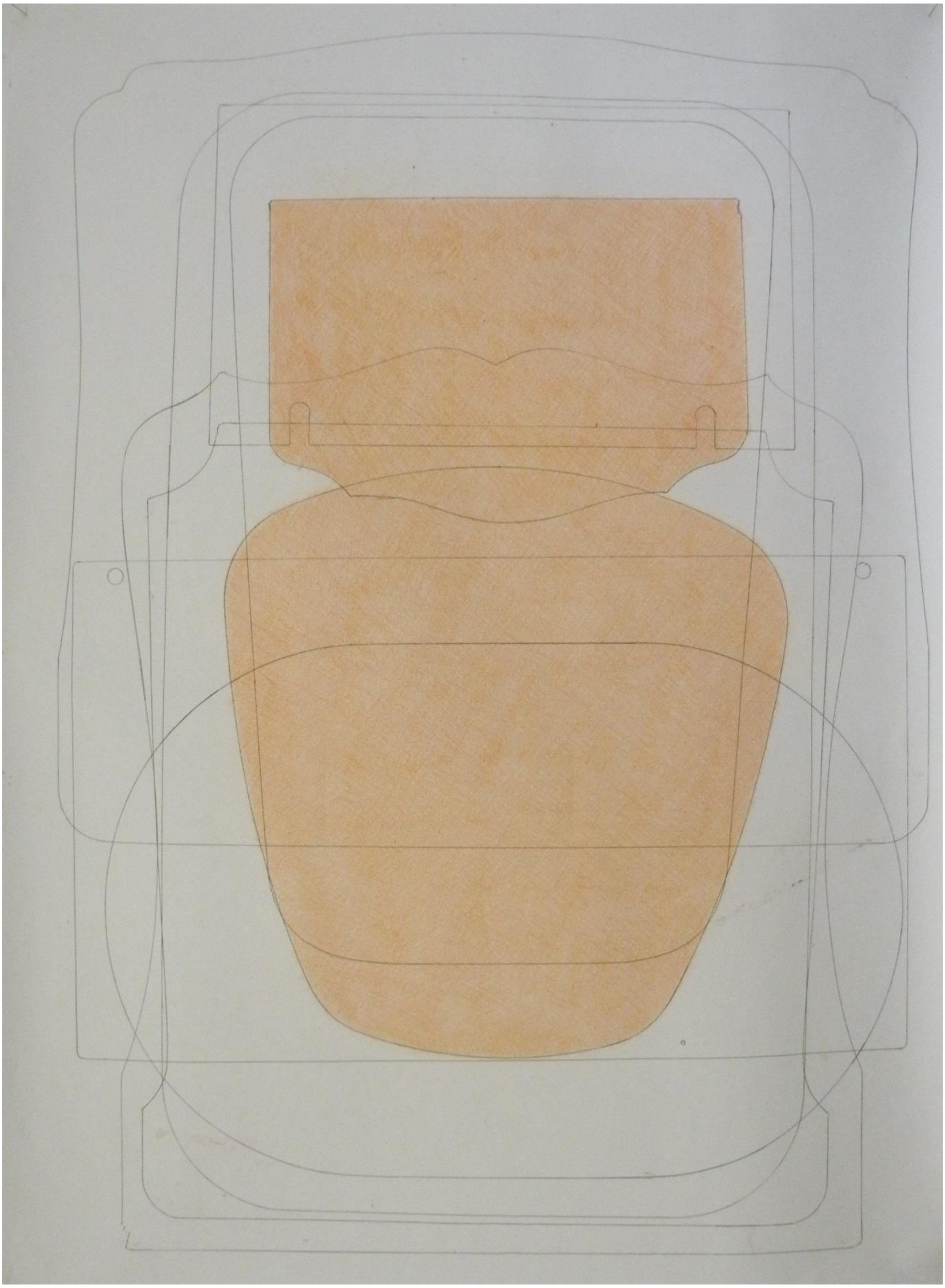

Figure 14 Tracing Form and Tracing Space, pencil on paper, 110cm x 150cm, 2012.

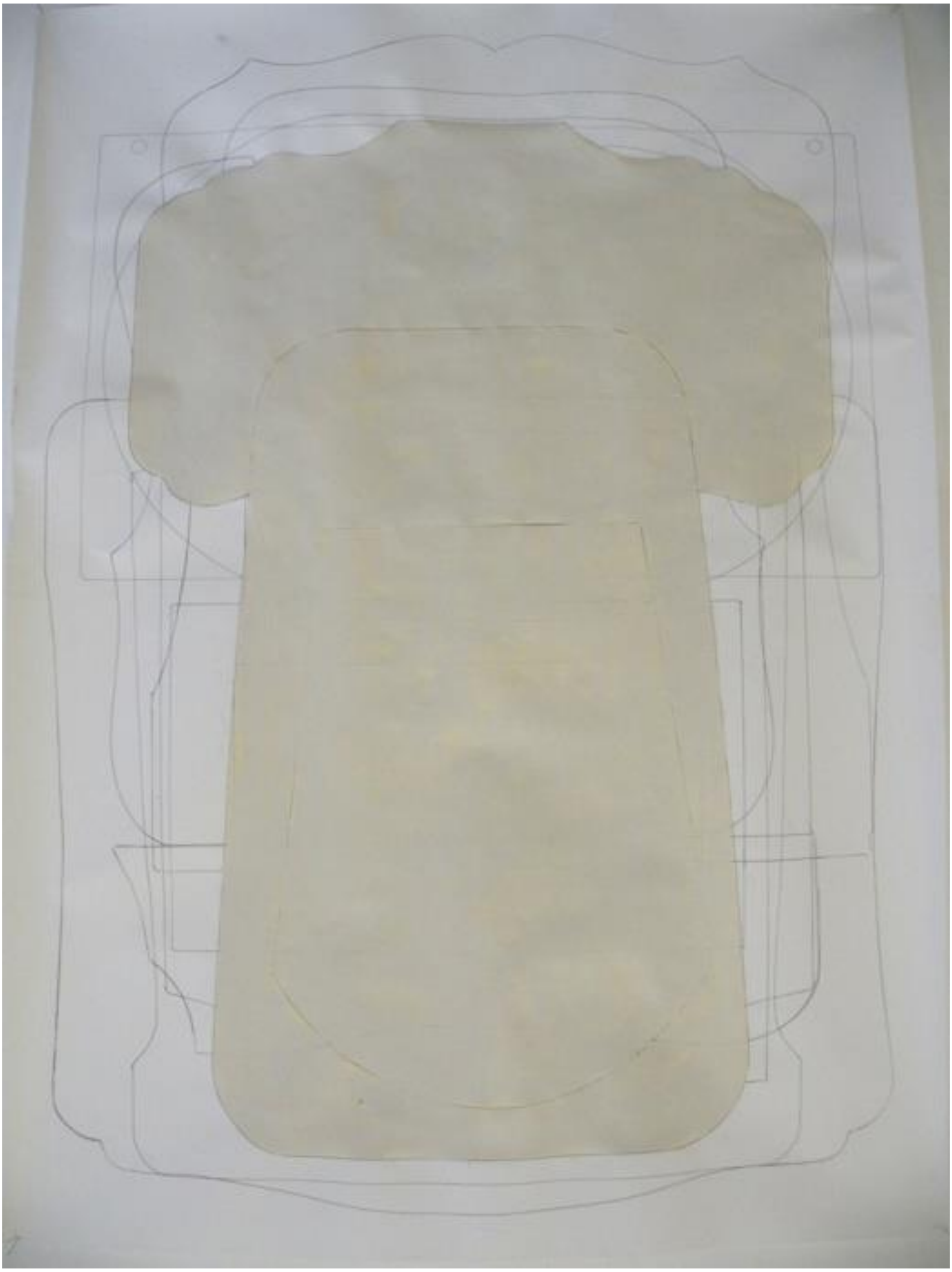

Figure 15 Tracing Form and Tracing Space, lacquer and pencil on paper, 110cm x 150cm, 2012.

4.5 Sculptural acts

Through of the interactions of the different acts, I learned something new with each tracing drawing. I investigated intensively the quality of the tracing lines and the formal outcome of the interaction with forms and lines. The result of every act generates new insight and provides inspiration for future acts. It's a process where the 'good drawings' possess an interesting interplay between line, form, matter and the idea of a mental space that I project onto the drawings.

It was my intention to explore ways of manifesting myself spatially with parts and fragments of ordinary objects. The drawing method helped me in doing so, but at a certain moment I started to question the role of the drawing paper, and I also questioned the complexity of the drawing itself. I could see that in some of the good drawings, the large format of the paper played an important role, as did the simplicity of the tracings

In the drawings of the German-Belgian artist Bernd Lohaus (1940-2010),[1] I noticed that he made his drawings as if making sculpture. The act of drawing a line, sticking paper or writing or carving a word in wood or concrete is of the same nature. In the momentum of a timespan. In the monumental sculpture Ich/Du (figure 17) it is the visitor who also executes an act by walking around the sculpture to read a word on either side of the sculpture. Both in the drawings and in the sculpture, there is an act on the material with hardly any compositional strategy.

This understanding made me reconsider my approach to drawing. Rather than focusing on composition, I focused on the sculptural acts. And I asked myself, 'If the drawing is the sculpture, what then could be its special context?'

Figure 16, ICH – DU, Bernd Lohaus , 1979, permanent sculpture in the SMAK, since 1999, Ghent, B.

5 On connecting form

In almost all the tracing drawings I made with the furniture parts, lines and forms overlap, creating internal interactions. In the overlapping parts, new connections are made with new referential form connotations. The tracings, hatchings, lacquerings and cuttings allow me to make new formal

[1] M KHA Ensembles, 'Bernd Lohaus', http://ensembles.mhka.be/actors/bernd-lohaus?lang=en, (accessed 06/03/2018). http://smak.be/nl/kunstwerk/7439, (accessed 06/03/2018).

unities. In the process of establishing the drawing method, I identified the connecting of form as a recurring and interesting aspect of the tracing act. I started to use it as subject matter.

In the overlapping tracings, I imagine on the one hand connections of architectural spaces and rooms and on the other circuits in mental spatial structures. The rooms of my studio serve as a spatial reference. In these drawings, the line is given a new meaning. In contrast with the hard and curved tracing lines, I add thin lines (made with a ruler) through the drawing. With these lines, I seek to define the mental space that I project onto the drawings. They are openings (cracks) in the materiality of the drawing itself, from where the underlying colour of the pencil is visible (figure 16).

Figure 17 Untitled, lacquer and pencil in paper, 54cm x 71cm, 2017.

3.1 Connecting units

In examining how I can connect the tracing drawings to three-dimensional space, I have explored the formal impact created when the tracings possess spatial qualities. I have noticed that the connecting of spatial entities is a recurring subject in my work. I made several videos, installations and sculptures in which I work with the specific spatial conditions of the three rooms of my studio. For example, in the work *My Double Studio Room* (figure 18). It is a sculptural model of two of the rooms in my studio that are connected with each other by a grid that traces the space of the rooms. In this work, the two rooms are presented as a unity.

Figure 18 My Double Studio Room, cardboard, wood, lacquer, 35cm x 34cm x 98cm, 2009-2013.

The connecting and merging of entities is also visible in the different children's pavilions that I have designed. As, for example, in the pavilions *Double Unit(s)* (figure 19). It's as if the units are stacked (upside-down) two by two. They are, however, made out of single sheets of wood painted in one or two colours. The visual play of the stacked and connected boxes creates a unity that looks like a play tower, with sculptural and architectural qualities. In both examples the connecting of entities results in an abstraction of the spatiality.

Figure 19 Double Unit(s), painted wood, 150 cm x 150 cm x 250 cm, 2009.

5.1 How to connect the drawing method to space

I investigated how to connect the tracing drawings to space, or, in other words, how I could make an interaction with the forms that occur in the tracing drawings and with space. I knew that the step up to space had to be made through a sculptural act. When I asked myself which space to connect the tracing drawings to, I considered my studio space as the obvious choice. The following text is an account of how I set up and realised a project in which I looked for a spatial interaction between a tracing drawing and my studio space.

Connecting Form and Space investigates the spatial possibilities of a particular drawing method. It seeks to emphasise the relationship between absence and presence, and aims to focus on the tactile and formal qualities of materials and objects. The drawing method under examination consists of a series of physical interventions. Fragments of old mirror and glass from second-hand table tops – often large, heavy and fragile – were carefully placed on drawing paper and subsequently traced with a pencil. The overlapping of the tracings resulted in new formal relations, but it was not always possible to anticipate what the impact of the new form would be on the previous tracings (figure 20).

Figure 20 Connecting Form and Space, (setting for studio project) 2013.

A research project was set up in which a ten-metre-long drawing of partly overlapping tracings was used to connect to the space of my studio. It was laid out on worktables across the three rooms of my studio on a structure of hardboard sheets. When the mirrors and glass tabletops were placed on drawing paper, they sometimes left marks and traces of dirt on the paper. In certain areas, the sharpness of the edges of the objects determined the quality of the pencil line.

A reference to the scale of the human body, which is present by design in the mirrors, can be recognized in the proportions of the tracings. In an attempt to connect the drawing to the space, a couple of mirrors were again positioned on the tracings and partly traced with a cutter. When cutting out forms from the drawing, the hardboard appeared through the paper. When cutting further across the hardboard, hints of the surfaces of the supporting worktables became visible along with glimpses of the studio floor. The connection to space occurred through the formal qualities of the drawing itself. The holes functioned as frames, in the sense that there was a graphical quality in the perception of these fragments. The fragmented view articulated the materiality and the forms under the table. A selection of tables, objects and sculptures present in my studio was used to compose the views of the different holes in the drawing, with the intention of accentuating the essences of their spatial and material qualities. In collaboration with the

photographer Kristien Daem a series of photos was made looking down at the tabletop (figure 21). These photos were used in a publication.
http://www.merpaperkunsthalle.org/projects/view/1117?catId=7

Figure 21 On Connecting Form and Space, (project presentation) Faculty of Architecture KU Leuven, 2014.

5.2 *On connecting form and space*

Once again, I used the big tracing drawing (and the underlying boards) but now as a display structure to communicate on some experiments and tryouts on connecting form and space.

I considered other possible support structures for the tracings, as well as other ways of tracing. I used permanent markers and an etching needle to trace forms on plexiglass (figure 22). I made some simple constructions with the plexiglass to investigate the spatial impact of the lines. The transparency of the plexiglass reduced the lines to elegant, spatial marks. Their forms interacted with the space as if it were a three-dimensional drawing.

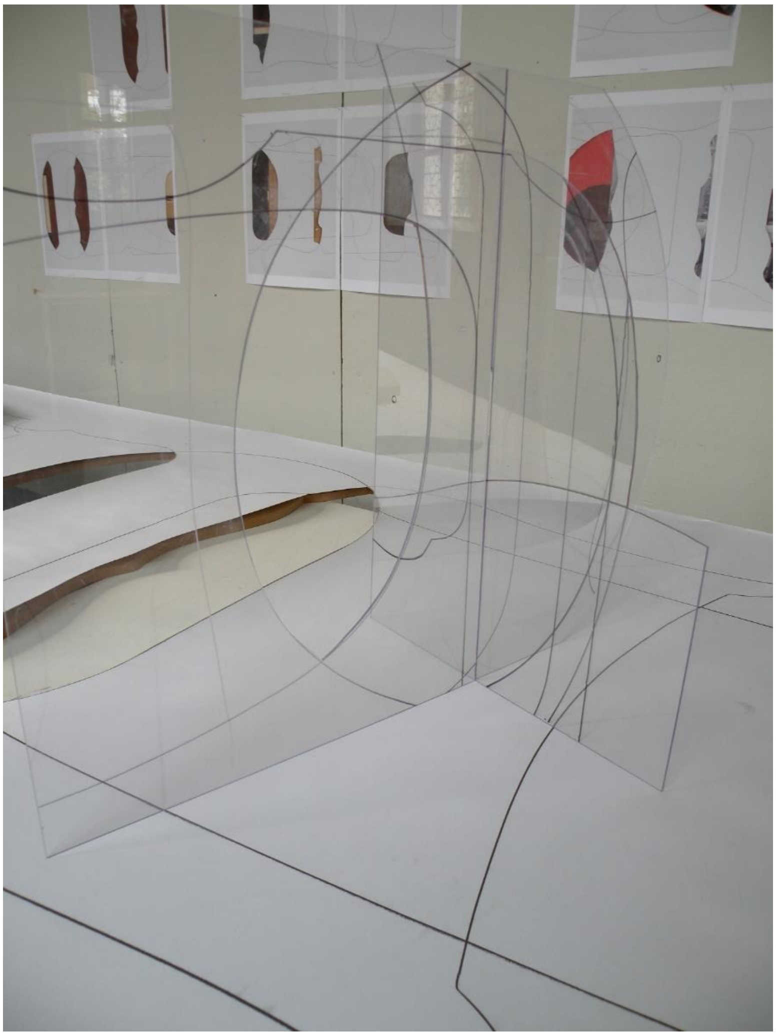

Figure 22 On Connecting Form and Space, (project presentation) Faculty of Architecture KU Leuven, 2014.

I explored the three-dimensional and sculptural possibilities of the tracing drawings, where the (overlapping) forms of the tracings are materialized into sculptural installations (figure 23). The pencil tracings have become engravings into a painted plywood panel, and it's as if I can now 'fold' the drawing by means of the plywood. The holes in the panel now connect to the space up, under and around the trestle table. I can stick works under the tabletop and on top the table as to accentuate the notion of the imagined landscape.

The pencil tracings are then an in-between stage in the process of making installations. They allow me to see the ordinary objects on an abstracted and formal level. They inspire. The transformative process into three dimensions is about investigating new spatiality, new forms, materials and functions. In these new spatial constellations, the sizes and forms of the ordinary objects are still present as an echo.

Figure 23 Dealing With Ordinary Form, (installation fragment) Netwerk, centre for contemporary art, Aalst, B, 2015.

I made some plaster forms in a similar way to how I made the tracing drawings (figure 24). This time, however, I placed some mirrors on a bed of clay and traced the forms by cutting though the layer of clay with a wooden stick. I created a void by carving clay away, and then poured plaster into it. The plaster tiles are, in a way, drawings in three dimensions and could be interpreted as materialized voids. When placed on the tracing drawings again, these forms bear a direct visual relation to the type of forms on the paper. They interact with the line, but also with the spatiality of the cut-out forms. When different forms are stacked on top of each other, there is a new spatial and sculptural reading due to the curved forms and the shadows on the white plaster that in a way recall architectural forms.

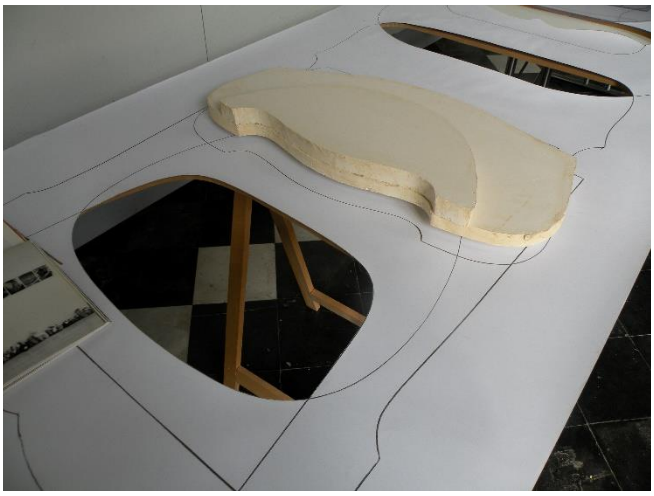

Figure 24 On Connecting Form and Space, (project presentation) Faculty of Architecture KU Leuven, 2014.

Together with an artist-friend Koenraad Dedobbeleer (1974). I designed a set of stools and a small table based on the form connections that occur in the drawing process (figure 25). The forms are made of laminated wood and the feed are made of steel tubing. The roundness and the size of the forms invite for particular spatial use and handling in relation to walls and the body. The particularity of the fragmented mirror forms add a playfulness to the functionality of the objects.

Figure 25 Two Stools and a Table, laminated wood and lacquered steel, 2013.

6 Imagining space

6.1 Frames

The drawings arise from pencil tracings of old mirrors and glass and marble leftovers from second-hand furniture. The cabinets on which the marble and glass were lying have disappeared. When tracings are made from the marble and glass tops, only the shape and the size of these flat objects refer as a distant echo to the original furniture. But the shapes of the tracings contain a specific typology, and in the size of the tracings one recognizes the human scale and the previous function. The tracings still contain a level of reference to the original object, but generally they seem abstract and therefor trigger the imagination. The tracings are like the frame of a white canvas, where by means of a drawing method new space, aesthetics and materialities can be imagined, not as a nostalgic approach but rather as a search for new understanding and reading of the spatial quality of the tracings.

In this respect the reflections of T. Lagrange (2015) on indistinctness in reference to the Carceri etchings of Batista Pisanesi somehow approach the type of spatial imagination I look for:

> *What emerges in front of our eyes can be referred to as indistinctness, but it is an indistinctness that is framed within a well-established, familiar structure: the structure of an architectural theory. Moreover, the indistinctness appears in images that are very well designed, balanced, constructed by architectural minds. Thus the indistinctness is situated in a perfectly conceivable mental framework. Looking at this image and interpreting its graphic elements, viewers can smoothly enter the newly constructed space. Once in there, they are confronted with indistinctness generated by an intriguing use of space and image as alternative forms of communication. This indistinctness functions as a laguna, a void that can fill up with thoughts and ideas… or be used as a refuge from controlled systems of functioning and communicating and as such it is of vital importance, as it allows these prints to become stimulators and generators of new*

insight. (Lagrange, T, Look Space! A Story of Analogous Spaces. Grafische Cel, LUCA School of Arts; 2016, p. 12)

6.2 The generic and the creative act

The drawing method that is being examined possess a strong generic component. It consists of a set of convertible drawing acts. These acts arise from the formal qualities and functions of the drawing and painting tools. Pencil tracings alongside the glass and marble objects, colour pencil hatchings and overpainting with lacquer. By alternately using the different tools the drawings reach a point where spatiality, materiality or even choreographic lines can be imagined (figure 26).

The drawing acts are used in a generic process where things are convertible, and where somehow other people could execute these acts. Every act is equally important and will be repeated in slightly different ways. The drawing act itself constantly develops as a creative response to the former act. It is in the overlap of the generative drawing method and the creative response, that the imagination is triggered, and a delicate world sees the light. The drawing method functions like a chain reaction of creative decisions. It is a construction that arise from the making itself. In the final results these drawings show traces of the momentum; not as deliberate gestures, but as residues of the need to respond to former acts.

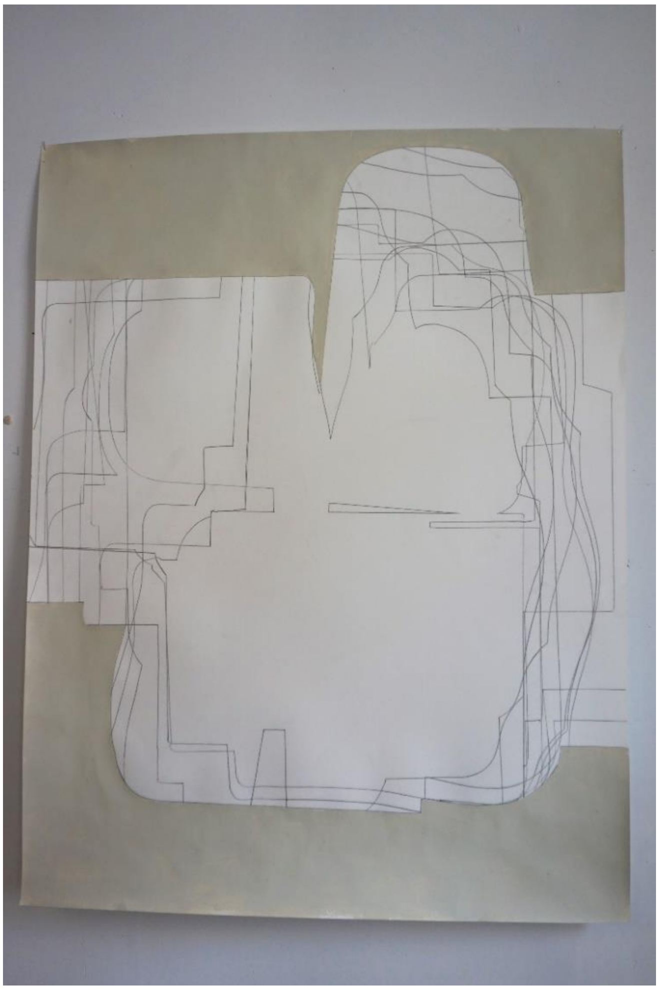

Figure 26 Five Make One, lacquer and pencil on paper, 73cm x 94,5cm, 2016.

6.3 The tracing line as a boundary for a field of imagination

The drawing has accentuated boundaries. I look for clear boundaries in the drawings by accentuating the tracing lines. By means of the two-dimensional traces of the marble or glass sheets I wish to start a process of imagination of the three-dimensional in the drawing. A tight tracing is the starting point from where the imagination of the three dimensional can take place. It is as if the defined form wants to come lose from the paper. The tracings define a precise field. They define, like a clear border, where I can investigate poetic and aesthetic notions of imagined space and matter.

The notion of the boundary present in the drawings, arise out of the tight and detailed line tracings in conjunction with the hatching and the lacquer. When lacquer is applied the drawing will shrink slightly. Through this shrinking of the surface the drawing changes from being pure two-dimensional and becomes a three-dimensional object. Even to the point that I sometimes cut our drawings, thus activating their shape and materiality in order to let the drawings enter into a dialogue with the physical space. The imagined space within the drawing and the actual physicality of the drawing as an object in space find each other in the clear tracing of the shapes, but also in the precise application of the drawing and painting method (figure 27).

Figure 27 Overlap, lacquer and pencil on paper, 54cm x 99cm, 2013.

6.4 A sense a materiality

In the drawings a sense of materiality is created through the immediacy of the drawing acts: the hardness and tightness of the tracings, the surface texture of the hatchings, the silky quality that arises from the slightly transparent lacquer and the shrinking of the paper. The specific pixeling of the lines in the drawings, that arise from the closeness of the lacquer to the line, makes the line vibrate and feel as a cut through matter, through a volume or a space. All these aspects are added to create and represent a material thing. The feeling of materiality can be so strong that it feels as if the shape wants to be cut out of the paper to exist in physical space, like an object. Now and then this actually happens, but most of the drawings remain in the limited space of the drawing paper that I decided for. (figure 28)

Figure 28 It's Taking Form, lacquer and pencil on paper, 53cm x 83cm, 2017.

6.5 Imagination through abstraction

The drawings arise from a sequence of different acts where then imagination plays an important role. The imagination of spatiality, corporality, sculpture and architecture. The drawings are always abstract in themselves, and this abstraction level provides room for imagination. Through the abstraction one can imagine scale in the drawings, as well as volume, spatiality and materiality.

The drawings will always be slightly different, and variations will arise from the fact that the acts are reversable. In each drawing the drawing and the painting act have a slightly different outcome because of the inherent coincidence of each act. Each drawing demands different creative decisions to be made.

The imagination through abstraction that is present in the drawing process is part of an aesthetic desire on the one hand, but on the other hand the imagination is triggered by the static and robust form qualities of the mirrors and furniture parts. These abstracted forms somehow contain aspects of a collective memory of a typology of form (on a small or bigger scale).

Imagination is a necessity in the drawing method. During the process the imagination can follow a track about imagination of space or a track of imagined architecture. The track will be defined during the process of creative decisions, and not so much on basis of formal compositional solutions.

7 Conclusion

Through a profound reflection on the different aspects that constitute the drawing method, I can now clearly say that the creation of new spatial entities (on the a imagined level, and on a three dimensional level) is first of all triggered by the abstraction that is present in the pencil tracings. In this abstraction there is always a level of recognition; the forms remind us of something. This fuels the imagination and associations with other types of objects, and allows me to imagine rooms, spaces, body parts, architectural forms. Next to that the scale 1/1 aspect of the drawing method avoids all representational reading. This 1/1 scale is like a skeleton that refers to human scale and where by means of the different creative acts and moments of speculations new meaning is added. My interest in sculpture and my experience with making sculptures and installations based on second hand objects is the source from where the new meaning in the drawings originates.

As a result of the level of abstraction and of the scale 1/1 of the drawings, particular designerly elements surface in the drawings as well as in the three-dimensional work.

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Acknowledgements: The author would like to thank Ane Vester for her grateful support.
Note: All photos are the author’s except otherwise mentioned. Figure 17 photographer not found

Drawing to See / Drawn to Seeing: Multimodal Reinterpretation in an Autonomous Drawing Machine

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Drawing is celebrated as a powerful tool in the designer's toolbox. While it is generally understood to be a useful method in the visualization of abstract concepts and complex scenarios, it is equally important to understand drawing's role in the pursuit of novel solutions. Drawing affords enough physical and conceptual space between modes of representation to permit the designer to reinterpret the design. With this creative act as inspiration, this paper reviews the topic of *computational play* as a framework for implementing autonomous, creative design in computational systems. The framework is demonstrated in a proof-of-concept drawing machine. Specifically, the machine uses shape grammars to exhibit multimodal reinterpretation in its drawing process: It physically draws each step of the design and then visually reinterprets the drawing in an iterative, playful process.

shape grammars; computational play; reinterpretation; drawing machine

1 Introduction

In *The Thinking Hand*, architect Juhani Pallasmaa depicts an elaborate relationship between hand, mind, and drawing. He describes the inherent spatiality of the act of drawing and celebrates its role in the design of space, stating:

> *When sketching an imagined space, or an object being designed, the hand is in a direct and delicate collaboration and interplay with mental imagery. The image arises simultaneously with an internal mental image and the sketch mediated by the hand…The second meaning of the word 'drawing' - to pull - points to this essential meaning of the drawing as a means of pulling out, revealing and concretising internal mental images and feelings as much as recording an external world. (Pallasmaa, 2009, p.91-92)*

This is a sentiment echoed repeatedly by architects and designers. In *Why Architects Still Draw*, architect and poet Paolo Belardi celebrates drawing as an act that will never be fully replaced by digital tools. Belardi lauds the speed and ease of sketching, and the possibilities it affords. He writes:

> *Sketching is a notational system that is not only rapid and ready but also a mode of accessing information...Sketching, both because of its small dimensions and indeterminacy on paper as well as its independence from any code, is able to continuously regenerate itself, always offering new suggestions - sometimes ones that prove surprising even to their author. (Belardi, 2014, p. 30)*

Such descriptions point to drawing not just as a means for communicating problems to other parties or visualizing complex scenarios, but as an act that holds almost mythical creative potential. In reality, there is much less mystery to drawing's power, even if there is still near-limitless possibility. Drawing, as the intentional effort to translate a concept between different modes of representation, inherently embraces the vagaries and novelties that arise in an active engagement with a medium.

While aspects of performance, engagement, and making are finding their way into the discourse surrounding creative practices, there has been less effort put forth toward implementing these behaviours in computational models. Drawing provides an entrance point to this discussion. This paper reviews the topic of *computational play* as a framework for implementing autonomous, creative design in computational systems. The paper reviews four characteristics key to computational play, with special attention paid to the role of *multimodality*. While multimodality is defined simply as *variation in representational form*, its benefits are discussed with respect to creative design practices. This framework is implemented in an autonomous drawing machine that iteratively plots, views, reinterprets, and interacts with a drawing process. The drawing process itself is based on shape grammars and is,c structured so as to encourage the kind of exploratory curiosity that lies at the heart of creative design.

2 Background | Drawing to Make

2.1 Drawing as Cognitive Offloading

Design is full of what Professor Richard Buchanan calls *wicked problems* (Buchanan, 1992). Such problems are ill-defined, indeterminate, dynamic, and confusing. The problem space of an architectural design, for example, is a complex, fluctuating landscape that incorporates often-conflicting considerations of aesthetics, culture, structure, and budget, among a myriad of other factors. In dealing with such issues, designers explore with limited or no knowledge of what the end goal should be, or even if the considerations of today will be the same as those of tomorrow. Often, before the designer can even pursue the answer to a question, he or she must formulate the question itself, an activity that philosopher and urban planner Donald Schön calls *problem-framing* (Schön, 1990).

Manoeuvring in such scenarios requires an open mind and a readiness for change. Schön describes the designer's ability to deal with surprise as *reflection-in-action*, a type of improvisational problem-solving and on-the-spot experimentation that allows designers to try previously untested ideas (Schön, 1990). Sociologist Richard Sennett reflects on a similar scenario at the heart of craftsmanship, stating that the experienced craftsman must be able to localize, to question, and to open up a problem (Sennett, 2008).

Navigating such a complicated terrain is a challenging task that necessitates some type of supportive tool, as demonstrated by the ubiquity of drawing and model-making in creative industries. Drawing serves as a powerful method of inquiry, allowing the designer to realize even the most complex or abstract concept with relative ease. Drawing enables designers to offload and test their ideas, shifting their focus from one part of a design to another (Suwa & Tversky, 2002). This can be a useful tool in complex scenarios, as drawing allows designers to study a concept visually, rather than cognitively. At the same time, it permits the designer to approach the issue from a different perspective and see the problem anew.

Even as technology has progressed and digital tools have come to replace analogue ones, the humble pen-on-paper sketch still occupies a primary spot in the designer's studio. Sketching is fast and, with practice, borderline effortless. The sketched drawing is an intentionally quick, loose effort to visualize an idea. Too quick, and it is illegible, but labour over it for too long, and the sketch becomes a full-fledged blueprint, wearing undesirable grooves into the mind of the designer.

Schön summarizes this rapid process as a cycle of *seeing* and *moving*. He states that:

> *...designers construct and impose a coherence of their own. Subsequently they discover consequences and implications of their constructions—some unintended—which they appreciate and evaluate…Their designing is a web of project moves and discovered consequences and implications, sometimes leading to reconstruction of the initial coherence—a reflective conversation with the materials of a situation. (Schön, 1990)*

A conversation demands a partner, and for the solitary designer, the medium of drawing stands in as an alternate voice.

2.2 Drawing in Shape Grammars

Computation theorists George Stiny and James Gips capture many of the practices of creative design in their formulation of shape grammars (Stiny & Gips, 1972). In shape grammars, visual drawing rules are used to perform calculations on shapes. These rules can be additive and/or subtractive, permitting any kind of transformation that can be drawn. The rules supply some kind of shape or set of shapes to be recognized (on the left-hand side), and a resulting shape or set of shapes to be drawn (on the right-hand side). In the case of the diagram below (Figure 1), the rule involves rotating a triangle 180 degrees around its centroid, indicated by the light grey cross.

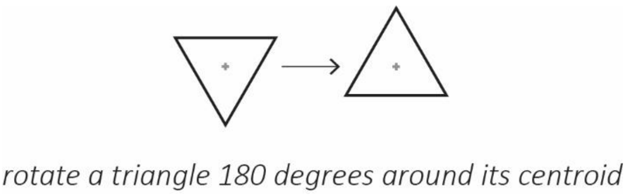

Figure 1 Rule application: The left side of the rule specifies what shape to look for, while the right side specifies what shape to draw. In this case, once an equilateral triangle is found, it is rotated 180 degrees around its centroid (erased and redrawn).

Multiple rules can then be strung together into a computation. Each step in the computation, indicated by a double arrow, involves the application of a chosen rule, indicated by a single arrow (Figure 2).

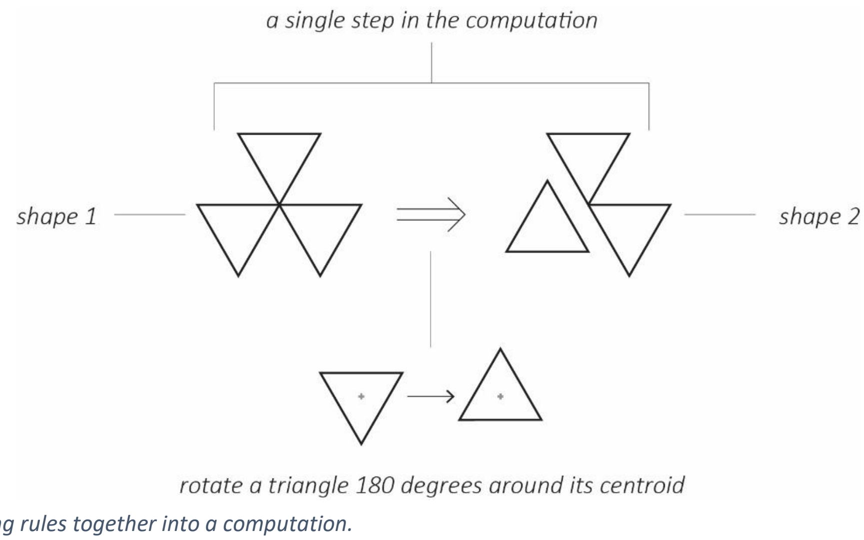

Figure 2. Stringing rules together into a computation.

Stiny describes design drawing as an iterative, calculating process of open-ended discovery (Stiny, 2011). It is up to the designer to decide when and where to apply the rule. Within this process, the designer identifies and *embeds* content into what he or she sees as a part of the drawing calculation. Once the drawing step is complete, the content *fuses* and loses any of its previous definitions, leaving the designer to see it anew (Stiny, 2006).

Although shape grammars is formalized as a computational process, it can seem counterintuitive in the context of computer science. Why intentionally ignore the steps leading up to the current position? The reason stems from shape grammars' appeal to novelty: Each new step brings with it a multitude of new content, some of which the shape grammarist may never have predicted. Stiny draws together a number of descriptions for this phenomenon from a variety of artists, linguists, theorists, and philosophers, calling it:

> *ambiguity, emergence, epiphany, eureka (aha) moments, figuration, flexible purposing, impression, intuition, invention, irony, negative capability, new perception, privileged moments, re-description, strong imagination, vitality - strange surprises (Stiny, 2017)*

How the designer acknowledges and processes this content is critical to the design process. Shape grammarists welcome such content, actively encouraging the kind of sudden insight that is so critical to design. In so doing, shape grammars reverses the typical relationship between description and calculation: Instead of calculating with content that has already been described, the shape grammarist (visually) calculates first, only *then* providing a description *as a result of* the calculation. The description of what's on the page takes a back seat to the process of discovery that occurs during design (Stiny, 2015). Dethroning the description in such a way allows – in fact, encourages – multiple descriptions of the same content, once again appealing to the variability at the heart of design. In this way, shape grammars faithfully represents not just the technique of the drawing process, but the ideology behind it as well.

2.3 Drawing as Making

Schön's seeing and moving and Stiny's embedding and fusing bear a striking resemblance to one another. Both point to the agential act of isolating content in an externalized representation, and then transforming that content through the act of drawing. Additionally, both insist on design as an ongoing, cyclical construction of meaning (Figure 3).

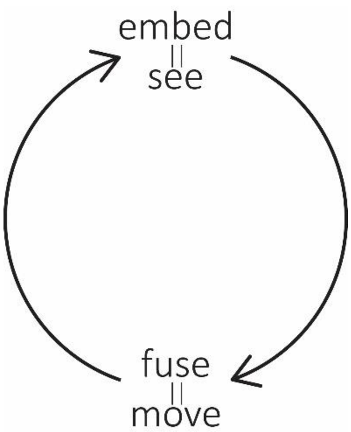

Figure 3. Comparing Schön's description of design as a cyclical conversation of seeing and moving to Stiny's description of embedding and fusion in shape grammars.

Perhaps another way to understand the similarities of these two approaches, as well as the potential that drawing holds for design, is through the idea of *making*. Anthropologist Tim Ingold uses this term to depict the creative process, describing it as "an ongoing generative movement that is at once itinerant, improvisatory, and rhythmic" (Ingold, 2010, p. 91). He later states that practitioners "are wanderers, wayfarers, whose skill lies in their ability to find the grain of the world's becoming and to follow its course while bending it to their evolving purposes” (Ibid., p. 92). In a recent issue of *Design Studies* dedicated to this topic, professor of design and computation Terry Knight and co-editor Theodora Vardouli define making as:

> *…a process that is time-based (unfolding in real-time, in-the-moment), dynamic (changing), improvisational (dealing with uncertainty, ambiguity, and emergence), contingent (subject to chance and the unique), situated (within a social, cultural, physical environment), and embodied (engaging the (maker’s) active body and sensorimotor capabilities). (Knight & Vardouli, 2015, p. 2)*

Characterized this way, design is an iterative, meandering search for interesting questions and possible values in an ambiguous and dynamic space of possibilities. Designers make their own way through this indeterminate space, often with very little guidance. In order to do so, designers cultivate certain behaviours—of curiosity, open-mindedness, and freedom from external constraint. These behaviours indicate a willingness to change that stands contrary to traditional notions of problem-solving.

All of this contributes to an understanding of the role that drawing plays in the design process. These curious, exploratory behaviours are facilitated by drawing, an added modality that forces the designer to translate and reinterpret the design at each step of the process. The act of drawing allows designers to roam, discovering both interesting questions and potential creative solutions.

3 Methods | Making the Machine

3.1 Computational Play

The creative process described above is fluid and dynamic, and providing some kind of all-encompassing description of it is a famously controversial effort. That being said, the activities embedded in design practice can serve as excellent references for the development of creative computational agents. The discussion of the multimodality of drawing fits into a larger framework that I call *computational play*. The framework draws from research into the nature of play and its role within the design process to create a set of characteristics typically observed in a playful designer. This research is summarized below.

Play is the autotelic behaviour of a subject temporarily exploring a system of rules (Penman, 2017). This definition succinctly captures many of the qualities of Dutch historian and early play theorist Johan Huizinga’s original description:

> *…a voluntary activity or occupation executed within certain fixed limits of time and place, according to rules freely accepted but absolutely binding, having its aim in itself and accompanied by a feeling of tension, joy and the consciousness that it is ‘different’ from ‘ordinary life.’ (Huizinga, 2014, p. 28)*

It also bears a strong resemblance to game designer Brian Upton’s depiction of play as “free movement within a system of constraints” (Upton, 2015, p. 15). Playful behaviour is meandering and exploratory, but also very orderly, as it is based on rules (Gadamer, 2004). The rules form the playground, or setting, for the play. Huizinga refers to this as the magic circle of play (Huizinga, 2014). Players are driven by an inner curiosity and motivation, often eschewing external guidance in favour of their internal interests (Bruner, 1979). This characteristic is captured in play’s autotelism, which specifies that play has no goal other than self-perpetuation (Hein, 1968).

The framework for implementing play in a computational setup involves four characteristics. First, as elaborated in this paper, computational play is facilitated by *multimodal* representation conducted by the agent. This can take a variety of forms, but the process must be significant enough that it requires the agent to translate the work between different representations, reinterpreting the content along the way. As discussed, an example is the designer’s tendency to sketch. This externalizing process is key to the designer’s ability to shed a cognitive bias and approach a topic from a different perspective (Suwa & Tversky, 2002). Insisting on multiple modes of representation acknowledges that the process of translation often ignites our subconscious, causing the kind of insight that often proves so fruitful to the design process (Stiny, 2015).

The second characteristic of computational play is its focus on *generative* techniques that do not rely upon results for justification. Designers—as well as many other artisans, craftspeople, and creative professionals—improvise. Rule-based behaviours work well in this regard, as they specify behaviour without relying upon efficiency or other heuristics for guidance.

Third, computational play is *iterative*. Combined with the insistence upon multimodal representation, this lends play a cyclical structure reminiscent of the design processes outlined independently by both Schön and Stiny (Schön, 1990; Stiny, 2011). Iteration opens the design process up to shifting contexts and changing requirements. Iteration grants the same level of importance to both question and problem. At the same time, it also results in a natural discretization of the creative process that is conveniently applicable to computation.

Finally, computational play should be *autotelic*, or internally driven. While the three traits described up until this point provide a strong framework for observable playful activity, autotelism serves as the inferred component to the process. Autotelism provides a strategy for untethering the designer and encouraging the kind of curious exploration at the centre of play.

3.2 Hardware

The framework discussed above might be difficult to reconcile with a traditional interpretation of computation, but it is not inherently difficult to implement in a computational machine. In order to test this framework, including the insistence on multimodal drawing, I have developed a computational drawing machine that is capable of drawing, viewing its own drawing, and making decisions based on what it sees. This machine has provided me with a way to explore my ideas, and with it I have attempted to demonstrate that computational play can be implemented relatively simply. This section will discuss the construction of the machine, which demonstrates computationally playful behaviour through a multimodal, generative, iterative, autotelic drawing process.

The machine hardware is a Makeblock XY Plotter (V2.0) resting on a 2 x 2 ft acrylic base (Figure 4). The Z-axis of the machine is outfitted with both a dry-erase marker and an eraser. The stepper motor for this axis is fixed with an elliptical rotor. Resting on this rotor are two separate 3D-printed mechanisms that individually hold the marker and the eraser. As the motor turns, the elliptical rotor causes one mechanism to rise while the other falls; turning in the other direction reverses the motion, yielding both “Draw” and “Erase” modes (Figure 4, upper-right corner). When the rotor is positioned so that the long axis of the ellipse is horizontal, both marker and eraser are lifted above the acrylic base, yielding “PenUp” mode (Figures 4, 5). In this way, the machine is capable of both additive and subtractive drawing procedures.

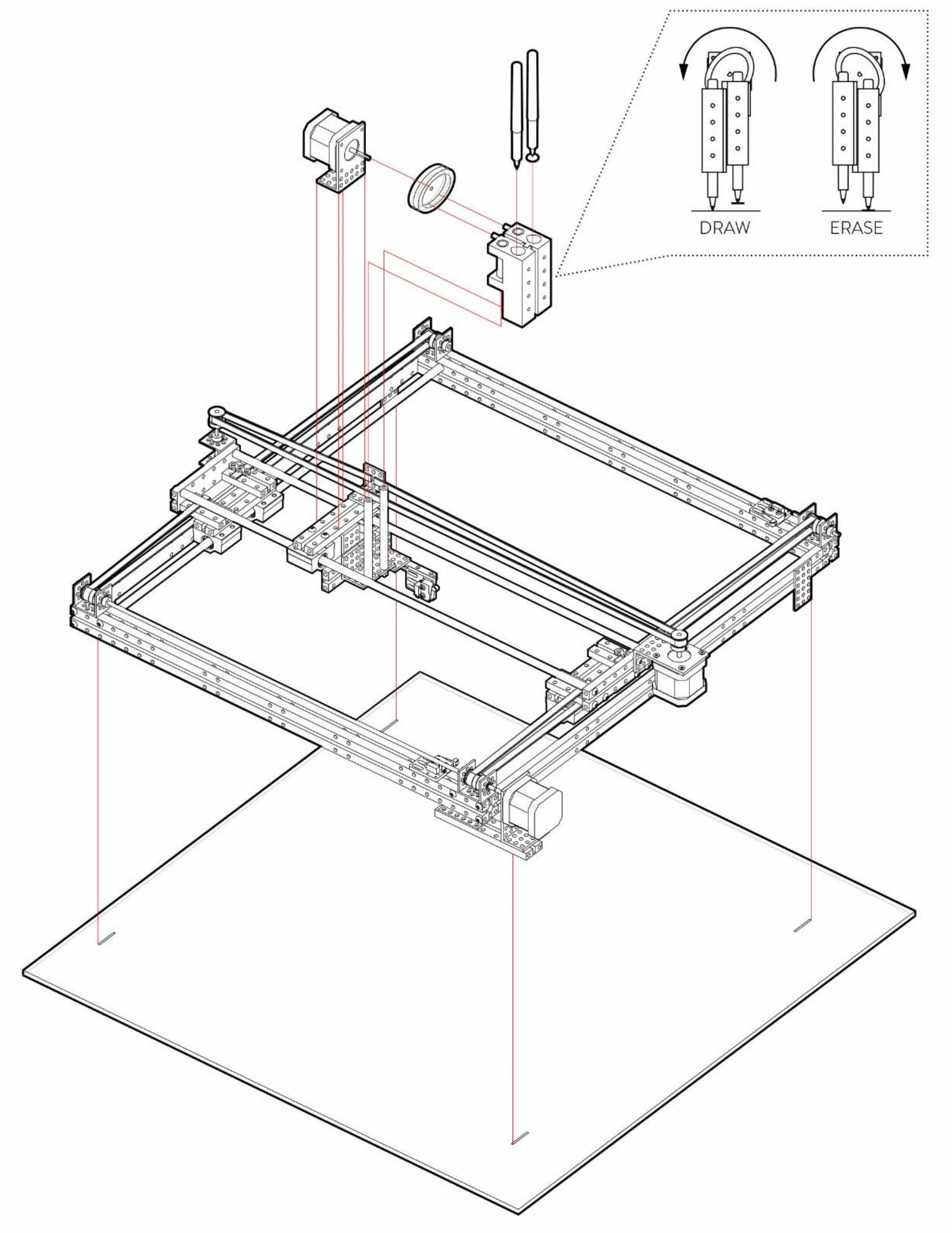

Figure 4. Exploded axonometric of drawing machine. The diagram in the upper-right corner shows how the motion of the elliptical rotor on the Z-axis allows the machine to both draw and erase.

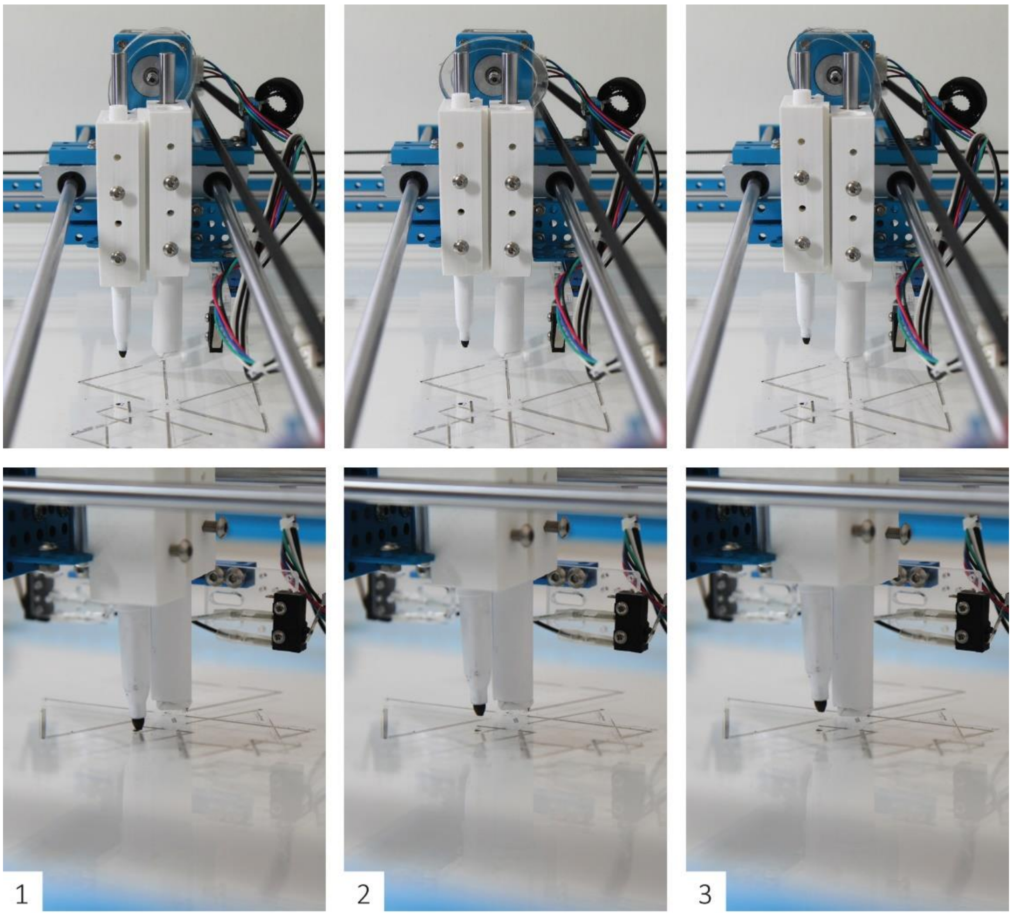

Figure 5. Detail photos of drawing machine Z-axis, showing Draw [1], PenUp [2], and Erase modes [3].

A webcam sits near the centre of the machine, approximately 250 mm above the surface of the acrylic base. In order to ensure an evenly lit drawing surface, LED lights line the underside of the machine around the entire perimeter (Figure 6).

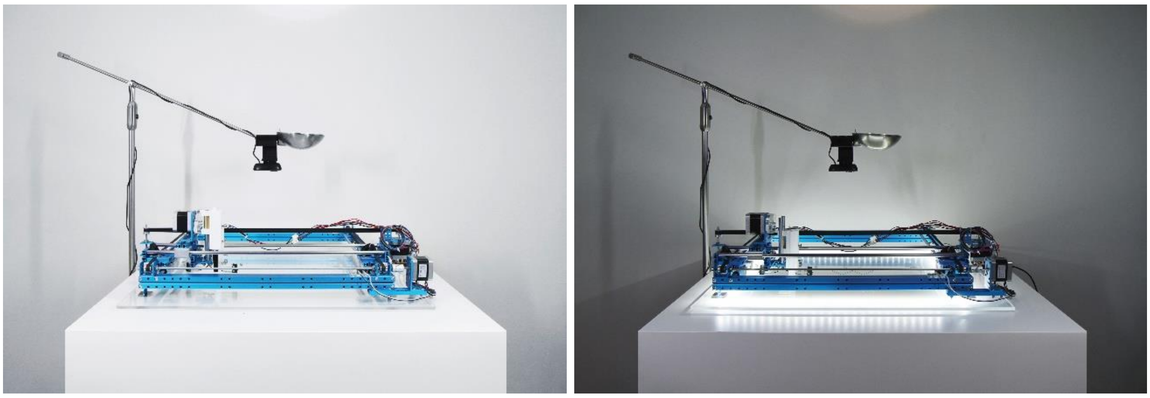

Figure 6. Drawing machine with overhead camera and under-frame lights toggled.

A connected computer acts as the digital "brain" to this plotter "hand" and webcam "eye." All of the computational processes—the webcam feed, the digital drawing manipulations, and the G-code processing—are managed in Grasshopper for Rhino. The components for receiving the video feed and communicating with the Arduino are provided through Firefly. Once the G-code has been determined, it is communicated from Grasshopper through Firefly to the Arduino, which then uses pre-loaded Grbl software to translate the G-code into commands for the plotter's motors.

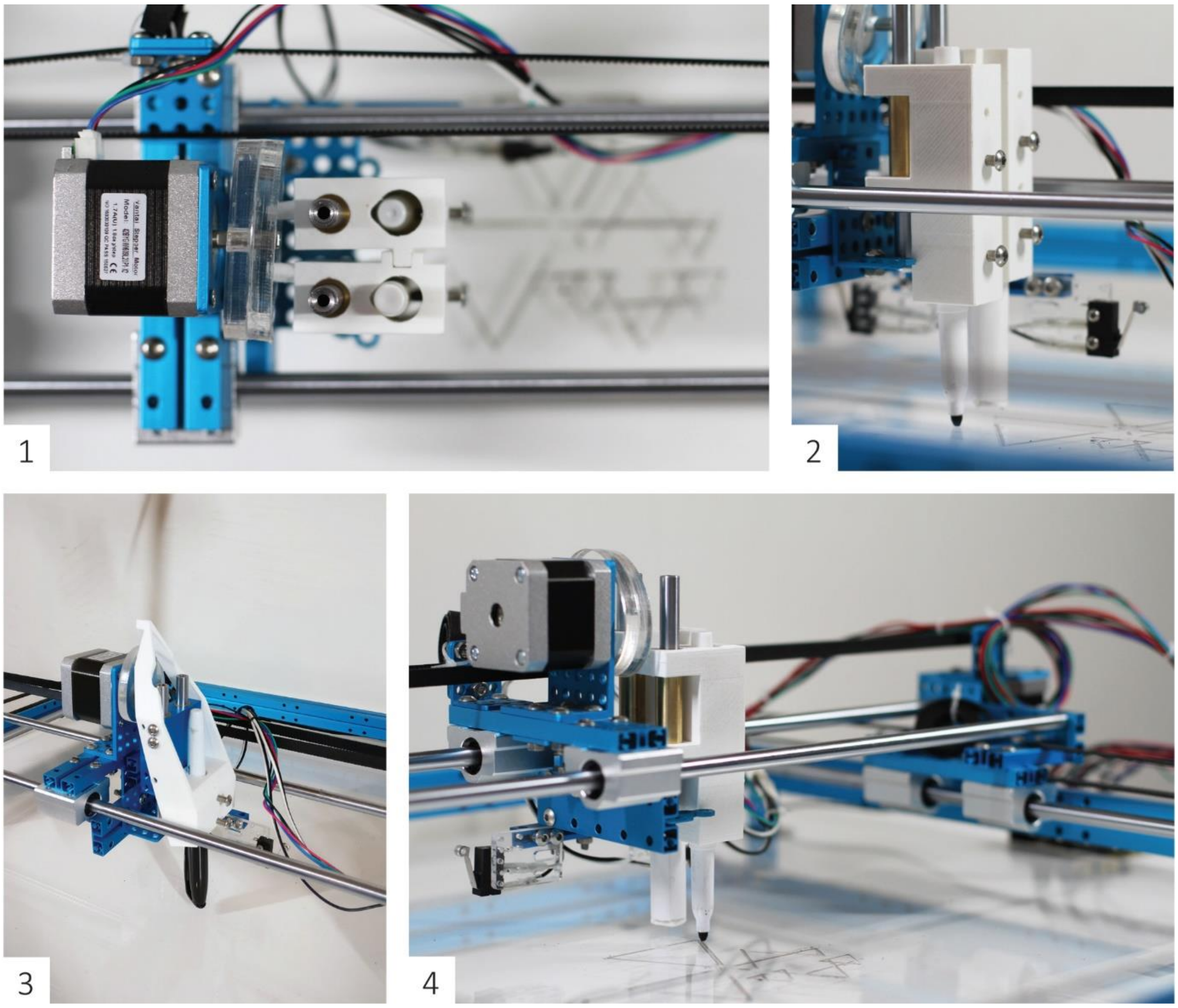

Figure 7. [1, 2, 4] Detail photos of the machine’s drawing mechanism. [3] Detail photo of an earlier iteration of the drawing mechanism (without eraser).

3.3 Software

Echoing the design process espoused by both Stiny and Schön described earlier, the machine works through an iterative cycle of embedding/seeing and fusing/moving. The computational framework is divided into three stages: machine vision, rule application, and plotting. These stages roughly align with the seeing-moving cycle of design, with the intermediate rule application section representing the conscious processes that designers use to choose what to draw. The resulting cycle is see-*choose*-move (Figure 8).

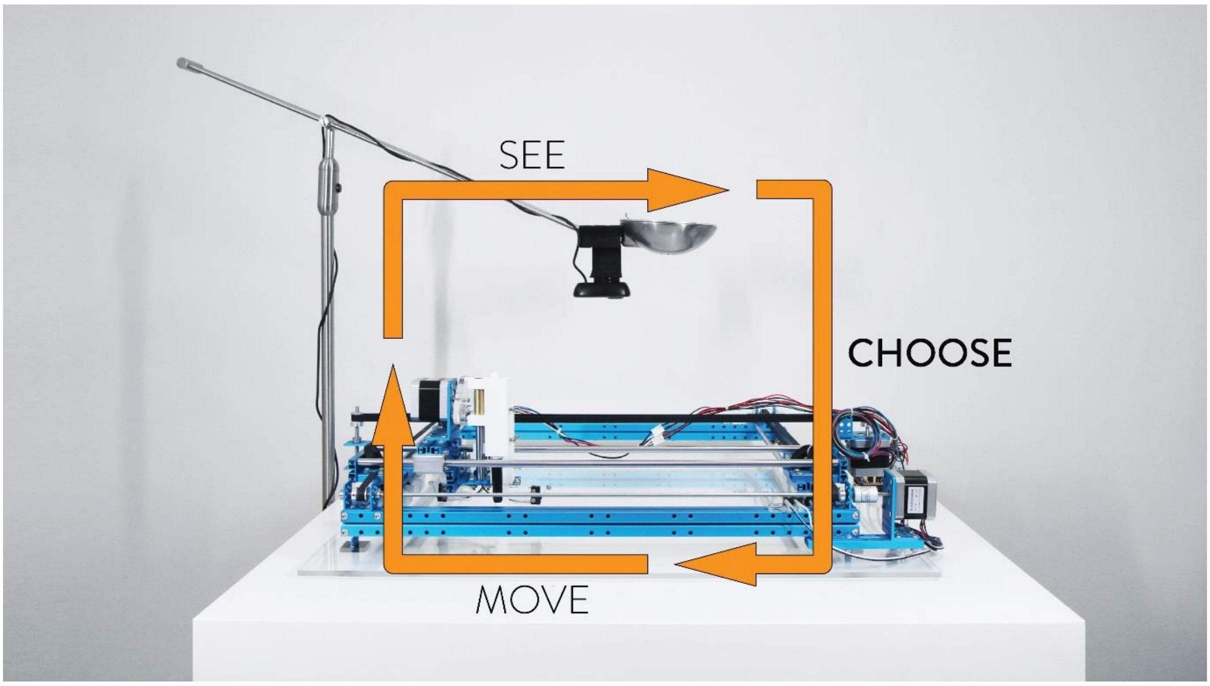

Figure 8. Drawing machine with iterative see-choose-move cycle overlaid.

In the first stage, the machine views its drawing. The webcam feed that is passed to the computer is immediately processed into a more usable format through brightness and threshold controls. Next, the computer uses a set of custom machine vision scripts to extract edges from the image and collect them into digital curves. This rough geometry is then smoothed into a cleaner interpretation. A separate data tree is constructed that describes the connectivity of the curves: Each branch of the tree is an intersection of two or more curves, and each leaf is a neighbouring intersection. Using this data tree, the computer uses classic search algorithms to determine every possible closed, non-self-intersecting path that exists in the drawing. After removing duplicates, the computer uses the unique paths to build closed shapes, which are passed to the next stage in the computation.

In the second stage, the machine determines all of its possible next moves, decides whether or not it will continue, and chooses a move to make. The moves are determined through the use of the drawing rules described earlier: The machine takes as input a certain shape or drawing and outputs a modified shape or drawing. While any number of drawing rules can be utilized, even the use of a single rule can afford a vast space of possible trajectories.

The machine matches the curves supplied from the previous stage against all of its internal rules. Having discovered all of the shapes that match a particular description, the actual rule applications are carried out, resulting in a number of possible next moves. One of these shapes is then selected to be drawn. The rule application portion of the computation also includes the implementation of autotelism. This component takes as input both objective values (the number of possible next moves) as well as subjective values (a measurement of the machine's own internal interest in continuing the activity) in order to determine whether or not to continue. While the subjectivity of the machine is simplified to a stochastic value, the importance of its inclusion lies in the unpredictable-yet-attributable behaviours that result. For more on this, please see Penman, S. (2017). Toward Computational Play.

In the third and final stage, the computer instructs the plotter to draw the new geometry. First, the digital lines are connected together into a toolpath, complete with initial travel distance, intermediate travel steps, draw and erase information, and concluding travel distance. This toolpath is then broken into individual points, which are converted into corresponding G-code and sent to the machine. At the end of the drawing process, the plotter returns to the home position, at which point the entire computation iterates, returning to the machine vision stage.

3.4 Multimodality

While this drawing machine has been constructed to demonstrate all four characteristics of computational play, the very aspect of building the machine is an ode to the importance of multimodality. The process could potentially have been left in digital format without any externalized drawing, but to do so would be to miss the opportunities available in varying the mode of representation. The software "brain" of the machine stands as one representation of the design, while the drawing stands as another. Pulling the two apart creates the physical and conceptual space for productive exploration to occur.

The insistence on externalizing the drawing through the plotter and reinternalizing it through the webcam is inefficient by most computational standards, but this only highlights the gap between computational optimization strategies and creative design practices. As the multimodality of drawing is critical to design, so it has been deemed critical to the drawing machine.

4 Results | The First Drawings

The machine demonstrates a cyclical drawing process that is entirely reminiscent of a designer iteratively constructing a drawing. It begins with an initial shape, views the shape, and cycles through possible next steps based on its drawing rules. By overlaying footage of the digital drawing process with the physical one, we see the rule application process in action: After using machine vision to recognize the current geometry, the machine cycles quickly through its possible options, before choosing one and proceeding to the plotting stage. All three computational stages blend into one continuous process.

In an early drawing experiment, before the ability to erase had been added, the machine handily demonstrated the ability to deal with novelty imposed by environmental accidents. In this case, the only rule supplied was a triangle inscription rule visualized in Figure 9.

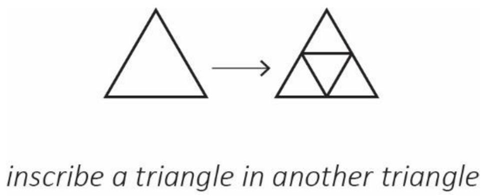

Figure 9. Drawing rule involving the inscription of a triangle in another triangle, using the centerpoints of the outer triangle's sides for the vertices of the inner triangle.

Using this, the machine demonstrated the ability to see multiple options at once (Figure 10, [1-3]), including new options that showed up in subsequent stages [4-6]. In an interesting twist, the machine accidentally trailed the pen across the drawing as it was resetting during one iteration. Unfazed, it incorporated this additional line into the digital interpretation of what it saw [7], and then was able to recognize a new triangle as a result of the accident [8]. It deviated from the space of possibilities projected by the drawing rule and instead dealt directly with the content at hand.

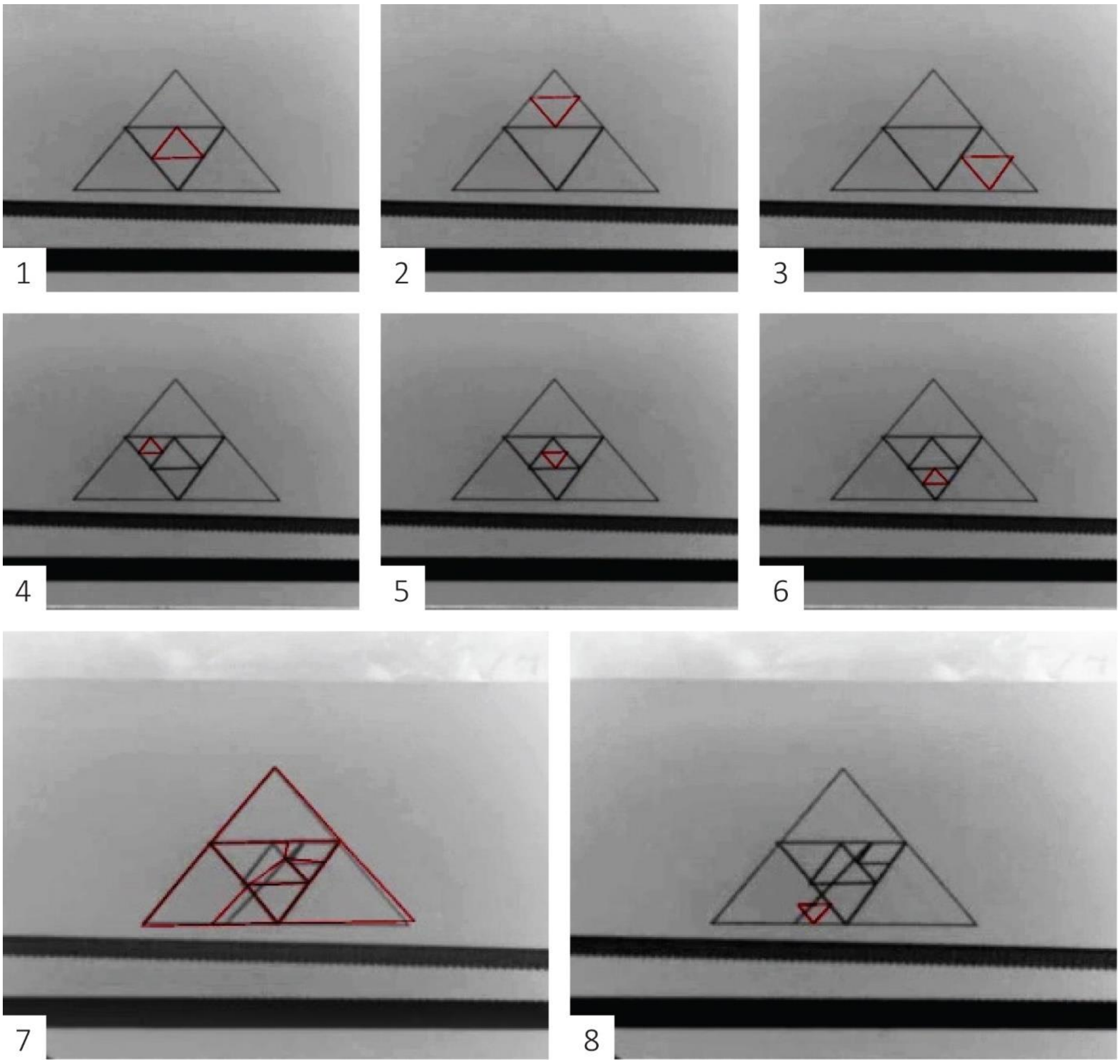

Figure 10. Initial drawing attempts using the rule in Figure 9. The machine did not have an eraser at this point. The red shape is a post-process digital overlay of what the machine is considering at that moment. In [1-3], the machine is cycling through different opportunities afforded by the drawing rule. In [4-6], it has added a new triangle (the one indicated in [1]) and is re-considering its options. In [7], the overall digital representation of the drawing is shown, including the accidental additional line that was created as the machine dragged the pen across the drawing. In [8], a new, unintended rule application emerges and is shown.

After installing the erasing mechanism, the machine completed a reconstruction of a triangle computation described in Stiny's *Shape: Talking About Seeing and Doing* (2006, p. 296) and reproduced below (Figure 11). In this computation, the only drawing rule is a triangle rotation rule, depicted in Figure 1. In each step, the vivid red outline indicates the shape that is chosen for rule application, and the light pink outline indicates the result of the previous step's transformation. Critical to this computation is the emergence of a new, larger triangle: In Figure 11 [4], this triangle is visibly composed of the outer edges of the three rotated triangles. This triangle is only available via active engagement with the drawing rules and iterative reinterpretation of the content in the drawing.

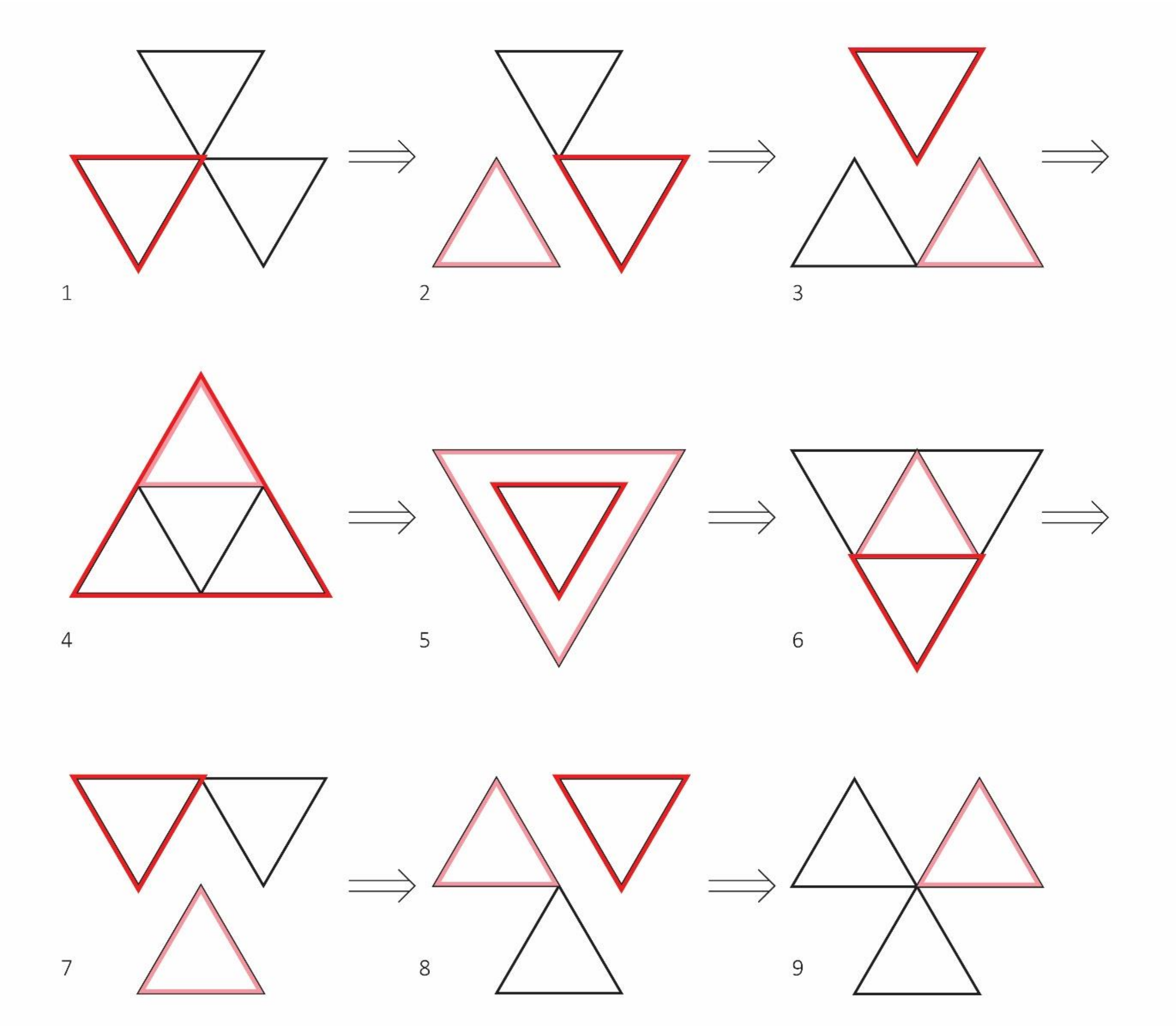

Figure 11. Encountering emergent information in a computation. The red outline indicates the content that has been identified for rule application; the pink outline indicates the result of the rule application. In [1-3], the three initial triangles are individually selected and rotated. In [4-5], the emergent outer and inner triangles are selected and rotated. In [6-9], three new triangles have emerged, which are again individually rotated in order to create a drawing that initially appears similar to the initial state [1], but in fact cannot be easily derived from it. Adapted from Stiny, G. (2006.) Shape: Talking About Seeing and Doing. p. 296.

In the images below (Figure 12), the lower red shape indicates the shape that the machine intends to erase (the offset is due to the physical separation between the pen and the eraser). The upper red shape is the shape that the machine intends to draw. After rotating (erasing and redrawing) the three initial triangles [1-3], the machine recognized the emergent outer triangle, which it proceeded to rotate [4]. It also recognized the emergent inner triangle, which it rotated [5]. This provided the machine with three new triangles to rotate [6-8]. In the final step, the machine accidentally trailed both pen and eraser through the drawing, resulting in the strange-looking result shown [9].

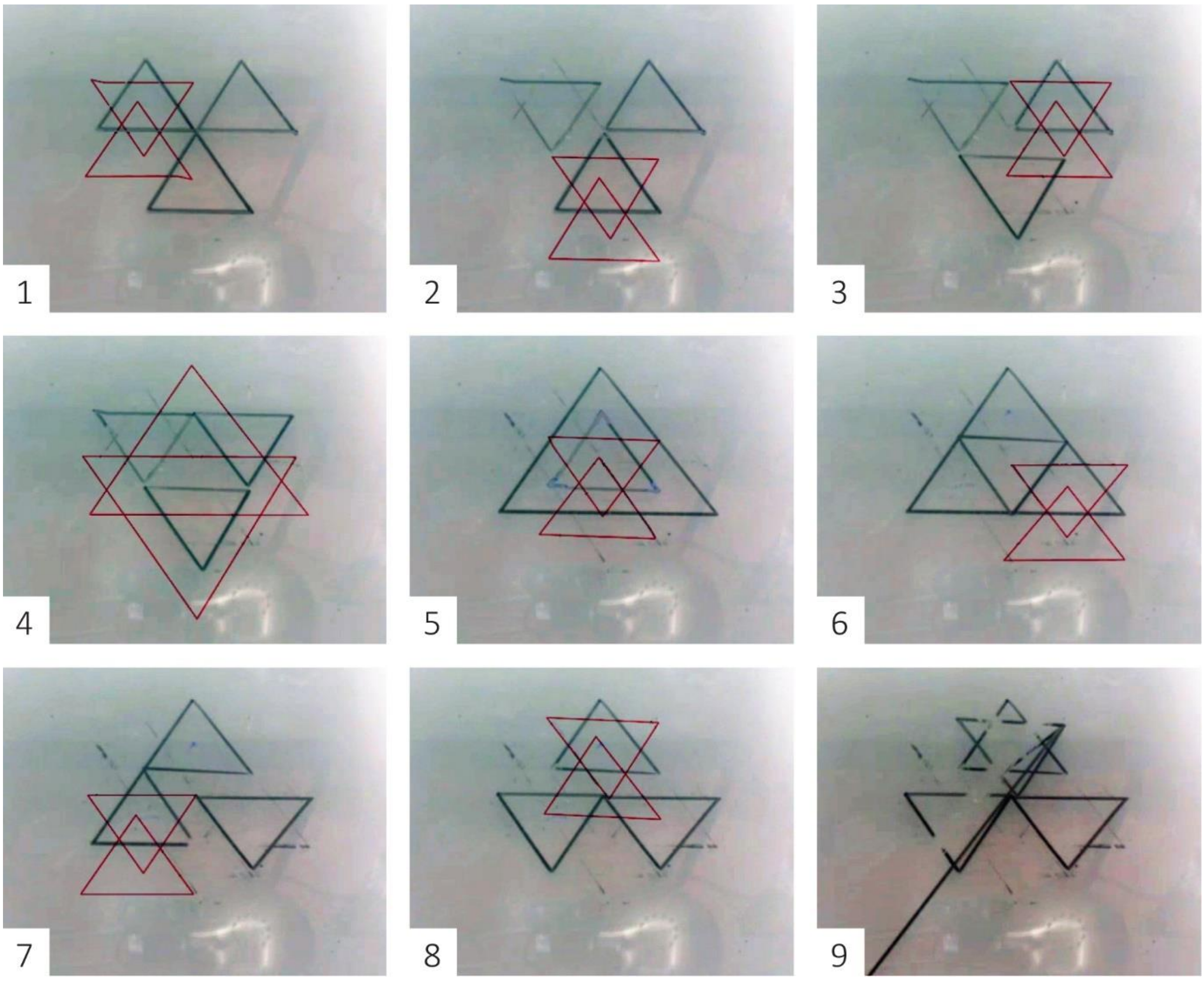

Figure 12. Drawing sequence using the triangle rotation rule in Figure 1. In each image, the lower red shape is the shape to erase (the offset is due to the physical separation between the pen and the eraser), and the upper red shape is the shape to draw. The drawing sequence largely follows the same progression as Figure 11.

In a subsequent drawing, the machine was supplied solely with the triangle rotation drawing rule in Figure 1. Due to a slight misalignment of the eraser, the machine repeatedly failed to fully get rid of the triangles it was trying to erase (Figure 13, [1-2]). Once again, the machine took these residual marks in stride. The lines resulted in additional, small triangles appearing in the drawing, and the machine repeatedly chose these accidental shapes as its targets for new drawing rule applications [3-4].

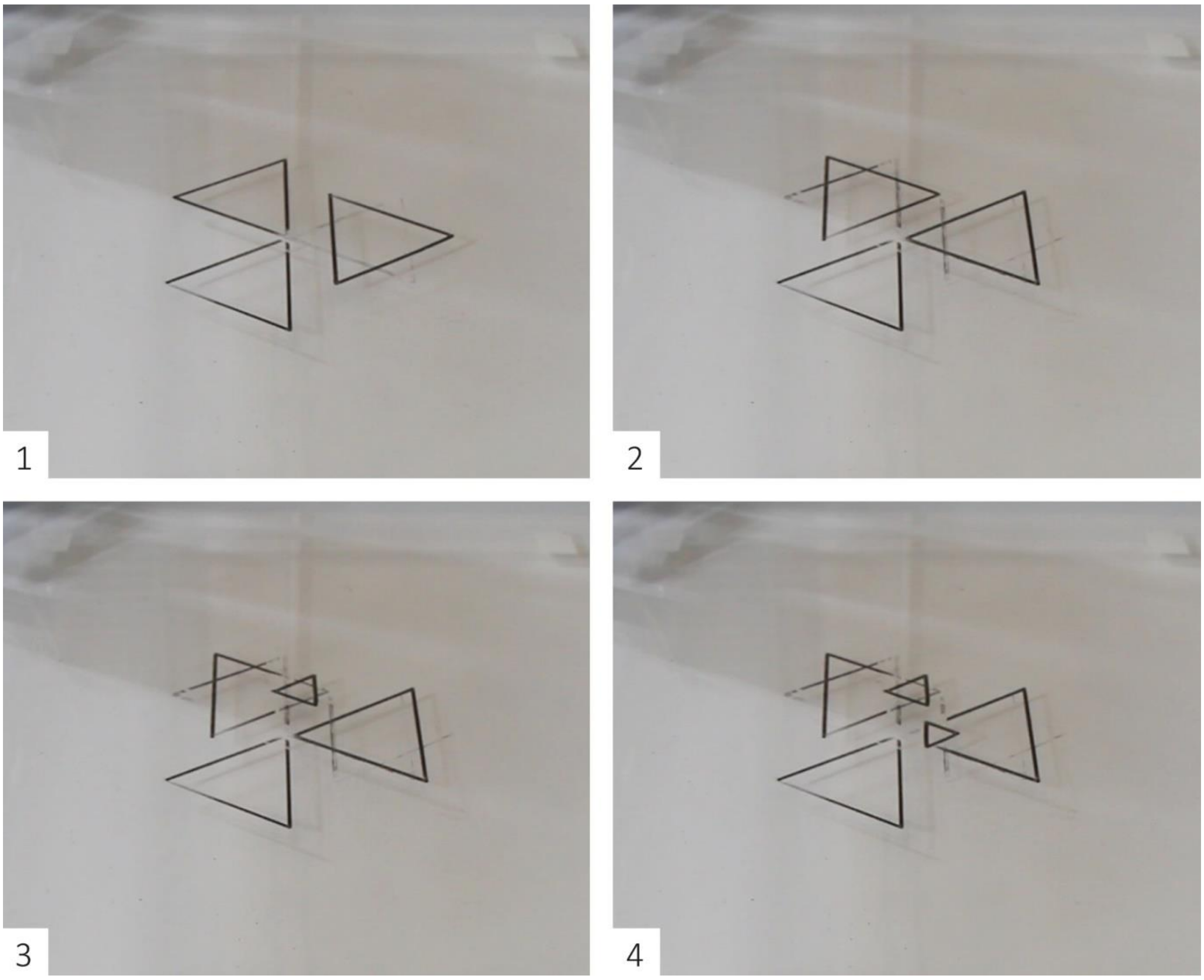

Figure 13. Drawing sequence using the same triangle rotation rule as in Figure 1. The rough application of the eraser results in residual lines [1-2]. The machine incorporates these residual lines and extracts new triangles to operate on [3-4].

5 Conclusion

This machine is a proof-of-concept of the proposed computational play framework. It demonstrates an autonomous, playfully creative drawing process that is multimodal, generative, iterative, and autotelic. In early drawing experiments, the physical setup of the machine resulted in messy drawings that did not reflect the possibility space projected by the idealized computational process. While these outcomes could be written off as mistakes, I contend that it is more important for us to consider the opportunities they open up. As the machine began to make errors, I found myself moving to correct the process. It is that very reflexive action, however, that must often be stymied in order to make use of productive failure and discover novel opportunities. Where I might have quit the drawing process, the machine didn't; in fact, it handily incorporated the leftover lines, resulting in unpredictable drawings (Figure 14). This open-ended pursuit of emergent values begins to approximate aspects of the design process that can be difficult to model.

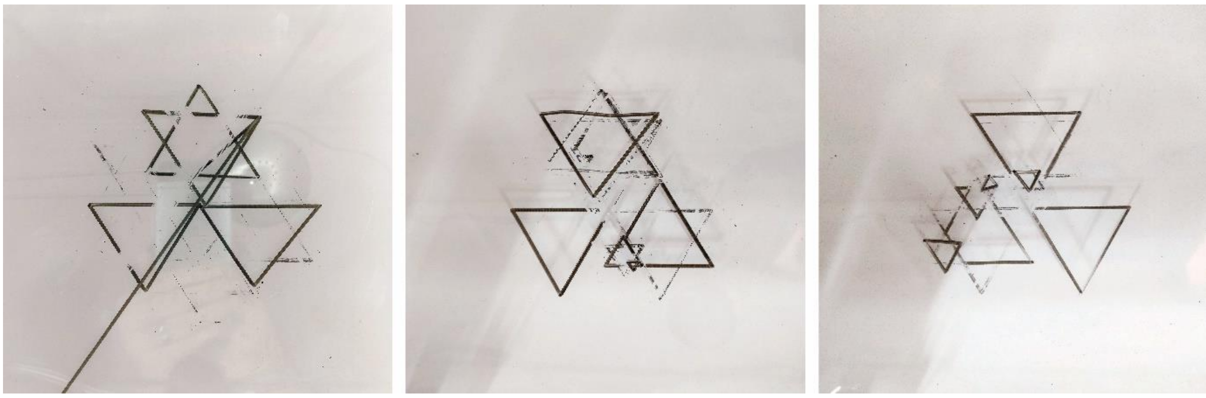

Figure 14. Initial drawings produced by the machine.

With the invention of Sketchpad, Ivan Sutherland highlighted the usefulness of the digital drawing's inherent geometrical structure. He compared this to the unstructured "dirty marks on paper" (or, in this case, acrylic) made by the analogue draftsman (Sutherland, 1975, p. 75). It is perhaps just such a lack of structure that has proven to be invaluable to the fast-paced, creative environment of design. The fact that sketching is still central to design indicates that a drawing's true value is not always in its accuracy of representation, but rather in its ability to be *reinterpreted*. Drawing enables the designer to shed the weight of an idea such that he or she might shoulder a new concept; in fact, designers sometimes draw in order to see new things. Drawings are "not merely a static medium for externalizing internal visions, but rather a physical environment from which ideas are generated on the fly" (Suwa & Tversky, 2002, p. 342).

The machine is meant to provoke discussion as much as it is meant to provide useful technical insight. As computation and creative design become increasingly entwined, it will be imperative to consider how we model creativity. The act of drawing, as a method for designers to reinterpret their design concepts, encourages open-ended exploration through playful engagement with possibilities. Drawing enables the design process to be truly multimodal and provides a rich field of inquiry for autonomous, creative computational processes.

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Section 14.

Experiential Knowledge

DRS 2018 Design Research Society 2018 Catalyst

University of Limerick
25th–28th June 2018

Editorial: Experiential Knowledge in Collaborative Interdisciplinary Design Research

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1 Introduction: Collaboration and experiential knowledge

Design practice has transformed from one based on the production of artefacts to one that engages expertise and knowledge from multiple disciplines. Collaboration between stakeholders has become indispensible, and research has played a crucial role in exploring the changing territorial context of designing and making (Nimkulrat & Matthews, 2017; Bowen et al., 2016). This is particularly evident in the fields of New Materials, Smart Textiles and Human-Computer-Interaction (HCI), where research tends to be conducted in teams comprising different disciplinary experts who may work across academic, commercial and public sectors, and may include designers alongside, for example, scientists, technologists, artists, business strategists and policy makers (e.g. Bhömer et al., 2012). Various partners are in dialogue with one another, developing, consolidating and enhancing knowledge while generating new opportunities for interdisciplinary knowledge exchange.

Experiential knowledge, as knowledge gained by experience, signifies ways of knowing and understanding things and events through direct engagement with people and environments (Niedderer, 2007). The DRS Special Interest Group on Experiential Knowledge (EKSIG) since its establishment in 2007 has focused on experiential knowledge, thinking and knowing at the core of design practice. It attempts to illuminate how a design process conducted in a research context begins and ends in the domain of experience, which is in turn changed by design.

At the *DRS 2018: Design as Catalyst*, the EKSIG track aims to examine collaboration within design research teams that comprise members with diverse disciplinary expertise. This is to understand: 1) how individual experiential knowledge, or knowledge gained by practice, is shared; 2) how collective experiential knowledge is accumulated and communicated in and through collaboration; and 3) how it is embodied in the outputs and may be traced back to the origin of the practice. The track also aims to illuminate the act of making as the action of change in which matter and materials are transformed through collaboration, interaction or negotiation between the collaborative team and their material environment. Collaborative making and knowledge creation occur in multiple forms, on many levels and in different contexts and, through the act of making, meaning is made, communicated and shared (Ingold, 2013). This collaborative learning is a process of exchange where existing knowledge and experience of a certain topic is reviewed, added or transformed. The track explores how learning is transferred and articulated within multidisciplinary teams. Starting with an understanding of making and collaborative learning, it discusses how we can create a greater awareness of our responsibilities as designers, researchers, consumers, teachers and members of society.

2 EKSIG track: Selected papers

In response to the EKSIG track call, international researchers and practitioners, whose work is centered on the experiential knowledge of collaborative work in interdisciplinary projects, submitted their papers that describe and discuss cases studies regarding collaboration in design and design research practices. We received 19 paper submissions from 12 countries, including Australia, Canada, China, Denmark, Finland, India, Norway, the Netherlands, Sweden, Turkey, UK and USA. After the double-blind peer review by the panel of 34 international reviewers, nine papers were selected for presentation at the DRS 2018.

The selected papers exemplify interdisciplinary collaboration or the sharing of expertise through various worked examples. Many of the selected papers touch upon the sharing of expertise between stakeholders in different contexts. The sharing and combining of expertise are generally reflected on in positive wordings, especially highlighting the widening of perspectives and the added insights in all participating domains. However, a number of challenges are emphasized, for example, the communication of experiential knowledge and the utilization of the added value of the collaboration in a meaningful way.

The first paper, ‘Transdisciplinary PhDs in the making disciplines’ by Anne Solberg, discusses doctoral research in art and design. Solberg highlights the benefits of multi- and interdisciplinary projects in research in that they encourage the sharing of the research process and findings to a larger audience. Nevertheless, she finds that support from each specific discipline is important in such collaborative processes in order to maintain expertise and in-depth knowledge on the subject . The next paper, ‘The future of heuristic fossils’ by Simon T. Downs and Claire A. Lerpiniere, presents a critical view on the use or idea of design methods/design thinking, as these leave several contexts of design uncovered. For example, the tacit areas of ‘crafts’ practice, which require different kind of iterations and are not typically reflected in a design thinking manner, do not readily fit within the model of ‘Discover > Define > Develop > Deliver’ mainly developed for industrial design domains. Yubo Kou and Colin Gray discuss the different aspects of communication of design related knowledge in their paper entitled ‘Distinctions between the communication of experiential and academic design knowledge: A linguistic analysis’. As communication between stakeholders often happens between peers online, it is interesting to see how experiential knowledge communicated virtually differs from that communicated in design practice and in academic contexts. Kou and Gray present a mixed-method analysis, comparing ways in which experiential design knowledge is communicated in two online practitioner-oriented venues and two leading design research journals. Unsurprisingly, they found that the articulation of experiential academic knowledge differs in many ways in these two contexts, and in their analysis they let us know how these contribute to the construction of design knowledge.

The next three contributions all engage in the study of designer’s collaboration with craftsmen, highlighting different aspects in these engagements. The paper ‘One over, one under: A dialogue between design and craft’ by Can Altay and Gizem Öz looks into the practice of basket weaving in Turkey. The student project described in the paper aimed to intervene in traditional process of basket weaving by utilizing methods of digital manufacturing and, as a result, ‘clashing the craftspeople’s traditional methods of making and the new technologies that the designer is proficient in’. Intentions of sharing knowledge through making together and learning from the inside worked both ways as the designer learned craft skills and the craftsmen were introduced to 3D manufacturing methods. Similarly, design and craft practices are shared in Michael Nitsche’s and Clement Zheng’s paper ‘Combining practices in craft and design’. Based on a case study describing an interaction designer and a ceramic craftsperson consolidating their expertise in the creation of an interactive lamp, the paper discusses models of collaboration on a theoretical level. Nitsche and Zheng offers a collaboration model that builds on distinct expertise, evolves through a design-based brief, and is realized through a shared dialectic object. In the following paper 'Co-creation in professional craft practice' by Camilla Groth and Arild Berg, designers process of outsourcing the making of their designs to craftspersons are problematized. Issues of authorship and trust, together with the role of experiential knowledge and the communication of design restrictions, are vented. A tradition that is as long as design history is about to change due to the development of notions of co-creation and cultures of interdisciplinary collaboration.

Sucharita Beniwal describes a communal design practice that is shared between members of the community, perhaps unpronounced but certainly global, in her paper 'Embodied knowledge in a community adaptive practice'. The described case study takes us to a market place in India where load-bearers design and make their own tools for carrying heavy loads on their backs. Beniwal argues for the collective body of experiential knowing that is a form of open-authorship in which any user-maker can try new iterations. 'Designers emotions in the design process' by Monica Biagioli, Silvia Grimaldi and Hena Ali is a newly found initiative for investigating designers' emotions, especially as part of their decision-making processes. The authors aim to start a focused discussion network across geographies and cultures, the function of which is to foreground the experiential and emotional domain of designers' practice. As the paper describes a future endeavour, the intended outputs will be: an index of emotional and experiential aspects; a cross-referencing of those with cross-cultural elements; and an index of qualitative methods examined within the framework of emotion, experience, and culture. The last contribution to the EKSIG track, 'Understanding the evaluation of new products through a dual-process perspective' by Anders Haug, is likewise looking in to human aspects of decision-making in design, namely the evaluation of new products. The gap between what the designer designs and what consumers like needs to be narrower, whereas the understanding of how consumers evaluate new products needs to improve. He studies the problem through interviews of 12 designers of consumer products and identifies 24 distinct types of pitfalls for new product designs.

The selected nine papers build a rich collection of case studies that potentially contribute to a more systematic approach for studying and integrating experiential knowledge into design practice and research. The papers focus on peer-level collaboration, illuminating its usefulness for the partners involved, and highlight the relationships built within the collaboration, as well as the approaches used and the new knowledge gained and transferred within the team.

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Transdisciplinary Doctorates in the Making Disciplines

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This article is a discussion on interdisciplinarity and transdisciplinarity in doctoral works in *the making disciplines*, which include art, design, architecture and affiliated areas. The article includes examples from nine doctoral theses in the making disciplines that are the objects of investigation in the doctoral thesis of the author. This article holds that while interdisciplinary approaches contribute to sharing knowledge and have the potential to communicate research outputs to a broader audience, transdisciplinarity has an even wider scope of knowledge sharing. Hence, inter- and transdisciplinarity are catalysts, by the crossing of discipline borders, that allow knowledge and understanding to be transmitted. However, disciplinary and field-specific research is required for in-depth knowledge building.

Interdisciplinarity; transdisciplinarity; the making disciplines; doctoral theses

1 Introduction

At present, there is a strong demand for specialist competences within academia, as imposed by, e.g., the EU Services Directive (2006/123/EC, 2006). Interdisciplinarity counterbalances this specialisation. Large and complex research projects are an increasing international trend, needed to meet major problem areas in society, and complex research requires combinations of expertise inside or even outside the academy.

This article is a discussion of the contribution of interdisciplinarity in research within the so-called *making disciplines*, which include art, design, architecture and affiliated areas. For this purpose, I use as examples nine doctoral theses that I have analysed as a part of my doctoral work (Solberg, 2017). All the theses entail a creative practice component with various roles in the doctoral work. They were chosen from within the European Higher Education Area, which is the topic of my PhD project.

The following is a brief description of the major concepts used in the article. Then I discuss the roles inter- and transdisciplinarity have had in the nine theses.

2 Academic Disciplines and the Making Disciplines

Leonardo da Vinci worked as an artist and an architect, even dealing with technical inventions, thus representing the Renaissance humanist ideal. He was a fifteenth-century polymath, but he was not *interdisciplinary* in our sense of the term, because the concept of academic disciplines was not yet established. Neither were art and architecture included in the academy. This was the era of guilds, though art academies emerged in the following years. Academic *disciplines* in our sense of the term were not established until the nineteenth century. In this article, I use the term *disciplines* in the sense of *academic discipline*s, entities that are based on academic fields of study. Sharon Parry said:

> *Disciplines are abstract entities, with a heterogeneous international population, and they are identified as being the intellectual society to which the doctoral student aspires. … it is the discipline and its norms that are of the most importance and value to doctoral students. For this reason, the discipline is identified as being the intellectual society to which the doctoral student aspires. (Parry, 2007, p. 23)*

This reflects that the doctoral thesis is an indicator of disciplinary competence and that it is examined, except in rare cases, by scholars drawn from the international disciplinary arena. From a sociological perspective, Foucault described disciplines as "groups of objects, methods, their corpus of propositions considered to be true, the interplay of rules and definitions, of techniques and tools" (Foucault, 1972, p. 222).

In this respect, there is a distinction between discipline and *profession*. While the profession concerns knowledge for current professional practice, the academic discipline allows study that is external to current practice (Andersson, 2001, p. 295). This means that the scope of the discipline is wider than that of the profession while at the same time potentially less dedicated to the professional practice. The distinction between profession and discipline represents a dichotomy embodied in a number of fields: the need to be accepted as academic disciplines versus the need to remain relevant to the practice field. This is also true for the so-called *making disciplines*, a traditional Nordic designation for the fields of art production, object design, industrial design, architecture, landscape architecture, urban design and spatial planning (Dunin-Woyseth & Michl, 2001, p. 1). In order to clarify this concept, Dunin-Woyseth said:

> *A Scandinavian concept of the making disciplines has been an attempt to formulate a kind of quality supportive framework for making discourse rather than of a sensu stricto traditional discipline. (Dunin-Woyseth, 2009, p. 9)*

By this statement, Dunin-Woyseth, to a certain degree, modified the *discipline* aspect, underscoring that even if called disciplines, the making disciplines are not academic disciplines in a conventional understanding of the term. Inherent in this clarification is an ongoing debate on what constitutes an academic discipline. The way I see it, *the making disciplines* is a fortunate concept because of the *making* aspect, the action orientation, the approach of producing things. This reflects the link to practice, being part of a creative, productive community. At the same time, this is combined with the term *discipline*, as I see it, primarily referring to an *academic discipline*. Even though I am aware of a debatable conflict embodied in this term, I use *the making disciplines* in a way that includes *academic discipline*. Of note is the plural form, which indicates that this is more than one discipline; the *making disciplines* is a multi-disciplinary concept.

In the process of defining the position of the making disciplines in the academy, one may search for their domicile within the broad domains of natural and social sciences and the humanities. In a study of Swedish doctoral theses in architecture, Biggs and Büchler defined three main cultures of knowledge: Human and the Humanities, Natural and Technology and Applied and Social. They found that the architectural theses were distributed among all of them and, for the most part, each thesis tended to belong to more than one culture of knowledge. However, they also identified one component that could not fully be positioned in any of these. This was the *creative practice component*.

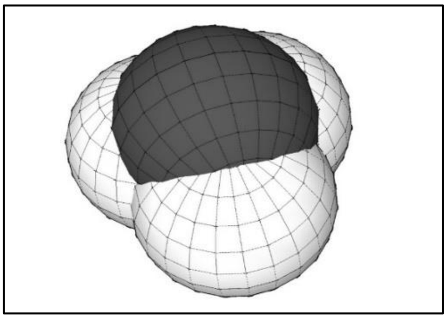


Figure 1 Illustration of the architectural theses and three main cultures of knowledge. The dark globe, partly within and partly outside the other three, represents the creative practice component (Biggs & Büchler, 2011b p. 70).

Hence, the making disciplines is a multi-disciplinary concept that, in respect to its creative practice component, may be regarded as exceeding the broad academic domains.

3 Interdisciplinarity and Transdisciplinarity

A number of terms are used for the crossover and interaction between different disciplines in academic enterprises. In the following, I use the terms *interdisciplinarity* and *transdisciplinarity*.

Interdisciplinarity is "a means to share disciplinary knowledge in order to create new concepts and theories, create a product to solve specific problems" (Forty et al., 2006, p. 42), or "…the connecting of contribution from several disciplines, directed towards elucidating a common meta-level problem complex" (Dunin-Woyseth, 2009, p. 65). Hence, interdisciplinary projects cross the borders of disciplines and tend to have problem-solving objectives.

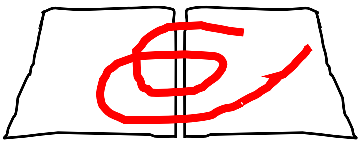


Figure 2 Interdisciplinarity. Interaction between disciplines

The concept of ***transdisciplinarity*** has been increasingly discussed in recent years as a designation for enterprises that not only transgress the borders of disciplines but even the borders of the academy, including a broader scope of competences.

> *…transdisciplinary contributions involve a fusion of disciplinary knowledge with the know-how of lay-people that creates a new hybrid that is different from any specific constituent part.*

Transdisciplinarity is not a process that follows automatically from the bringing together of people from different disciplines or professions but requires an ingredient that some have called "transcendence". It also implies the giving up of sovereignty over knowledge, the generation of new insight and knowledge by collaboration, and the capacity to consider the know-how of professionals and lay-people on equal terms. (Forty et al., 2006, p. 32)

Thus, following Forty's definition, transdisciplinarity is not only an approach for exceeding the borders of the academy but should also include a way of *transcience* that has consequences for the very concept of knowledge, as well as the acceptance within the academy of knowledge from non-academics and lay-men.

I have used this understanding of transdisciplinarity in my analysis of the theses. This means that I looked for possible exceeding of academic disciplines and also for the way multiple disciplines were interacting within the projects.

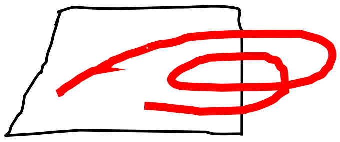


Figure 3 Transcending the academic disciplines

4 Transdisciplinarity and Mode 2 Knowledge Production

Transdisciplinarity is a key component of Mode 2 knowledge production, characterised by Gibbons et al. as knowledge which emerges from a particular context of application with its own distinct theoretical structures, research methods and modes of practice, but which may not be locatable on the prevailing disciplinary map (Gibbons et al., 1994). The following definitions clarify their agenda:

> *Mode 1: The complex of ideas, methods, values and norms that has grown up to control the diffusion of the Newtonian model of science to more and more fields of enquiry and ensure its compliance with what is considered sound scientific practice.*
>
> *Mode 2: Knowledge production carried out in the context of application and marked by its: transdisciplinarity; heterogeneity; organisational heterarchy and transcience; social accountability and reflexivity; and quality control which emphasises context- and use- dependence. Results from the parallel expansion of knowledge producers and users in society. (Gibbons et al., 1994, p. 167)*

Hence, transdisciplinarity is included in the definition of Mode 2 knowledge production by Gibbons et al. A number of scholars endorse Mode 2 as particularly appropriate to the making disciplines (Biggs & Büchler, 2011; Doucet & Janssens, 2011; Dunin-Woyseth & Nilsson, 2011; Schwab & Borgdorff, 2014). Schwab and Borgdorff even regarded art as the most extreme case of Mode 2 knowledge production. In 2011, Dunin-Woyseth and Nilsson argued that while knowledge production by transdisciplinarity and creative practice had been regarded as an extreme position, a more inclusive model of research had been developing in the last decade so that these approaches were on the way to achieving academic recognition as well as gaining the interest of practitioners (Dunin-Woyseth & Nilsson, 2011, p. 92). Discussing *post-academic science,* Ziman regarded Mode 2 knowledge production as having some post-modern features that, in his view, are much needed corrections to what he called an excess of "scientism", and it also helps to rescue the scientific imagination from entrenched specialisation (Ziman, 2000, p. 329).

On the other hand, Helga Nowotny, who was one of the authors of the 1994 book (Gibbons et al., 1994), said in 2001 that Mode 2 had been criticised for being simplistic or banal, though the book struck a chord of recognition among both researchers and policy-makers. Nowotny observed that those with the most to gain from the thesis of Mode 2 knowledge production accepted it the most warmly. These included researchers in professional disciplines such as management, who were struggling for acceptance by the more established and more "academic", disciplines; as well as researchers in newer universities, other non-university higher-education institutions, or outside the strictly defined academic and scientific systems.

While looking for inter- and transdisciplinarity in the nine theses of my doctoral project, I was well aware of a close relationship between these and Mode 2 knowledge production.

5 Nine Doctoral Theses

Figure 4 The nine doctoral theses

The nine doctoral theses that are presented in this article (Solberg, 2017) all have a component of creative practice as an essential part of their research projects, though with various roles. In most of the projects, this component is included in the research output. The theses were chosen in order to expose this diversity. When my PhD project was initiated, the number of theses in which the creative practice part had a pivotal, decisive role was restricted. Therefore, the theses in this analysis are not representative of a larger number. For my further research, there will be more theses available. The theses in this project have been accepted in recent years by four higher education institutions in four countries: KU Leuven in Belgium, Aalto University in Finland, the University of Gothenburg in Sweden and Oslo School of Architecture and Design in Norway. These countries represent different traditions within the European Higher Education Area (EHEA), which was the geographical area of my doctoral work. The theses are all from the making disciplines – in principle, three from architecture, three from design and three from the field of art – though there are various combinations of these disciplines within the projects.

The analysis includes issues of purpose and the results of the research projects, as well as the research methods and strategies used, one of which is the aspect of inter- and transdisciplinarity that is the topic of this article. The theses were analysed as academic texts. There have been no interviews. The theses are publicly available documents, but the authors have been asked permission for presenting images from their theses.

During this analysis, three categories emerged: first, projects with collaborative working groups; second, projects with two interacting disciplines; and third, projects with what I choose to call “multifaceted monodisciplinarity”. In the following, the theses are organised according to these categories.

6 Collaborative Working Groups

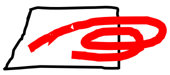
6.1 Otto von Busch

Fashion-able. Hacktivism and Engaged Fashion Design (von Busch, 2008)
University of Gothenburg. PhD

Figure 5 From the Hackers and Haute Couture Heretics workshop, Istanbul
Figure 6 Redesigned denim from the Swap-O-Rama, Istanbul, 2007
Figure 7 The Swap-O-Rama catwalk. Photo: Von Busch. Source: von Busch (2008)

von Busch is a designer within the field of textile and fashion. His doctoral project included a number of workshops with the purpose of designing and making clothes. The workshops comprised combinations of professional designers and non-professional participants. In some of the workshops, there were mostly or even solely non-professionals. The researcher arranged the workshops. The objective of von Busch's doctoral project was a contribution to turning fashion upside down, allowing non-professional participants to make their own garments and to learn from designers and from each other. He had an activist approach, as in *hacktivism*, and deliberately included people of different backgrounds, rich and poor, professionals and lay-men, in his workshops. In his words, this inspired and motivated the participants, and the products of their creativity became a spur for continuing to work with their new ideas after the workshops. von Busch regarded the workshops as vehicles for self-enhancement and for the reinterpretation of what he described as the top-down fashion myth (von Busch, 2008, p. 135). Thus, the workshops were materialisations of the ideas of the project, and they were crucial for the research project. The concept of using participatory working groups from within and outside the academy to conduct the research made this a transdisciplinary project.

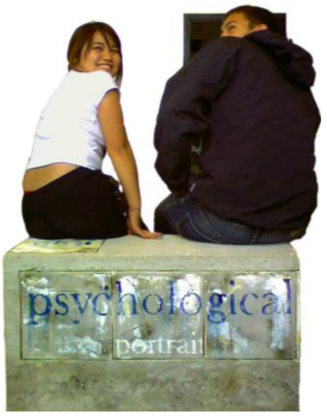
The contribution of transdisciplinarity in this project was the inclusion of lay-men and non-academic expertise in the workshops, which was the very core of this project, aiming at contributing to turning the fashion industry upside down. Collaboration between professionals and lay-men demanded that the professionals share their expertise and popularise their language in order to communicate to the working groups. This gave the non-professional participants the ability to learn from the professionals, trigging their creativity and developing their self-esteem. However, this also meant that the expertise of professional designers was tuned down in these projects, potentially causing them to crave respect for their artistic professionalism and design quality.



A transdisciplinary project. Collaborative working groups including lay-men and non-academic expertise

6.2 *Arild Berg*

Artistic Research in Public Space. Participation in Material-based Art (Berg, 2014)
Dr. of Art, Aalto University



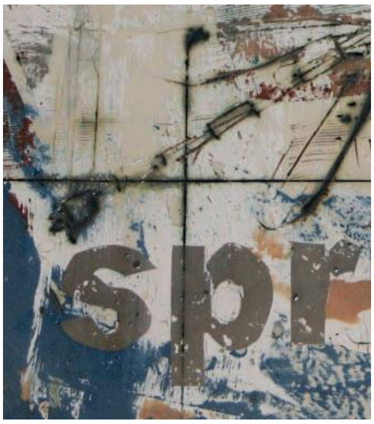
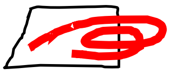


Figure 8 and 9 From the art project in the school.
Figure 10 Sketching for the resting-room in the church. Photo: Berg. Source: Berg (2014)

Arild Berg is an artist in the field of ceramics, in his terms, a "material-based art". His doctoral project included artwork in three public buildings in Norway: a school, a hospital and a church. In these art projects, Berg collaborated with participatory working groups in which he was the professional, performing artist. There were working groups for each of the three projects. Participants were users and resource persons of the institutions in question. The working groups participated in the making of the artwork, both in planning and in material experiments. Berg underscored the importance of the acceptance of the artwork by the people who were using the buildings, and, in this setting, he regarded the artwork as a transformative social force. As a result of these projects, he found that, to some extent, the art created a new sensory presence: it was a materialisation of the identity of the people on site.

The collaborative working groups were crucial to this research project. The artist-researcher gathered information from a combination of professionals and non-professionals from inside and outside the academy, which is a transdisciplinary approach. The collaborative working groups, including the users of the buildings, secured the relevance of the artwork. They contributed to the acceptance and understanding of the artworks by the users of the buildings. By including the working groups in the process of making the art, the artist was able to make his artwork communicative. In the working process, the artist had to share his knowledge by communicating to lay-men and professionals of other disciplines. This required popularising his language and making sketches and suggestions that were understandable to the members of the group. As I see it, this is of relevance to the problematic *insider's perspective* of the artist-researcher. By communicating to the working group and including the members in the decision process, the artist-researcher allowed other perspectives on the process and, thus, took a step outside his insider's perspective. However, this "democratic" process of artistic expression may lead to artwork that is predictable and safe. Securing the acceptance of the artwork by the users of the public spaces in question meant avoiding provocative artwork. The collaborative working process – the inclusion of the participants of the working group into the decision-making – may weaken artistic freedom and narrow the scope of opportunities for the artist.



A transdisciplinary project. Collaborative working groups including lay-men and non-academic expertise

6.3 *Thierry Lagrange*

Look Here Now. Mapping Design Trajectories (Lagrange, 2012)
PhD, K.U. Leuven

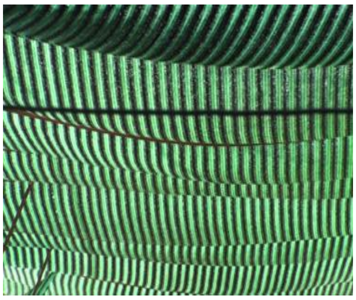
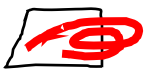


Figure 11 From Matrix Method workshop with students. Photo: Lagrange
Figure 12 Hybrid Seoul
Figure 13 Hybrid Mont Blanc. Stills from videoworks: Lagrange. Source: Lagrange (2012)

Lagrange is an architect who also works with photography. In the first phase of his PhD project, he used photography and video as tools for the act of *looking*, focusing on architecture and landscapes. Photography was a working tool for this research project. The two disciplines of architecture and photography were interrelated and intertwined, though with different roles in the project. This integration of two disciplines represents an interdisciplinary approach that also, because of the different roles of the disciplines, may have transdisciplinary aspects. However, over time, the project developed from an initial exploration phase of combining photographs and text into a matrix system to an enterprise of using these components as a method for generating ideas and creativity: the Matrix Method. This process included workshops with architect students and working groups from various other milieux. The researcher used these working groups for developing the Matrix Method, which was a result of his doctoral research project. As I see it, this constitutes a distinct transdisciplinary approach.

The interdisciplinary approach of this project exposed a close relation between two making disciplines, architecture and photography, and the way they can interact in a research project. The workshops communicated this to the members of the working groups, who shared the potential of idea generation and creativity embedded in these disciplines. At the same time, the qualifications of members from other fields contributed to this concept. Hence, the transdisciplinary approach constitutes communication across and outside the academic disciplines in a reciprocal way. However, from a disciplinary point of view, one may ask where this research project belongs, whether it was a project within the field of architecture and the broader field of the making disciplines, or whether transdisciplinarity took over, making this project leave its original academic basis.



An interdisciplinary project: The researcher is working within two making disciplines
A transdisciplinary project. Collaborative working groups from various fields including lay-men and non-academic expertise

7 Two Interacting Disciplines

7.1 Arnaud Hendrickx

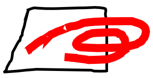
Substantiating Displacement (Hendrickx, 2012)
PhD, K.U. Leuven



Figure 14 and 15: From art project 1: ProMotion. Arnaud Hendrickx and Gabriël Lester
Figure 16: From the exhibition of seven artefacts. Photo: Arnaud Hendrickx Source: Hendrickx (2012)

Hendricks is an architect who, in his PhD project, collaborated with artists on a number of exhibitions and performances. There was one collaborating artist in each project. The artist and architect both contributed with their professional expertise. The results of the projects reflected both and might be fruitful to both. Hence, this combination of architecture and art tends to constitute an interdisciplinary project. However, Hendrickx regarded this as a Mode 2 project, which suggests a transdisciplinary approach. This distinction must be sought in the design of the research project. The topic of investigation was the personal development of the researcher as an architect. The art projects related to this investigation. In these projects, the artist was moving out of his comfort zone, from the field of architecture to the field of art, which was foreign to him. The *art* projects were collaborations between him and the artists, while Hendrickx was the one that conducted the *research* project. For the purpose of his own investigation, he sought assistance from professionals from another discipline. This feature approximates the concept of transdisciplinarity. I find Hendrickx's suggestion reasonable; this was a research project with Mode 2 characteristics.

The major contribution of transdisciplinarity in this project was the opening of architecture for the artist and of art for the architect. The two participants shared expertise. In order to achieve this, they had to communicate in the other's premises, use language and actions that were understandable for each other and concentrate on understanding the approaches of the other participant. Beyond this, what was the role of the artists in these projects? Hendrickx called them *mediators.* Were the artists and the architect-researcher co-operating on equal terms? Or did the concept of transdisciplinarity encompass a potential bias, one discipline assisting the other? In these projects, the architect was the researcher, and the works of the researcher were the topic of investigation. This is what made this an interdisciplinary project. At the same time, this included a certain bias between participants in the project when it came to the research aspect.



A transdisciplinary research project: The researcher seeking expertise from another making discipline. Interaction from the two in order to obtain new knowledge.

7.2 Arne Magnus Johnsrø*d*

Microbial Patination of Copper and Brass (Johnsrød, 2009)
PhD, Oslo School of Architecture and Design

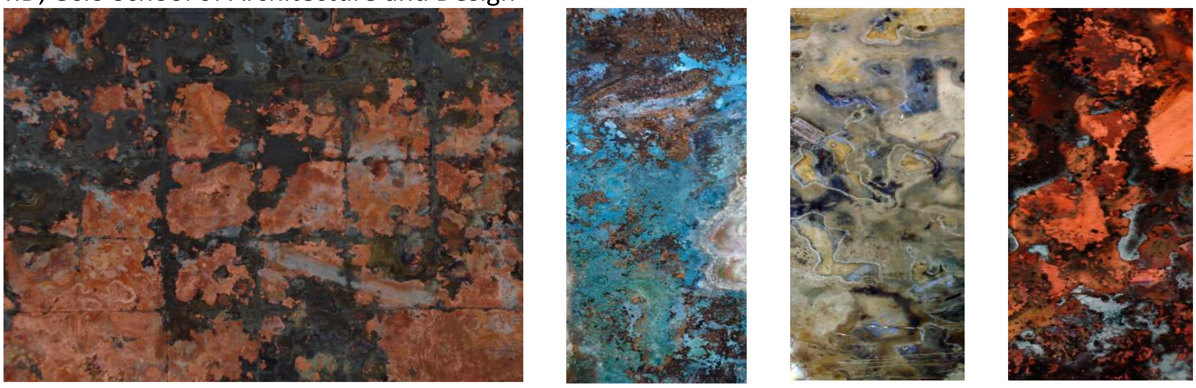
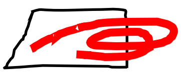


*Figure 17, 18 and 19: Microbial patination of metal sheets. Bacterial cultures on test samples, copper and brass sheets. The left sample is 3*5 cm. Photo: Johnsrød. Source: Johnsrød (2009)*

Johnsrød's project was within the fields of metalworks and biology, a collaboration between himself as a designer and artist and experts from the field of biology. The project is an example of applied research; the purpose was to create biological patination methods for artists' metal corpus work. As an artist, Johnsrød had seen the need for research on this issue. He contacted experts in biology at the University of Life Sciences, who joined him in the development of a research project. Johnsrød then conducted the experiments needed, using the research methods of biology throughout. Thus, the project was a combination of disciplines of substantial distance from each other. It included qualified scholars on both sides; therefore, one may characterise this as an interdisciplinary enterprise. However, again there is the question of the role of the disciplines. In this project, a researcher from one discipline needed expertise from another discipline. The researcher transcended his own discipline in order to obtain the expertise needed for his own project. This tends to be a transdisciplinary approach. It also has characteristics of Mode 2 knowledge production, by the context of application and its position that does not fit into the prevailing disciplinary map. As I see it, this is also an example of engaging in an informed dialogue with an academic discipline, which Dunin-Woyseth recommended for the making disciplines (Dunin-Woyseth, 2009, p. 9).

In collaboration between projects from distant academic disciplines, the need to make oneself understood by the other participant is crucial and a particular challenge to the communication of academic expertise. The project opened the field of art to biologists and vice versa. Though, even if this was a project for artists, supplying artists' needs for new patination methods, the research project as such was conducted within the field of biology. One may ask whether this was not actually a research project in biology, even if artists may benefit from the results.



A transdisciplinary project. Seeking expertise from another discipline. Collaboration between experts from distant disciplines

7.3 *Janne Reitan*

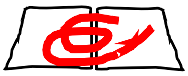
Improvisation in Tradition: A Study of Contemporary Vernacular Clothing Design Practiced by Iñupiaq Women of Kaktovik, North Alaska (Reitan, 2007)
PhD, Oslo School of Architecture and Design

Figure 20, 21, 22: Making Iñupiaq clothing. Video stills: Reitan. Source: Reitan (2007)

Janne Reitan is a textile designer and a teacher educator. The topic of her doctoral work was the making of vernacular clothing by women in Kaktovik, Alaska, as well as how this making process is learned. In her research project, she made the same kind of garments herself, using her qualifications as a textile designer, which she regarded as crucial to her investigation.

The setting was the everyday working process, the seamstresses making garments the way they use to. Reitan participated in their work, learning and performing the art of making the traditional garments. She took the role of a participating observer. Therefore, this was not a collaborative working group arranged by the researcher, as in the projects of von Busch, Berg and Lagrange, and did not have the same features of transdisciplinarity. However, Reitan had two perspectives in her investigation: investigating both the vernacular design process *and* the learning process. Thus, this project entailed the twin competences of textile design and pedagogy. The research questions of her project included both perspectives, and both were entailed in the research result. Because of this combination of two disciplines, I regard this an *interdisciplinary* project, even if both disciplines are embodied in the same researcher, a *two-in-one researcher*.

The contribution of interdisciplinarity in this project was exactly this combined investigation of design making and design learning. Both were processes scarcely known outside the community of seamstresses in Kaktovik. Thus, this interdisciplinary approach contributed to making the tacit knowledge of this design process known to outsiders. This also goes for the way this tradition was transferred. Reitan, herself one of the learners, contributed to distributing this knowledge by her combination of designing and pedagogy. However, this double and interdisciplinary research approach may also imply a lack of depth in both aspects, since they were both to be embodied in one PhD project.



An interdisciplinary project: The researcher is combining two disciplines

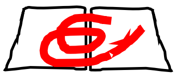
7.4 Pavlina Lucas

The Photographic Absolute: An Architectural Beginning (Lucas, 2013)
PhD, Oslo School of Architecture and Design

Figure 23. 24: Images from Logbook. Photo: Lucas. Source: Lucas (2013)

The doctoral work of Pavlina Lucas was in a crossover field of architecture and art. Lucas has a professional background in both. Her research project was propelled by her wish to introduce intuition at the outset of the creative process towards an architecture and was based on the proposition that photographic practice opens a way to disclose intuitive insights that can be brought into the production of spatial experience. In this respect, the art of photography was a vehicle for obtaining better architectural practice. Further, the photographs were included as artwork in the result of the research project and were exhibited at the defence of the doctorate.

Therefore, the two making disciplines of photography and architecture interacted in the project, though with different roles. In one way, this project exposed the close relation between two disciplines that are both included in the making disciplines concept. In this case, they were also tied together by the motifs of the photographs, focusing on space, the medium of architecture. At the same time, this also exposed the difference between the two, one being closer to intuition than the other. I regard this research project as an example of interdisciplinarity, with close and intertwined relations between the disciplines.



An interdisciplinary project. The researcher is working in a crossover field of two making disciplines.

8 Multifaceted Monodisciplinarity

8.1 Nithikul Nimkulrat

Paperness. Expressive Material in Textile Art from an Artist's Viewpoint (Nimkulrat, 2009)
Dr. of the Arts, Aalto University

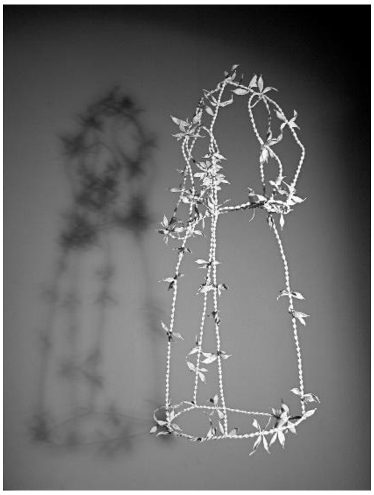


Figure 25 "Private Garden" from the exhibition "Seeing Paper". Photo: Nimkulrat
Figure 26 Detail from "The Growing Curtain". Photo: Phakphum Julnipitawong
Figure 27 From the exhibition "Seeing Paper" Photo: Nimkulrat. Source: Nimkulrat (2009)

Nithikul Nimkulrat is a textile artist. The topic of her doctoral work was the expressivity of paper cord as a material for textile sculptures. Her research project included artwork for two exhibitions, as well as discussions on the exhibitions and how the sites of the exhibitions affected the audience in their understanding of the artwork.

Her focus was on a particular feature of a concrete material: its *expressivity* when used for artwork. Nimkulrat discussed this from different angles: from the perspective of the artist in the process of making the artwork, from the perspective of the beholder, the audience of the art exhibitions, and from the artist when including the response from the audience in her next artwork. Thus, this project included the insider perspective of the artist-researcher as well as the outsider perspective of the audience. In other words, it resided in the intersection between first and third person perspectives. Nimkulrat argued that there is not yet a developed working method for this kind of research. The concrete materials, the artist's working process, the effect of the exhibition and the exhibition site and the experience of the audience can be regarded as different facets of a broader concept of research in the arts. In the context of this article, however, I regard this project as representing a monodisciplinary approach.

8.2 Wendy Morris

Drawing on the Past: Imlicit:Explicit:Complicit (Morris, 2013)
PhD, K.U. Leuven



Figure 28 Mealie. From "Off the Record"
Figure 29 Grenade. From "Off the Record"
Figure 30 Still from "Heir to the Evangelical Revival". Drawing and photo: Morris. Source: Morris (2013)

Wendy Morris is an artist who makes animated charcoal drawing films. Her works of art include three animated films. Writing is developed as an integrated part of her artwork. The major purpose of her PhD project was to make the tacit knowledge of this field of art explicit by exposing how the drawing films are made, the working process and the decisions taken during the work.

Included in Morris' doctoral work is a discussion on what kind of films her artwork are. The films in question concerned narratives related to her South African heritage. For this purpose, she used various historical material and photographs as a basis. She discussed whether her works were documentary films or not. This led to a discussion on whether she should use research methods from the field of history in her project. Her conclusion was that artistic communication was dominant in her films, making professional historical research methods less relevant.

The discussions in Morris' doctoral work exposed the close interaction of disciplines within research in the arts, in her case, the topic or literary content of the artworks and the artistic expression and the decisions to be made in the making of them. This kind of research may relate to a number of academic disciplines in a multifaceted mode. In this enterprise, there was an artistic core to the project that, in my view, made this project monodisciplinary, though with a multifaceted approach.

9 Discussion

What I have found in this study of a small number of doctoral theses is that the present trend of large, interdisciplinary research projects may be reflected in small-scale doctorate projects. Since the doctorate is a personal enterprise for the candidate in order to be awarded an academic degree, they may need expertise from other disciplines, while this external expertise does not necessarily use the project as a research project of their own.

Three of the nine doctoral theses presented collaborative working groups. All the groups contributed to developing the research results, which include artworks for public buildings, a creative idea-generating method and the contribution of changing the fashion industry. In the first project, the artwork was the objective and the result, while in the other two, the artwork were rather means of achieving other objectives of the projects. All the collaborative groups included both professionals and non-professionals, transgressing the borders of the academy, which is a vital feature of transdisciplinary approaches.

Four of the theses are examples of interaction between two disciplines. In one project, the artist needed expertise from biology for the research project. The artist himself crossed discipline borders by conducting the biology experiments. In another project, an architect used collaboration with an artist as a means of looking at his professional practice from a different position. By borrowing expertise from other disciplines for the purpose of their doctoral works, these candidates adopted transdisciplinary approaches. Then there are two projects in which the researchers combined two disciplines of their own, one combining architecture and photography, the other design and pedagogy.

The two remaining projects are within what I prefer to call multifaceted monodisciplinarity. In these projects, the artists both conducted research by means of and through their artistic working process. The making of animated coal drawing films may be regarded two different disciplines, coal drawing and animation, though in my opinion, these are two stages of the profession of making these films. One may also argue that making textile sculptures and art exhibitions are two separate disciplines. However, this research project did not concern the making of exhibitions as such but was a way of understanding the artwork better. Hence, mono-disciplinary projects may include elements of other disciplines, in what I regard as multifaceted working processes.

In general, the obvious benefit of interdisciplinarity is the inclusion of multiple types of expertise needed for the problem area. Combinations of expertise constitute a potential for creating new ideas and concepts. Since interdisciplinary discussions require a modified and popularised language inside the research group, there is also a potential for communication to a broader audience. However, what may be lost by this communication is the precision and efficiency of an expert vocabulary.

The wider scope of transdisciplinarity, which tends to require giving up sovereignty of knowledge, has the potential to tear down academic ivory towers, as seen in von Busch's thesis. However, respect for expertise is crucial. As stated by Forty: Without specialised disciplinary studies, there would be no in-depth knowledge and data (Forty et al. 2006 p. 33).

Some features of inter- and transdisciplinarity are of particular benefit to research in the making disciplines. It is generally accepted that performance in these disciplines requires non-verbal or tacit knowledge. Collaboration forces the artist-researcher to make herself understood, explaining her knowledge to people from outside the field. Thus, collaborative projects have the potential to make the artist-researcher's tacit knowledge explicit. Also, this kind of collaboration may mitigate the particular artist- or architect-researcher's problem – the insider's perspective – since the artist is communicating with partners on the outside throughout. At the same time, these disciplines need to develop their own identities as academic disciplines and build their own knowledge bases.

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The Future of Heuristic Fossils

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The authors propose that while many fields of design are involved in reflexive interactions with design research tools, others are strongly heuristic in both their application of historic knowledge bases and in the ways in which they allow themselves to move forward, to construct new knowledge as an extension of craft thinking with user-centred evidence. These historical frames become a limiting factor in both the ways that practice can develop but also, more worryingly, in the ways in which these fields can develop their own research tools.

graphics, textiles, research, philosophy

1 Introduction

The subject of design methods / design thinking has become well established, through decades of careful debate and painstaking testing, a state of affairs that is welcome. However, these methods are more strongly located in certain design disciplines. For example, Krippendorff's 2003 book The Semantic Turn contains a mass of information about industrial design thought and about half a page that directly engages with 2D graphic design (p. 208). As such, design research is extensively focused on slow development, product-outcome design, particularly product and furniture, architecture and the built environment. Famously, Cross (2011), Norman (2008) and Lawson (2005) have developed methods and models through which to situate and formalize the design process within academic writing. This enables protocols and approaches to be tested by designers across disciplines, and to record the outcomes and abilities of different models so as to be sympathetically adapted for different design scenarios.

Unfortunately, this desirable state of epistemological rigor leaves large areas of the design family uncovered. Tacit areas of 'crafts' practice, which have historically required iterations which aren't typically reflected in a design thinking flow chart, don't readily fit within this large-scale and heavy industrial model of Discover > Define > Develop > Deliver. For example, the Design Council's Double Diamond as a schematized description of the whole design process may be regarded as self-evident in many fields, while being read as a very partial description of the actuality in others. The authors propose that this may well be read as a function of heuristics in the field.

Yilmaz and Daly note some of the following characteristics as defining design's relationship with heuristics:

> *Heuristics are described as 'mental shortcuts' that capture cognitive strategies that may lead to solutions… (Nisbett & Ross, 1980), and are ubiquitous in human reasoning (Goldstein et al., 2001). Heuristics capture important features of problem situations and solutions that tend to reoccur in experiences (Clancey, 1985).*
>
> *…Riel (1996) has described the heuristic approach as 'specific experience-based guidelines' that help developers make good decisions…. Lawson (2005) concludes, 'An examination of protocols obtained from such closely observed design sessions reveal that most designers adopt strategies which are heuristic in nature. Heuristic strategies do not so much rely upon theoretical first principles as on experience and rules of thumb' (p. 132). When generating new concepts, designers appear at times to offer intuitive responses derived from 'large pools of experience' (Cross, 2011) to make a 'best guess' at a new design (Yilmaz & Daly, 2016).*

Katsikopoulos also notes:

> *Psychological heuristics are models for making inferences that (1) rely heavily on core human capacities (such as recognition, recall, or imitation), (2) do not necessarily use all available information and process the information they use by simple computations (such as lexicographic rules or aspiration levels), and (3) are easy to understand, apply, and explain. (Katsikopoulos, 2010)*

This is particularly true in those design domains where (see Figure 1):

- The process of design requires historic and tacit experiential knowledge, encapsulated as heuristics (Katsikopoulos' 'simple computations')
- The final outcome is to achieve completion through the physical manipulation of materials, or in disciplines where an outcome of the design process is one part of a larger, fast-moving and ill-defined problem
- There is a very short time to production (and is especially problematic in design domains where both features are present).

The two fields of Graphic Communication and Textile Design are representative of this class of disciplines, typically being enacted through bridging parts of a larger design process, in between one state of design problematics and another. For example, a completed textile design will typically be developed or extended via another, final stage, into a garment, vehicular or interior product. In this sense, the designer can be anonymous and tacit, not only on their design output, but on the processes which they employ, prior to the final stage of the design of a 'thing' or 'product'. Similarly, graphic design will frequently occur as process of mediation between the client and an outcome, such as for rendering for print media, web or mass production print. These fields of design which 'service' other fields rely heavily on tacit forms of knowledge; this process of mediation demands specific design thinking approaches that fit existing cultural and industrial frames.

In such circumstances, many otherwise excellent design research models have deep limitations for fields like communication design. As Yee describes:

> *It is often difficult for practising interaction designers to engage with real end-users because of the competing economic pressures on projects (Yee, 2007).*

This situation leads to an exclusion from 'design thinking' fields in their application to design fields without a physically manifested and completed industrial or crafts 'product', as has been identified in the literature (Kane and Philpott, 2016; Igoe 2010, Hemmings, 2010, 2012a, 2012b, 2015; Harper, 2012a, 2012b). In particular, textile design research is typically characterized as 'underdeveloped' as an academic discipline, due to its focus on manufacturing, technique, and technical innovation, rather than development as an academic discipline (Hemmings, 2010, 2012a, 2012b, 2015; Harper, 2012a, 2012b).

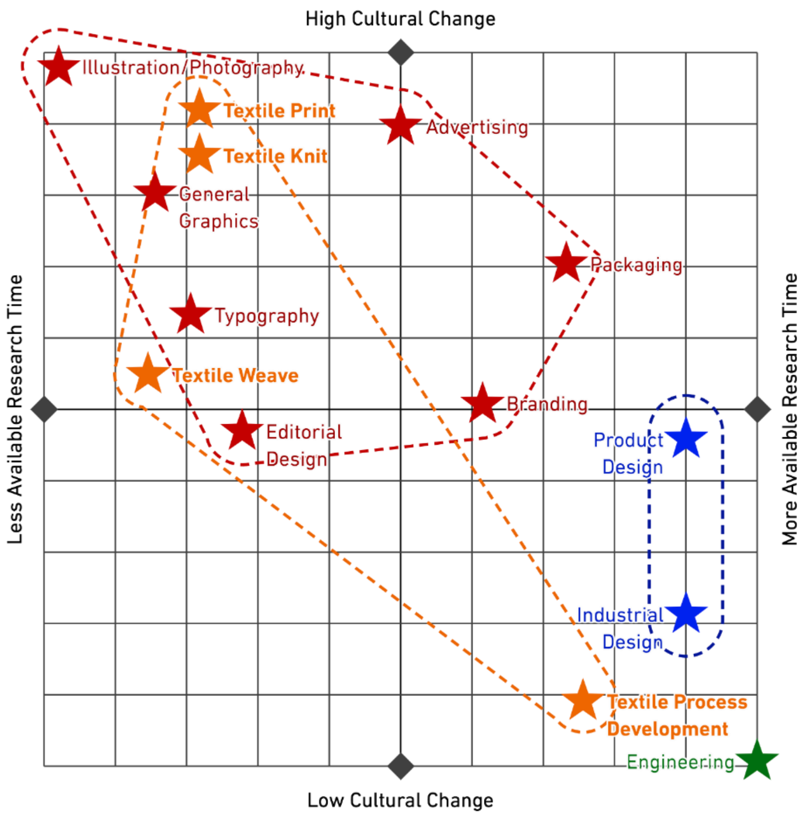

Figure 1. Time vs. Change across design disciplines

2 Poorly Defined

In the face of a well described industrial design problem, for example the design of a pair of scissors for the elderly with low grip strength, the researcher has the time (the task has urgency for the user, but not for the industry servicing the user) to research and test in ways that will generate optimal solutions before the project is finished. In a pluralistic problem space, like communication design and textile design, the 'truth' of a problem is open to interpretation, and that interpretation is dependent not only on the context and time in which a 'truth' is formed, but the shifting cultural, social and geographic dynamics which are downwardly causal on the problem. As Foucault noted, even the framing the problem is socially defined:

> *… it is not a change of content (refutation of old errors, recovery of old truths). It is a question of what governs statements, and the way in which they govern each other so as to constitute a set of propositions which are scientifically acceptable, and hence capable of being verified of falsified by scientific procedures (Foucault, 1980).*

And while Foucault is talking about the relationship of power (as a factor of a society) shaping viable methods in the sciences, the same can be observed in power (as a factor of a society) shaping viable methods in design. Ihde also discusses this effect, as instrumentality, or the problem of how an instrument is involved in creating knowledge within experience, in this case, technology and design (Ihde, 1979, 2005, 2008). Goldman discusses this constructivist effect in the epistemological creation of 'knowledge' in culture (Goldman, 1999). The very 'semantic turn', that Krippendorff encouraged, in which the meaning and affect a designed artefact engender is key to consider as a factor for design research and practice (Krippendorff, 2003) becomes less of a factor and more of the whole point at issue in fields like graphics and textile design.

This leaves a pair of confounding issues at play for researchers in communication and textile design: time and cultural context. Together these bedevil the application of existing design theory or thinking methods or paradigms in these fields. In communication design fields the combination of technical context and cultural change means that the field possesses a profile typified by low available time for research (compared with industrial design disciplines) and a high rate of change in the problem set's main variable (user culture). In textile design the time for formal research may be there, but the nature of the economy of the field means that it is rarely cost-effective to engage in long research processes (many sets of textile designs must be produced for a given selling point, all on spec', none with a guarantee of sales), against the needs of a fiercely dynamic market culture (fashion, lifestyle and trend).

3 Flexible, adaptive and contextually utilitarian

The authors of this paper have previously proposed that this uncertainty requires the formation of methods which are not intended to stand as universally valid design research principles, but which are flexible, adaptive and contextually utilitarian (Author, 2009). Contextually utilitarian is given as a measure of fitness with the working lives of the designer practioner. The advantages that these fields have in engendering innovation are in their very speed and mercurial flexibility, to embrace and develop the new, as new technologies emerge. The need to identify and develop relevant applications of design thinking research which could be embedded in these subjects, informed by and informed through practice, is imperative.

To borrow a term from linguistics, we don't need access to the universal structures of language, just access to the pragmatic utterances of our users.

> *The pragmatist or instrumentalist theory tries to bring truth down to earth by linking it to the results of action. An important feature of true beliefs is that they usually lead to desirable outcomes.… Instrumentalism elevates this feature into a definition, saying that a proposition is true just in case it would prove useful to those who believe it (Goldman, 2003).*

Goldman characterises this 'down to earth' truth as W-Knowledge (Goldman, 2003), Mansell and Silverstone characterise its application in social and political communication as 'Middle Range Theories' with specific connections to heuristics of practice (Mansell and Silverstone, 1996), while Simon applies the idea to design as 'Satisficing' (Simon, 1972).

This is not to say that there are no methods available to the fields in question; auto-ethnography, photo/video elicitations, culture probes, drawing experiences, brainstorming (and many, many, more variants on the same theme); it is just that even when the method is intentionally resource light and moderately quick to deploy (e.g. Yee's *Explorer Cards*; Yee, 2007) the demands of the method put it out of consideration for many design tasks.

To use a textile metaphor, the theoretical structure of a design method can act as the warp, or basis for a cloth, with the weft, or interlinking yarn, being selected on a case-by-case basis, adapted and changed as necessary. Design methods which investigate a design approach within a specific context will not stand as overarching truths and certainties, but which can be selected and adapted for each case as it arises, are tested within this specific context.

Unfortunately, both domains hold onto identities that are sustained by traditional craft heuristics accumulating the status of statements of faith.

4 Becoming fossil disciplines

Historically, both textiles and communication design practice have focused on the development of innovative technical outcomes. Both forms of design are common and exist across cultures, and both are heavily based on the substitution of heuristically refined hand processes, developed across centuries and passed down master-worker to apprentice, in place of formal research processes. Traditionally, graphic layouts were produced on drawing tables using hand-drawing, hand-cutting and hand-setting processes, which depended on learned physical ability applied as finesse. A failure of craft physicality would halt a production process, no matter how intelligent the intentions of the designer were. A textile designer lacking the ability to interpret imagery or structure across a range of technical processes was impaired from the first design.

These circumstances created a self-reinforcing feedback loop in the field which, without positive research inputs, lock current designers and design researchers in these fields into historically informed iteration. Creating patterns of practice which are consequently self-limiting of responsiveness to external change, resistant to testing, and developments of the vast majority of design methods research tools. Tools often possess characteristics which are demonstrable (and desirable) in the academic domain: while making no sense at all in the field.

Crafts fossilise when viable models of practice that address the condition of satisfying in one technical or cultural frame, become a heuristically enforced fossil when the technical or cultural frames change. Content creation tools like Adobe Photoshop, AVA or InDesign are built around existing domain relevant concepts derived from historic processes that have become lived heuristics in the field. The icons, and digital effect, of the Dodge and Burn tools in Photoshop are both indexical to and referencing wet darkroom techniques that have similar functionality but different process. The typography of InDesign references strips of lead (leading) and kern pairs (a digital analogue of the physical overhangs on lead type – kerns – used in setting adjacent letters) is a deliberate digital recreation of an analogue practice letterpress process (Zapf, 1993). At this point the practice ceases to be 'crafty' and becomes a craft, which is to say a set of non-negotiable terms that define the boundaries of the practice. The truths of the historic craft are engineered into the code. Innovation is possible, but only within the frame allowed by the heuristics.

In the second half of the paper research findings from one such research method, of academic origin, that was designed from the ground up to be a resource light tool that is accessible to textile designers (as opposed to textile researchers), but which shows potential in many small to medium communication design projects is discussed.

5 Time for research

As the authors have argued in previous papers (Downs, 2016. Lerpiniere, 2013) design methods needs to do two things:

1. incorporate the knowledge that our domains are culturally framed aggregations of industrial practice, historic heuristics and socio-cultural inputs
2. develop methods that are flexible enough to address floating cultural values which are downwardly casual on both the practitioners and the cultures they inhabit
3. through methods that are nimble enough to catch the fleeting changes in these values.

Which leads to the conclusion that design fields need both a philosophic frame that acknowledges the limits inherent in working from historical evidence, and the necessity for nimble research methods to inject knowledge and rigour into the heuristic applications of craft – and rapidly.

The comparative timescales of different design fields limit or on occasion remove entirely the possibility of conventional design research (see Table 1). An editorial illustrator is likely to be working to a 3 to 5 day deadline, with initial ideation typically being done on the day of commissioning, and with research being consequently abbreviated. Even a short-duration elicitation study, for example Yee's *Explorer Cards* (2007), carried with a limited set of participants is going delay the job to an unacceptable degree.

Table 1: Comparative Timings for Design Stages

Domain	Research	Development	Refinement	Modelling	Testing/Revision	Production	Deployment	User Testing
Industrial (sample)*- After Core77	1 to 1.5 months	2 months	2 weeks	1 month	2 weeks	1 month	Ongoing	Ongoing/ Iterative
Graphic (independent)-	0 to 12 hours	6 days	2 days	-	-	1.5 weeks	One time	3 hours
Graphic (agency)	3 hours	1 day to 2 weeks	2 days	-	-	2 weeks	One time	None
Editorial Illustration -	3 to 6 hours	1 day	1 day	-	-	1 day	One time	One time
Branding - A nominal middle-sized job	*5 weeks*	*1 month*	*4 weeks*	-	*1 month*	*2 weeks*	-	-
Advertising -	*2 months*	*1 month*	*2 weeks*	*2 weeks*	*1 month*	*2 weeks*	*One time*	*Ongoing / Iterative*
Textile (print freelance)	1-3 hours	2 hours to 2 weeks	1 hour – 1 day	-	1 hour – 3 days	1 hour – 10 days	One time	Ongoing / Iterative
Textile (print studio)	1-3 hours	2 hours to 2 weeks	1 hour – 1 day	-	1 hour – 3 days	1 hour – 10 days	One time	Ongoing / Iterative
Textile (woven freelance)	1-3 hours	2 hours to 2 weeks	1 hour – 1 day	-	1 hour – 3 days	1 hour – 10 days	One time	Ongoing / Iterative
Textile (woven studio)	1-3 hours	2 hours to 2 weeks	1 hour – 1 day	-	1 hour – 3 days	1 hour – 10 days	One time	Ongoing / Iterative

While an ideal design process should incorporate research, the scale of existing design research methodologies themselves deny their own utility in these circumstances. Consequently, the practitioners in these fields are forced to fall back on heuristics, histories and myths of craft. New design research methods should be constructed for addressing these missions because, while craft heuristics serve as an excellent guide to process, they offer us very little guidance to the effective application of the process. Future tools need the following characteristics:

1. Light resource requirements. Research tells us that clients (even large design clients) are reluctant to add significant costs to their existing processes.
2. Actionable over short timescales. The tools must scale to the available time. Industry cannot brook additional delay in their schedules.
3. Requiring brief analysis periods, even at the cost of more universal truths.

Many existing research methods possess one or two of these characteristics. Few possess all three.

6 Truth (or close enough for jazz)

In most practical ways the named fields don't require the level of rigour that design research methods tools bring to bear. Such tools are simply overkill. For example, a month-long research program for a five-day long editorial illustration job in unviable. The nature of the illustration field is one where high levels of cultural change erode the value of initial research in subsequent design jobs. The dominant variables in the success of the illustration will be the fitness of its address to the brief, and its comprehensibility to the users. Both conditions are external to the illustrator, both are variables that change rapidly. A research conclusion from one iteration of a design cycle is likely to be sub-optimal in the next. An effect noted by Rittel in his work on wicked problems in design:

> *Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly.*
>
> *(Rittel & Webber, 1973)*

The timescale of a product design process is long enough to allow for iterations supported by research between jobs. This duration is appropriate for a task where an error is likely to delay or derail a project. A rebranding of a company, as described in Yee (2006), is the kind of once-a-decade communication design task where existing methodologies are fruitful. The timescales here are generous and the existing tools here are plentiful and useful.

The ephemeral nature of a graphic design 'spread' or a fashion print design is such that a minor flaw in otherwise useful research have low levels of consequences in practice. There is still a clear need for tools, but insufficient available time for a full deployment of existing tools. The authors are suggesting the creation of intentionally time or resource limited tools that give 'good enough' results within the three parameters above: we are looking at satisficing research tools.

This dichotomy of approaches was pointed at in Frayling's 1993 paper Research in Art and Design, where he notes the division between:

'Research with a little r - meaning 'the act of searching, closely or carefully, for or after a specified thing or person' (Frayling, 1993) and,

> *Research with a big R - often used in partnership with the word 'development' - means, according to the OED, 'work directed towards the innovation, introduction, and improvement of products and processes'. And nearly all the listed usages, from 1900 onwards, are from the worlds of chemistry, architecture, physics, heavy industry, and the social sciences. Research as professional practice, which earns it the big R. (ibid)*

The above definition is a good one for the last 50 years of design methods research. He goes on to suggest that large design research might usefully be characterised as "Research through art and design…" (ibid.) and that

> *…Research for art and design, research with a small 'r' in the dictionary…. Research where the end product is an artefact - where the thinking is, so to speak, embodied in the artefact, where the goal is not primarily communicable knowledge in the sense of verbal communication, but in the sense of visual or iconic or imagistic communication. (ibid)*

Which is a useful description of the kind of phenomenological or experiential relationship, not only between a textile design, their users and the artefact, but also between many communication designers on small scale projects and their audiences.

At this point it is useful to return to Rittel and Webber's wicked problem theory as a guide to the kind of fluid problems that communication and textile design face.

Both fields should be characterised as end points of complex layers of problems that are defined as being addressed through pre-determined technical means. The application is craft, but the problem is addressing a social need. A line of furnishing fabrics will be produced by the means the client has pre-determined, with the problem being answered through a complex mash of cultural and production variables being framed as style and trend. A fashion photo-spread in a magazine will respond to exactly the same variables (fashion and trend), while being pre-defined as fit for print publication. Each of the problems is, in Rittel's terms, a one-shot operation, with no room for error (e.g. technically fit), and symptomatic of deeper problems:

- *Every wicked problem is essentially unique.*
- *Every wicked problem can be considered to be a symptom of another problem.*

- *The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution (Rittel and Webber, 1973).*

A correct response to the problem that characterises the user's need is an emergent function of a complex adaptive system (Downs, 2016).

In such circumstances a research tool only has to satisfy a 'w-knowledge' definition of truth. One where knowing the correct variables, within limited values of correct, for the current state of fashion is required; not past, not far future, and not universal; is the requirement for satisficing the job in hand.

Complex Adaptive Systems (CAS) are sets of systems where the inputs, processes and outputs are so complex that they produce non-linear outcomes. The weather on the West Coast of Ireland is one such effect. The Gulf Stream, the North Atlantic Conveyor, carbon emissions, geology, human factors and more all combine to make yesterday's weather a fact that has little to contribute to the prediction of the state of tomorrow's.

These systems are acknowledged as fundamental in considering many parts of biology, economics, physics and some parts of the social sciences. As noted in a previous paper by Downs (2016), CAS connect on a fundamental level with wicked problem theory; through users, social and physical environments; creating a wicked mess of feedback loops that create affective problems with no intention behind them. We can see this in the upward march of the U.K. house price at a time when real wages are falling. No one set out to create this particular economic environment, but many parties are unintentionally contributing to the situation.

These effects are characterised in system's theory as Emergence. Emergent effects are: Radically novel – showing new features not present in the system, Coherent – wholes in the emergence maintain themselves over some time, Global or Macro – there is a property of wholeness, Dynamic – the emergence evolves, Ostensive – it can be perceived, and lastly Supervenience – it is downwardly causal on the elements of the parent system (Goldstein, 1999)

In such an environment there is no utility in or expectation of the research tools or the product of these tools as having long-term validity, only that they should meet the terms of W-Knowledge / Satisficing / Middle Range theory correctness.

Which in turn highlights the absolute necessity for reflexive and responsive research methods that define application beyond the designer's brief. A method analogous to Kane and Phillpot's 'textile thinking' (2016) or Igoe's (2010) 'textile concepts'.

7 The IPA method as applied in the field

As discussed, overarching theories of design thinking can be too generic to address all design practices, in all fields. Design thinking investigates and articulates the processes of design as problem solving applications. Design knowledge requires skills which enable the conceptualisation of artefacts for use within particular social environments, by designers as interpreters of concept and materials. As Chon notes,

> *The epistemological dimension of this knowledge shifts from tacit to explicit forms, moving and transforming thought into action, to question what designers know and how they come about knowing* (Chon, 2015).

As noted, design problem solving in fields which rely on the taking of thought (concept) into action (crafted outcome), can depend on the adaptive tools which account for the experiential and tacit knowledge of the researcher to emerge.

The fields of textile design and graphic communication frequently operate over very short time spans, and within the time frame of a larger, longer design and production process, such as the production of printed or online media or development of a fabric into a garment or medical application. In this way, due to the ‘hidden’ or ‘embedded’ nature of these parts of the design process, the ‘design thinking’ in these fields is tacit, and often embodied in nature, dealing with complex layers of practice, including material knowledge, understanding how materials adapt and perform, and the subtleties of embodied ways of being and knowing (Kane & Philpott (2016), Nimkulrat (2012), Igoe (2010), Author 2). Prior research studies by the Author (Author 2) demonstrates that phenomenological research methods are grounded in the understanding that the individual is the expert on their own experience, and that this tacit experience requires drawing out.

It is proposed that phenomenological research methods can draw out such tacit expertise in other fields, and have potential to do the same for these ‘linked’ forms of design. An indicative example of an academic design method demonstrating specific benefits for a design practice (for textiles but communication design practice), is Interpretive Phenomenological Analysis (IPA). (Author 2)

An applied research method developed from the field, IPA is positioned here as a framework with the potential for developing an original take on the method, in order to develop a research approach drawing on the strength and potential of IPA research, whilst accounting for the specific requirements of the field of textile design research. IPA research focuses on areas of practice-based research, particularly in nursing, education and psychology, but is increasingly being used as a tool within design research to uncover tacit experience, through the analysis of first-hand interviews and identification of key themes integral to a user’s experience mediated through textiles (Sadkowska, Wilde, & Fisher, 2015; Author 2, 2013) It maintains links with and is informed by the central three lines of enquiry of phenomenological philosophy: ontological, existential and methodological (Macann, 1993).

Interpretative phenomenological analysis is an idiographic research method, whereby each case is a piece of a wider puzzle, indicating wider concepts or themes which emerge through the investigation of a particular experience (Smith, Larkin, & Flowers, 2009). Tacit experience is an area which IPA is particularly adept at uncovering, so adopting this analytical approach has the potential to unlock this implicit knowledge.

IPA has been developed by psychologists to explore the hidden, and perhaps unconscious, nature of an individual's experience. In this way, it is tested for its potential for examining an embodied user experience of the design process. The method has the specific benefits of low material inputs (it is semi-structured interview based), no requirement for specific facilities (it can be done in a user’s home or working environment), and with a low number of participants to get viable results (as a qualitative method it works on sample sizes of 5-10 participants). It has the disadvantage of requiring a significant input of time to carry out the interpretation, in order to enter the ‘lifeworld’ of the individual. While this renders the tool unsuitable for many communication design tasks (e.g. editorial illustration), the overall timescale combined with the lightness of required inputs makes it a viable tool for a freelance textile designer doing a post-facto review of a collection of designs.

A brief summary of the recommended process for conducting a study using IPA, and based on a semi-structured interview, is below.

8 Interviews

The interview stages of the study are in the form of semi-structured interviews, using the same question set as part of the SOP. The questions (in this case) are derived from Ashworth’s Fractions of the Lifeworld (2003a, 2003b), and the interviewee is asked to supply a focus for elicitation, which the questions then prompt a response about. In this case, a textile was the prompt.

Figure 2 Subject's mother's signature tablecloth – as a prompt for an elicitation

Figure 3 Two subjects' Punjabi wedding costumes as elicitation prompts

9 Transcription and reading

The intention is that the researcher and allows the authentic voice of the interviewee to emerge. The first step in this process is to recursively listen to the interview recording, for familiarity, before a completing a full transcription of the entire interview. Upon completion, the transcribed interview is once again read through several times, for familiarity.

10 Initial noting

The transcription is produced as a table, to create space for recording 'exploratory comments', which comment on the textual data as it arises. The table for the initial noting is detailed below. This 'initial noting' is to produce comments which explore and question the experience the interviewee is communicating, as the first step towards analysis. The focus is on noting the multi-faceted aspects of the lived experience of the interviewee, particularly their social contexts and other aspects of their lifeworld as expressed through their interview (Smith et al., 2009).

Table 2: Transcript Analysis

Emergent Themes	Original Transcript	Exploratory comments

11 Developing Emergent Themes

In essence, the IPA approach searches for emergent patterns and themes that constitute an experience, particularly those which the individual may not be conscious of, which can be explored through analysis. For example, an IPA study will ask questions around,

> *What is the person trying to achieve here? Is anything meaningful being said here, which was not intended? Do I have a sense of something going on here that the person himself or herself is perhaps less aware of?' (Pietkiewicz & Smith, 2014)*

Themes are identified and explored within each individual interview, before comparing different interviews to see where themes converge and diverge across the body of research (Smith et al. 2009). From this basis, the researcher makes a further exploration of the emergent themes and develops links to the local cultural context, in order to situate this lived experience in wider theory and understandings. Such concepts may include metaphors and narratives, which can be considered as a means to bring depth and clarity to the themes (Langdridge, 2007, 2008).

Table 3: Material domains: how the individual's textiles relate to themes of embodiment, archiving, and design and craft

	Parminder	**Paul**	**Norma**	**Judith**	**Eve**
Archiving: being an archivist through valuing and caring for the personal textile archive					
Acquisition of artefacts	x	x	x	x	x
Location of artefact	x		x	x	x
Frequency of viewing	x	x	x	x	x
Preservation	x			x	x
Material condition		x	x	x	x
Monetary value	x	x	x	x	x
Dynamic archive	x	x	x	x	x
Photographs	x		x	x	x
Sentiment			x	x	x
Embodiment: how experiential and emotional domains relate to the personal textile archive					
Physical interaction	x	x	x	x	x
Emotions	x	x		x	x
Transformation		x			
Design and craft: the role of craft skills and design in relation to the personal textile archive					
Colour	x	x			
Design elements	x	x	x	x	x
Craft skills			x	x	x

12 Chronological list of themes / Super-ordinate themes

The next stage is to produce a chronological list of the themes within the transcript (Smith & Osborn 2007, Smith et al., 2009). This list of themes is developed further into super-ordinate themes, either manually (cutting and pasting onto paper and moving around) or via software.

Table 4 Social Domains: how the individual's textiles represent a sense of identity, culture, family and friendships

	Parminder	Paul	Norma	Judith	Eve
Social domains: how a sense of identity, culture, family and friendships are represented by the symbolic personal textile archivel domai					
Friendships	x	x	x		x
Husbands and wives	x	x	x	x	x
Family	x	x	x	x	x
Culture	x	x			
Playing a role	x	x			
Identity	x	x	x	x	x
Temporality: how time, eras and events are represented by the symbolic personal textile archive					
Time	x	x	x	x	x
Era	x	x	x	x	x
Location: how real and imagined locations are symbolised by the personal textile archive					
Real places	x	x	x	x	x
Imagined places	x	x			

13 Master table of themes from the group

In IPA studies, narratives to describe an experience are produced from the themes at the end of the process of: transcription, commentary, theme compilation and super-ordinate theme completion. A master table of themes from the entire group of interviews aggregates the themes from each individual interview (Hefferon & Gil-Rodriguez, 2011; Smith et al., 2009; Smith and Osborn, 2007).

As a research tool it bridges the personal, to the local, to an actionable narrative that can feed a design practice. This tool presents no global results, but it defines a meaningful local narrative, where each iteration is subtly different. 1

As a designer, the author found that while one aspect of the meaning could be contained within a short part of the interview, the theme continues to be developed further later on in the text. (Author 2, 2013) In this way, narrative elements, such as fragments of a longer experience, are drawn out and put together, to form more complete stories for interpretation, from each individual case.

Drawing out such accounts requires careful questioning which references all the domains in which a design is created for being experienced. For textiles, this would include the visual elements, including colour, pattern and design, and the haptic, including touch, drape, softness, weight and handle.

While similar research could be investigated through a broader quantitative survey, to broader global levels of epistemological viability, this method allows for small data sets to work to the shorter schedules imposed by real-world design time-scales – for the specific set of problems local to freelance textile designers, while giving pertinent data. In this case IPA presents a suitable tool for a specific task.

14 Conclusion

The tension between an academic desire for best-of-class tools for producing global knowledge, and the communication and textile practitioner's need for tools to access the user's world defines a real need. This paper lays out an argument for the needs of a field specific position in design methods that works for these designer, moving beyond the fossil heuristics of these domains.

The example offered by IPA offers a possible address, and one that is only suitable for certain ranges of project timescales but not others, but it represents a class of nimble tools that move the debate on. Others have previously noted the need for an initial research process that defines problem space, in design fields existing outside of the *Industrial* domain (e.g. Van Der Waarde, 2014). The authors contest that the existing industrial design tools are not suited to address the issues of fields where the semantic 'truth' of a design is not just the 'plus part' applied to an existing product (Dwiggins, 1941), but a core factor in its functionality. Equipped with this knowledge these fields can move their practice beyond fossil hunting and do meaningful design research.

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Distinctions Between the Communication of Experiential and Academic Design Knowledge: a linguistic analysis

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Design research has historically focused upon collocated design practices where the production of artefacts, collaboration between designers, and designers' learning practices are geographically bounded. Information and communication technologies are rapidly transforming this territorial context of designing and making by supporting designers to share experiential knowledge with peers online. But it is unclear how experiential design knowledge should be characterized, and how it may be different from academic design knowledge. In this study, we present a mixed-methods analysis to compare experiential design knowledge communicated in two online practitioner-oriented venues and two leading design research journals. We found that the articulation of experiential academic knowledge unsurprisingly differs in multiple linguistic measurements such as patterns of word usage and language formality. However, we also found that these distinctions are not absolute; in certain instances of online argumentation, practicing designers are able to effectively discipline their language use with the purpose of articulation and accuracy. We argue for increased attention to the ways in which online discussions regarding design practices contribute to the construction of design knowledge.

experiential knowledge; academic knowledge; online design practice; linguistic analysis

1 Introduction

Rapid developments of information and communication technologies (ICTs) have enabled the transformation of design conversations into online forms, allowing designers to enact numerous core activities such as critique (Xu & Bailey, 2012), learning (Arvola & Artman, 2008; Gray & Howard, 2014), and collaboration (Luther, 2009). Online design practices differ from collocated design practices in that the former materializes through online texts or visualizations of design work, containing a representation of experiential knowledge that remains accessible and searchable by a wide range of designers for an extended period of time.

In this paper, we align ourselves with Stolterman's call to describe design complexity from the practitioner's perspective (Stolterman, 2008) and Kuuti and Bannon's call for turn to practice in human-computer interaction (HCI) research (Kuutti & Bannon, 2014). We highlight online designerly communication as an essential contemporary competency-building and sustainment practice for designers, enabling them to keep up with emerging design news, products, tools, and other relevant designerly knowledge. In this paper, we examine practitioners' experiential knowledge that is articulated through online designerly communication in user experience (UX), a growing interdisciplinary area of design practice.

To capture the distinctive characteristics of UX practitioners' communication of experiential knowledge online, we performed a linguistic analysis of online designerly communication in comparison to what is considered by the design research community to be rigorous, empirically-driven communication of design knowledge. To accomplish this goal, we selected two online venues for designerly communication, the "/r/userexperience" community[1] hosted by Reddit, the top social news aggregation website in the world, and the UX-focused question and answer (Q&A) community[2] supported by Stack Exchange, one of the largest Q&A sites in the world. We also selected two well-known design research journals, Design Issues and Design Studies, and sampled ten journal articles from each. In total, we will analyze four settings for the communication of design knowledge, two experientially-focused and two academically-focused.

Using a mixed-methods approach, we analysed and compared these four knowledge scenarios to document how and in what ways the communication of experiential and academic knowledge converges and diverges. Using discourse analysis, we studied the distinctive characteristics of social languages in the four scenarios. Using computational linguistics, we found that the communication of experiential knowledge and academic knowledge differs significantly in terms of word choices in semantic categories such as analytic words and emotional words, and language formality in terms of using simple or compound words. In addition, the academic texts are more focused upon theoretical issues, while the experiential texts stress practical problem solving and concrete design scenarios. Online designerly communication also differs in the two scenarios, with UX practitioners in the Q&A site showing a greater tendency towards articulating experiential knowledge in precise, objective terms. Our conclusions suggest that more attention should be paid to understanding the unique characteristics of online design practices, and what kinds of experiential knowledge it conveys. Studying experiential knowledge in online designerly communication is crucial to a more systematic understanding of the actual or potential role of experiential knowledge in design practice and research.

2 Related Work

2.1 Interdisciplinarity of User Experience Design

User experience (UX) design has emerged as an important field of design practice, representing a disciplinary shift away from purely visual or product-oriented conceptions of design, towards the design of interactions and services. Buchanan considered such type of shift as a natural growth of design profession, containing an increasingly humanist, complex, and socially-intertwined understanding of design (Buchanan, 1995). UX is inherently interdisciplinary, bringing in knowledge, theories, concepts, and methodologies from numerous disciplines such as engineering, psychology, computer science, and sociology (Forlizzi & Battarbee, 2004). Blevis et al. noted that UX as an interdisciplinary field has created a new fusion of human interests in relation to interaction and service (Blevis, Chow, Koskinen, Poggenpohl, & Tsin, 2014).

[1] https://www.reddit.com/r/userexperience/
[2] https://ux.stackexchange.com/

2.2 *"Bubbling up" Design Knowledge from Practice to Research*

The academic community has long identified the research-practice gap between design researchers and design practitioners (Rogers, 2004). Recognizing the existence of such gap that prevents the consolidation, communication, and dissemination of design knowledge, Stolterman (2008) called for more endeavour into understanding design complexity from the practitioners' perspective. In line with this call, an emergent body of research has called attention to online social spaces where designers socialize and learn from each other as a core aspect of their practice (Gray & Howard, 2014; Marlow & Dabbish, 2014; Xu & Bailey, 2012). Research with a focus on designers' professional practices allows insight into how design practitioners refine and concretize abstract knowledge, which eventually has the potential to be "bubbled up" and validated through refined theories, concepts, and methods (Gray, Stolterman, & Siegel, 2014). In line with this practice-led trajectory, we consider the experiential knowledge generated by practitioners in social media spaces to be traces of actual design practices, which are currently understudied by design researchers.

2.3 *Rigor in the Communication of Design Knowledge*

In discussing practice-based research, Biggs and Büchler (2007) argued that rigor does not indicate "a certain stiffness of intellectual attitude or worldview that is in compatible with change and the new." If rigor was synonymous with inflexibility, they argued, then design communities would be opposed to rigor in practice because creativity would be inhibited. They proposed to consider rigor in the context of argumentation, that rigor represents an "unyielding severity of process that leads to valid conclusions" (Biggs & Büchler, 2007). In this regard, the rigorousness of communication of design knowledge is worth close investigation as we seek to understand how experiential and academic knowledge is discursively constructed.

3 Methods

We collected UX practitioners' discourses from UX Stack Exchange, and the '/r/userexperience' subreddit. Additionally, we selected articles from *Design Studies* and *Design Issues* for the purpose of comparison with traditional distillations of academic knowledge. Below we detail our approach.

3.1 *Participant Observation*

While our approach relies primarily upon linguistic analysis, deep understanding of designerly interactions in the two online venues is crucial for our interpretation of linguistic patterns that emerge from computational methods. Therefore, we first used participant observation (Boellstorff, Nardi, Pearce, & Taylor, 2012; Hine, 2000; Star, 1999) to build a shared understanding of each platform, contextualizing basic characteristics and features as they relate to UX practitioners' interactions. We developed an understanding of the platform features of Stack Exchange and Reddit. We read content *in situ* that had been created by practitioners, using these threaded conversations to obtain a sense of the communication atmosphere and norms in the two online UX spaces. Insights gained through participation observation in the two online sites informed our later linguistic analysis.

3.2 *Data Collection*

Stack Exchange (SE) is one of the largest Q&A sites in the world, supporting 170 topics at the time of writing this paper. We used Stack Exchange's official API to retrieve threads between January 2017 and June 2017, resulting in 1465 questions and their associated 2956 answers.

Reddit is one of the largest socially-driven aggregators of news and other content in the world, supporting one than one million subreddits by the time of writing this paper. Its "/r/userexperience" subreddit supports a vibrant online UX community where junior and senior UX practitioners communicate and socialize. We used Reddit's official API to retrieve threads between January 2017 and June 2017, resulting in a dataset of 825 threads with their associated 5433 comments.

We selected journal articles from two renowned design-focused journals, *Design Studies*[3] and *Design Issues*[4]. Each journal's website provided two criteria: most cited and most viewed/downloaded. On October 28, 2017, we selected and combined the top 5 articles from each of two criteria for each journal for further analysis, resulting in 10 articles from Design Studies and 10 articles from Design Issues. Appendix A lists the selected journal articles present in our collection. Table 1 shows the total number of words for each scenario.

Table 1 Word counts for four knowledge-building scenarios.

Scenario	Design Issues	Design Studies	UX Stack Exchange(SE)	/r/userexperience(Reddit)
Word count	55,168	81,544	610,375	408,284

The nature of these four sites are quite different, thus our data collection strategies were refined by venue in reasonable ways. For journal articles, we considered the top cited and downloaded articles as a representative sample, because these articles are highly visible on the website of the journals, as compared to other published articles. However, these criteria had to be modified in order to map to online discussions on Stack Exchange and Reddit. In online designerly communication, the criteria of top cited and downloaded materials were not included, because the publication timeline of a journal article is substantively different from that of an online post.

3.3 Data Analysis

We first used discourse analysis (Gee, 2014) to investigate the distinctive styles or varieties of languages used in the four sites. Specifically, we employed the "social languages tool:"

> *For any communication, ask how it uses words and grammatical structures (types of phrases, clauses, and sentences) to signal and enact a given social language. The communication may mix two or more social languages or switch between two or more. In turn, a social language may be composed of words or phrases from more than one language (e.g., it may mix English and Spanish). (Gee, 2014)*

For Gee, social languages are "styles or varieties of a language (or a mixture of languages) that enact and are associated with a particular social identity" (Gee, 2014). Drawing from this tool, we focused on word choices, lexical and grammatical structures, and "collocational patterns" where certain words or phrases tend to appear together in a sentence. Due to the limited space of this paper, we did not employ the big "D" discourse tool that goes beyond language-in-use and interrogates a distinctive set of interconnected ways of speaking, acting, interacting, valuing, and using artifacts to enact the social and cultural fabric.

We used two computational linguistics techniques for the purpose of data analysis. We used the n-gram technique to explore frequent word choices by academics and practitioners. The N-gram technique refers to the presence of a continuous sequence of *n* words in computational linguistics (Li, Wang, & Acero, 2008), allowing analysis of word groupings as well as individual word frequencies. We also used the Linguistic Inquiry and Word Count (LIWC) software program (Pennebaker, Booth, Boyd, & Francis, 2015) to calculate word frequencies in meaningful semantic categories across these four categories and analyse their differences.

4 Findings

Through initial observation and close reading of texts from the four scenarios, we were able to form initial impressions of the goal and agenda of communication in each venue. In the following subsections, we will first provide a description of the sociotechnical context or relevance of each source, and then proceed to a detailed linguistic analysis.

[3] https://www.journals.elsevier.com/design-studies
[4] http://www.mitpressjournals.org/loi/desi

4.1 *Contextualization of the Four Scenarios*

Design Issues is owned by MIT Press. The journal brands itself as “the first American academic journal to examine design history, theory, and criticism,” and seeks to “provoke inquiry into the cultural and intellectual issues surrounding design.”

Design Studies is a “leading international academic journal focused on developing understanding of design processes.” It covers studies that concern “design activity across all domains of application, including engineering and product design, architectural and urban design, computer artefacts and systems design.”

UX Stack Exchange (SE) is visually centered around the Q&A activity, with its central part of interface dedicated to a list of UX questions. Figure 1 shows an example of a question. The visual design of a question contains rich meta-information such as its tags, number of votes, number of answers, number of views, and questioner’s reputation and badges in the site. SE also supports a profile page for each user.

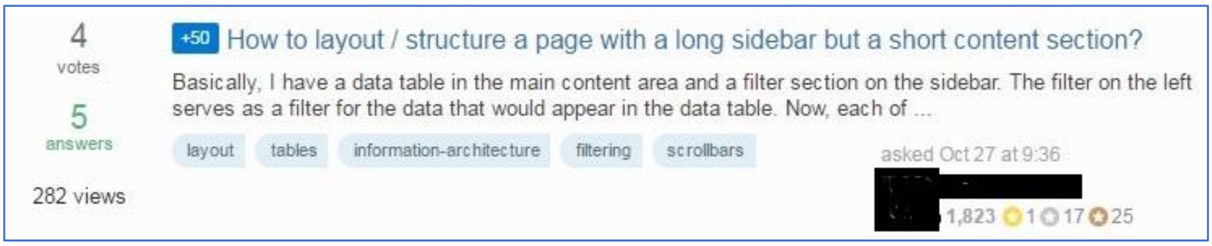

Figure 1 A question in the UX section of Stack Exchange.

SE’s moderators do not consider this section of the site as a general UX community. Rather, they emphasize the discursive communication of UX knowledge, claiming in their site description that “we're working together to build a library of detailed answers to every question about user experience.” They set clear boundaries regarding the proper formats of question and answer, noting that users should “avoid questions that are primarily opinion-based, or that are likely to generate discussion rather than answers.”

A series of reward mechanisms are in play to encourage quality questions, answers, and improvements of existing questions and answers. For example, a user gains more reputation as others vote up their questions or answers. A higher reputation allows the user to unlock new privileges such as the ability to comment and the ability to vote down.

SE also tries to regulate community members’ honesty and originality in designerly communication, in ways similar to academic research. For example, its policies explicitly prohibit plagiarism and promote honesty, evident in lines such as “posting the work of others with no indication that it is not your own—is frowned on by our community, and may result in your answer being down-voted or deleted” and requests that users should “always give proper credit to the author and site where you found the text, including a direct link to it.”

Holding high standards in articulating experiential knowledge relating to design, SE claims that “we're a little bit different from other sites [supported by Stack Exchange].”

The “/r/userexperience” subreddit (Reddit) is a general-purpose online community with a focus on UX. Therefore, a wider range of social interactions are present between UX practitioners, in sharp contrast to SE’s focus on Q&A. The visual design of its interface is also focused on discussions among UX practitioners (see Figure 2). In contrast to SE, which uses mechanisms for personal reputation an identity, Reddit places little emphasis on users, with no support for social networks or user profile.

Figure 2 A post in the "/r/userexperience" subreddit.

The community has generic behavioural rules in alignment with other online communities, although with more specific guidance relevant to a design audience. On the right side of the platform interface, six rules are provided:

> *1. Off-topic posts will be removed;*
> *2. No blog spam or marketing materials for agencies/services that masquerade to be articles;*
> *3. follow reddiquette [articulated norms by Reddit users];*
> *4. no self-promotion or surveys;*
> *5. No promotion of agencies, vendors, services, or software;*
> *6. No memes, image macros, screen caps of UIs you don't like (try /r/crappydesign) and other low effort image posts. Informative images, images necessary to illustrate questions, or imagery accompanied with useful analysis are generally allowed."*

Below the six rules, the site also recommends UX Stack Exchange as one of three useful sites.

4.2 *Discourse Analysis of Four Scenarios*

We selected one representative sentence from each site to further analyse through a discourse analysis approach.

> ***#1: Design Issues**: "I would like to begin this paper with a brief review of some of the historical concerns that have emerged with respect to the relationship between design and science."*

> ***#2: Design Studies**: "Creativity in the design process is often characterised by the occurrence of a significant event—the so-called 'creative leap'."*

> ***#3: Stack Exchange**: "When brainstorming features with stakeholders i commonly come across 2 kinds of reasoning 1 being this is feature is so obvious that the user will get it, maybe because they use other apps."*

> ***#4: Reddit**: "I'd like to hear some thoughts from you all about the ways in which you think your companies are doing UX well, and where they can improve."*

These four sentences were built upon distinctive lexical and grammatical resources to enact distinctive social identities. The *Design Issues* example enacted a thoughtful and critical thinker who reflected upon the history of design research in order to engage abstract concepts such as design and science. The *Design Studies* example enacted an empirical researcher who sought to ground a claim in relation to a well-known concept (i.e., the "creative leap"). The *Stack Exchange* example enacted an experienced practitioner who rationalized their design judgments in relation to their own lived experience. Finally, the *Reddit* example enacted a friendly and approachable UX designer who wished to chat about others' experiences in relation to design practice.

Most notably, the first two sentences are in an academic social language, while the latter two adopt a vernacular style of language. While both languages use correct grammatical structures, combining them in particular ways in an academic social language is "called for by certain social practices of certain academic (and school-based) domains" (Gee, 2014). In academic writing, each utterance tends to be grammatically correct, succinct, and meaningful, where removal of any word or phrase can change or alter the meaning of the sentence. In the first sentence, "some of" and "that have emerged with respect to the relationship between design science" are co-constitutive qualifiers that work together to describe the noun phrase "historical concerns." If the first qualifier "some of" is removed, the focus of this paper would be broadened extensively upon all the historical concerns that have emerged with respect to the relationship between design science. If the second qualifier is removed, the focus of this paper would become unclear, lacking critical details. In the second sentence, the grammatical devices including "in the design process," "the occurrence of a significant event," and "creative leap" co-locate in one sentence so that readers speaking this social language can easily understand the meaning of this sentence. In addition, the syntactic device of "right dislocation" (i.e., letting the phrase "the so-called 'creative leap'" hang out at the end of the sentence) appears repetitive in terms of not introducing new ideas to the sentence, but performs several social functions including: attaching importance to the phenomenon under study since there is even a term describing it, stressing the commonness of this phenomenon by using the phrase "social-called," and narrating readers' familiarity with this phenomenon.

However, in vernacular language, such is not the case. The third example does not either capitalize "I" or use punctuation correctly. It also employs vague phrases such as "so obvious" and "the user will get it." These languages convey only vague meanings and are not used in academic writing. In the last sentence, colloquial phrases like "I'd like to," "some thoughts," and "you all" are prevalent. These languages are consistent with the social settings being either academic or informal. However, an apparent distinction also exists between the third and fourth sentences. The third engages with a series of concrete practices or artifacts such as "brainstorming," "feature," "user," and "apps" that are central to the idea embedded in this sentence. In the fourth sentence, however, a long parenthetical device (i.e., "I'd like to hear some thoughts from you all about the ways in which you think") is in use that does not have any specific meaning. The sentence can be greatly shortened without meaning reduction to "how your companies are doing UX well, and where they can improve."

The ways in which the four sentences engage with the speaker's subjectivity in the subjects of sentences are remarkably different. The first one starts with the rather personal stance that "I would like to," signalling the "thinker" awareness of and emphasis upon the intricate and inevitable relationship between the speaker himself and the text he wrote. The second, quite contrarily, adopted an objective tone to describe a quality of creativity. The third and the fourth sentences adopted "I" as the subjects, which, however, should not be confused with the "I" in the first sentence. The use of "I" in the last two sentences was used to give rise to the telling of authentic personal experiences or opinions in a sociable and informal atmosphere.

4.3 Difference in Word Choice across Academic Knowledge and Experiential Knowledge

We calculated the top 15 popular unigrams, bigrams, and trigrams across the four scenarios (Figure 3). In calculating these n-grams, we removed those that contained only function words such as pronouns and prepositions, which are considered to have little lexical meaning. As shown in Figure 3, academic knowledge and experiential knowledge adopted strikingly different language systems, with the former using formal language, and the latter using casual, everyday language. In fact, the only overlapping top unigram across the four scenarios is 'design.' There are no overlapping top bigrams or trigrams among the four scenarios.

Design Issues and Design Studies share similarities in using formal language. However, even these two have differences due to their focuses. On the one hand, Design Issues is more concerned with criticality and depth of discussion, evident in the high frequency of unigrams such as 'research,' 'problem,' 'science,' and 'Simon.' 'Simon'-related unigram and trigrams (i.e., 'Simon's science of' and 'Herbert A Simon') are popular, as Design Issues manuscripts frequently engage with the work of Herbert A. Simon. On the other hand, Design Studies clearly has more pragmatic orientation, manifest in frequent unigram choices such as 'product,' 'process,' 'use,' 'practice,' and 'prototype.' Its frequent trigrams such as 'psychological experience of,' "the development of,' 'of the product,' ‘low-fidelity prototyping practice,’ ‘consumer response to,’ ‘of visual accessibility,’ ‘design for sustainability,’ and ‘of low-fidelity prototyping’ further confirm its focus on actual design encounters and practical implications.

While formal language is a vehicle for the communication of academic knowledge, it is not necessarily so in online contexts. In SE and Reddit, casual language is a common feature. One can argue that formal language contains substantially more and accurate information. However, it is also difficult to comprehend this language or apply it to specific situations, and is sometimes unnecessary for solving an actual design problem. Casual, situated, and pragmatically-focused language is used to communicate experiential knowledge that generally has direct and immediate use, and is open to a much larger community of designers, senior or junior.

Notably, SE is clearly results in more detailed communication when compared to Reddit; this difference is manifest in frequent unigrams that are directly related to elements of user experience, such as ‘button,’ ‘page,’ and ‘example.’ Its trigrams are also concrete, such as ‘download bmml source’ and ‘with Balsamiq Mockups.’ This demonstrates key differences between the function of SE and Reddit: while the former is specialized in Q&A about specific design situations, the latter is open to a much wider range of issues related to UX. Interestingly, the abbreviation for user experience, ‘UX,’ is the most popular unigram in Reddit. This suggests that in the specific subreddit, a sense of community is forming as people have built shared understanding of the use of special language.

Design Issues						Design Studies					
unigram	#	bigram	#	trigram	#	unigram	#	bigram	#	trigram	#
design	1546	of design	192	of the design	43	design	1398	the design	153	the design process	46
research	320	the design	133	the design process	43	product	548	of design	125	of the design	40
problem	233	design research	72	in the design	31	process	401	low-fidelity prototyping	100	in the design	36
science	220	design process	55	Sciences of the	30	designer	298	the product	99	a sense of	33
Simon	193	in design	47	of the Artificial	29	study	289	visual accessibility	90	psychological experience of	28
new	171	design Things	46	The Sciences of	26	use	241	design process	82	the importance of	27
innovation	165	design and	45	the development of	20	practice	235	the team	62	the development of	26
designer	154	Design Methods	42	science of design	19	prototype	213	a design	61	of the product	25
product	143	to design	40	of design research	19	more	174	in design	54	response to the	25
social	130	of Design	37	Simon's science of	16	work	165	graphic design	50	the Green Team	24
process	116	a design	36	Herbert A Simon	15	innovation	162	response to	50	low-fidelity prototyping practice	24
more	89	design as	36	of design as	15	research	161	product design	49	consumer response to	23
methods	86	and design	36	graphic design history	14	new	158	sense of	46	of visual accessibility	22
develop	83	in Design	35	the meaning of	13	team	148	Design for	46	design for sustainability	22
meaning	81	problem solving	34	object of design	13	tools	147	importance of	46	of low-fidelity prototyping	22

Stack Exchange						Reddit					
unigram	#	bigram	#	trigram	#	unigram	#	bigram	#	trigram	#
user	6769	the user	2481	the user to	298	UX	2914	want to	658	a lot of	377
more	2207	want to	879	a lot of	251	work	2680	a lot	578	you want to	188
like	2079	have a	824	be able to	246	design	1947	have a	557	be able to	174
make	2002	need to	786	you want to	203	like	1620	to do	535	I want to	134
use	1939	the same	767	I have a	179	more	1583	I think	521	I have a	119
button	1911	to use	529	I want to	157	get	1235	to get	473	you need to	93
need	1694	I think	512	the user can	154	think	1039	need to	440	I'm not sure	92
design	1442	to make	506	to the user	151	user	999	lot of	421	a UX designer	91
way	1348	way to	491	you need to	150	people	985	you have	407	you have a	82
want	1273	user to	404	there is a	149	research	973	a UX	343	to get a	81
page	1271	a user	390	for the user	149	good	917	the same	304	Thanks for the	79
example	1221	the best	383	the user is	145	really	901	going to	295	going to be	75
time	1133	a good	364	download bmml source	141	know	877	the user	257	I don't think	73
think	1080	the first	351	that the user	135	want	876	you want	254	if you have	70
see	1026	a lot	348	with Balsamiq Mockups	129	time	870	trying to	246	want to do	69

Figure 3 N-grams and their frequencies across four scenarios.

4.4 Semantic Differences between Academic Knowledge and Experiential Knowledge

We first examine the six *summary language variables* in these occasions. Below are four LIWC semantic categories:

> *<u>Analytical thinking (analytic)</u>: a high number reflects formal, logical, and hierarchical thinking; lower numbers reflect more informal, personal, here-and-now, and narrative thinking.*
>
> *<u>Clout</u>: a high number suggests that the author is speaking from the perspective of high expertise and is confident; low Clout numbers suggest a more tentative, humble, even*

anxious style.
Authentic: higher numbers are associated with a more honest, personal, and disclosing text; lower numbers suggest a more guarded, distanced form of discourse.
Emotional tone (tone): a high number is associated with a more positive, upbeat style; a low number reveals greater anxiety, sadness, or hostility; a number around 50 suggests either a lack of emotionality or different levels of ambivalence.
(Pennebaker et al., 2015)

The other two general descriptor categories are word count per sentence (WPS) and the number of words longer than six letters (Sixltr). In Figure 4, we show the rescaled percentages of each semantic category. To understand whether UX practitioners' language differs from general social media use, we also include the measurements of writing blog posts (raw data is not provided), one of the baselines provided by LIWC developers. We deem that compared to other baselines such as novels, natural speech, and Twitter, blogging is optimal for understanding how the focus on the specific domain of UX knowledge may intersect with the writing of social media posts.

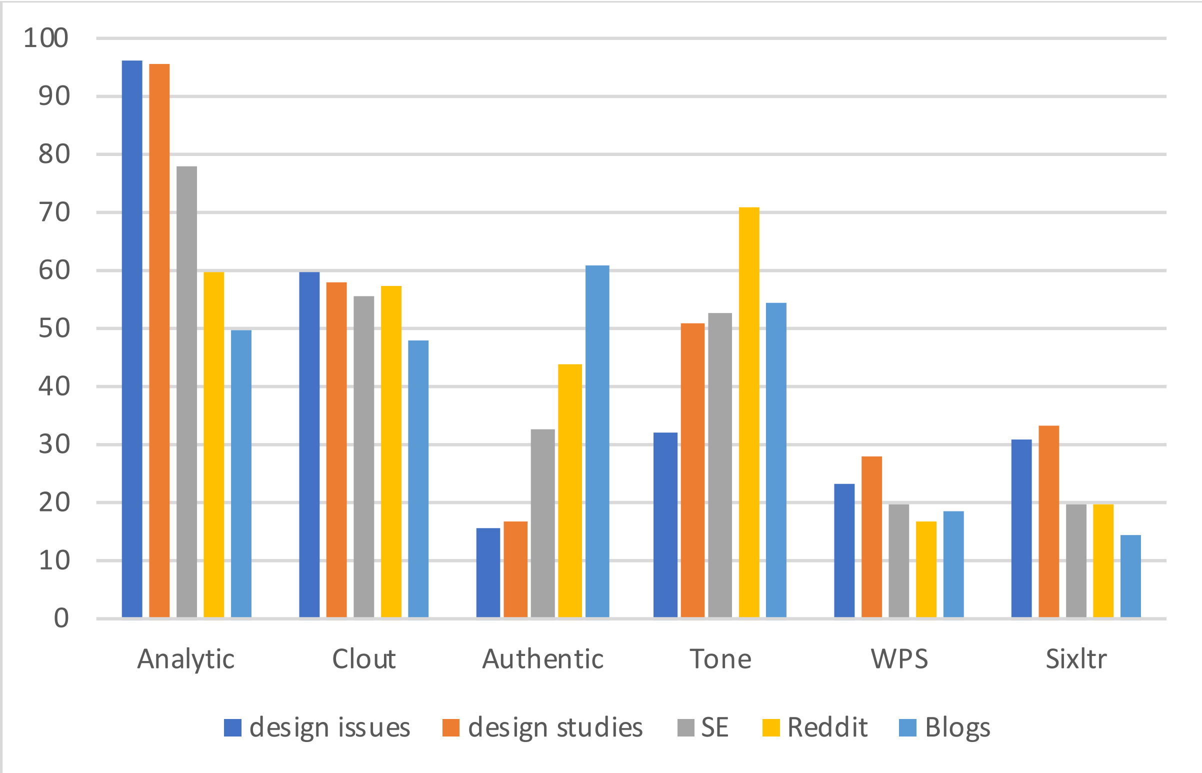

Figure 4 Frequency of summary language variables by Scenario.

Figure 4 indicates meaningful similarities and differences across the four scenarios and one general social media scenario (blogs). Categorically speaking, language use of design research, UX practitioners' conversations, and general social media differ significantly in terms of analytic, authentic, WPS, and Sixltr. Unsurprisingly, design research scored significantly different from the other two categories, as academic writing emphasizes on objectivity, clarify, rigor, and formal language (i.e., longer sentences and more complex words). There is no significant difference in the category of clout.

Interestingly, in the tone category, the language of articles from Design Issues seems to keep a very low degree of emotionality, but that of the articles from Design Studies tends to be upbeat, almost similar to the degree of designerly conversations on Stack Exchange. We suggest that the difference between Design Issues and Design Studies lies in the focus of two journals as described in the contextualization subsection.

Importantly, the linguistics characteristics of communicative practice in Stack Exchange and Stack in relation to academic writing reveals the two online venues' different functions for UX practitioners. In many categories, the patterns of SE are distinctive between academic writing and the subreddit. If the subreddit serves as a casual place where practitioners can engage in a variety of design topics, then SE represents a practitioner' approach to articulating their experiential knowledge.

In alignment with previous literature on the research-practice gap (Rogers, 2004), we add that such gap also exists in terms of linguistics of knowledge sharing and articulation. Also, notably, linguistic patterns of online UX communities also differ greatly from those of blogs. This observation points to the specific body of knowledge owned by professional communities which demands more careful, objective language use, compared to general-purpose social media such as blogs.

After looking at the overall language patterns, now we look into linguistic details of the five language scenarios (Figure 5). This time we only select major semantic categories. For example, we only use one category "function" for all function words, rather than break it down to more detailed categories such as pronoun and article.

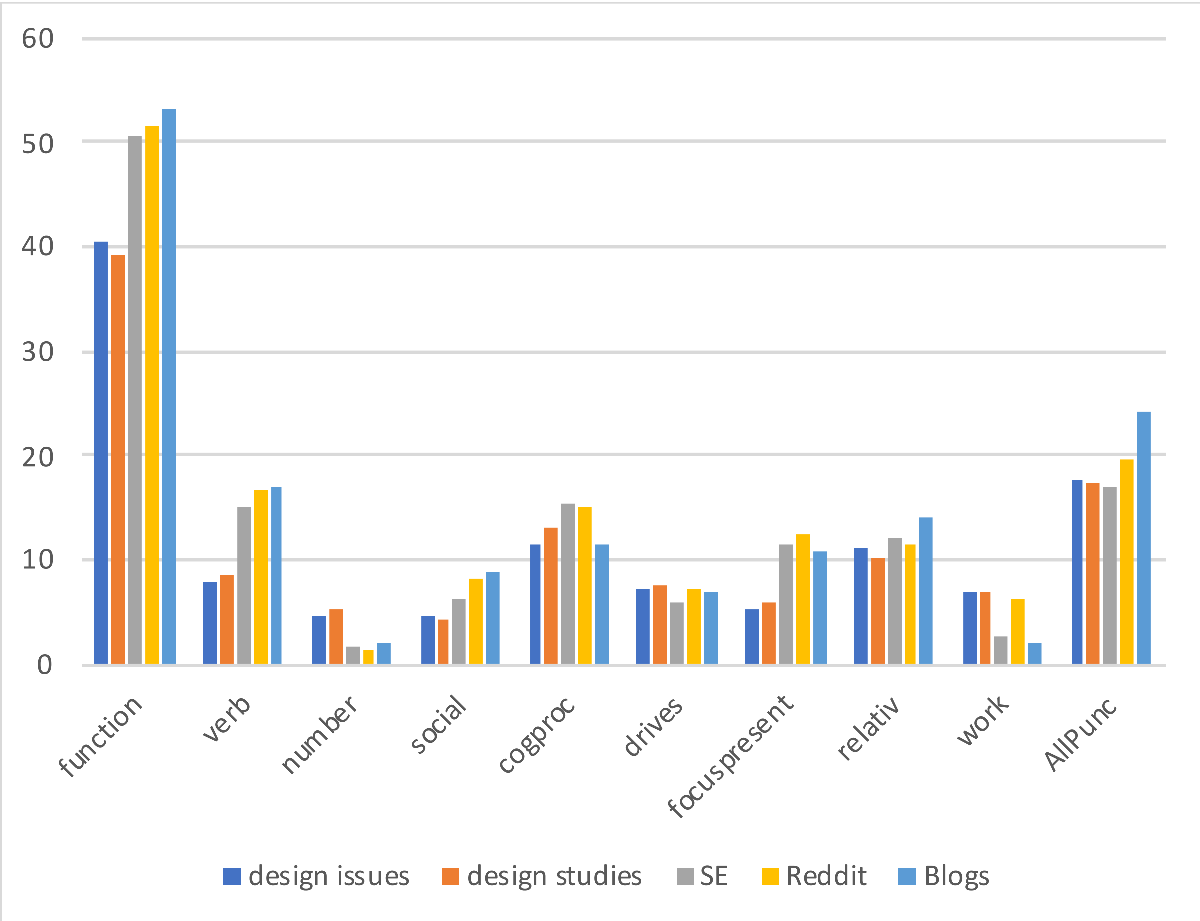

Figure 5 Semantic Categories (function: functional words such as pronouns, articles, prepositions, and adverbs; social: social processes related to family, friends, and female and male references; cogproc: cognitive processes such as insight, causation, and certainty; drives: affiliation, achievement, power, reward, and risk; focuspresent: time orientation; relative: relativity in terms of motion, time, and space; AllPunc: total count of punctuations like periods and commas).

As Figure 5 shows, two academic writing scenarios are similar to each other, but differ from the three online scenarios. Patterns of SE are ambivalent, sometimes similar to the subreddit and blogs (e.g., function and verb), sometimes in the middle (e.g., social), and other times similar to academic writing (e.g., AllPunc).

5 Discussion

Our findings showed that experiential knowledge expressed by UX practitioners through online designerly communication and academic knowledge articulated by academics in journal articles have varying content and linguistic forms. These differences lie in practitioners and academics' modes of thinking and purposes of communication as discussed in findings. However, the differences are not absolute. Expressions of knowledge on SE show a clear tendency towards rigorous argumentation in knowledge building. In the semantic category of tone, SE is already close to Design Studies.

Therefore, we do not come to the conclusion that design practice and design research has two opposing ends with differing goals, but rather see these related communities and knowledge building practices as being connected, with the potential for generative conversation and collaboration. In alignment with Gray et al.'s (2014) suggestion that practitioners have the potential to "bubble-up" relevant knowledge back to the academic community, UX practitioners at SE are clearly seeking to move in this direction. This leaves questions to design researchers as to how design research should respond to designers' knowledge practices.

Both experiential knowledge and academic knowledge are valuable for design practice, and exist within the huge spectrum of design knowledge which is composed of ultimate particulars, theory, and intermediate-level knowledge, which refers to "more abstracted than particular instances, yet does not aspire to the generality of a theory" (Höök & Löwgren, 2012). While academic knowledge, especially those discussed in Design Issues, is primarily about theory, experiential knowledge is highly pragmatic and detail-oriented, rarely engaging in a direct way with theories or theory building.

The means of communication of experiential knowledge can be different too, as demonstrated in SE and Reddit. SE's mission represents a conscious move towards knowledge building as an archival act, where the questioners carefully craft their questions and the answerers rigorously collect evidence in support of a sound answer. However, if we broaden the scope of experiential knowledge to include not only core knowledge regarding how to design artefacts, but also ideas and thoughts at the margin, such as how designers interact with their corporate environments, then shared experiential knowledge on Reddit has a broader range of potential pragmatic utility. In addition, sharing experiential knowledge might not be the sole purpose, but rather exists as a byproduct of everyday online social interactions such as exchanging salary information and telling a joke; in this way, social or phatic communication on Reddit has the potential to open up a communicative space where experiential knowledge can more easily be shared. In contrast, interactions on SE follow a rigid question and answer format that constrains the ability of users to engage in phatic communication; however, users are rewarded in other ways (e.g., reputation gained via upvoting) that allow them to express their social bonds and trustworthiness in the community.

5.1 Turn to Online Design Practice

Numerous scholars—particularly within the HCI discourse—have discussed issues relating to the research-practice gap, noting spaces where practitioners frequently lack recognition for the complexity of their practice and practical knowledge gained through their design activity (Goodman, Stolterman, & Wakkary, 2011; Rogers, 2004). These efforts are often situated in a shift from solely academic notions of knowledge production and use, and towards a "turn to design practice." In contrast, practitioners are often judged or evaluated using the standards of academic research, even while practitioners perceive that research knowledge—when viewed in isolation—is not addressing their everyday problems (Stolterman & Pierce, 2012). While this gap has not yet been properly and fully addressed, there has been increasing interest in the potential role of information communication technologies (ICTs) in influencing or bridging this gap. Empirical studies have shown that ICTs have already become an indispensable part of design practice, but if academic design researchers do not consider the role of ICTs and only focus on the collocated component of design practice, the gap will be enlarged in at least two directions. First, empirical design research will fail to capture the full picture of design practice, and the design complexity that is present in competency development, sustainment, and activation of tacit knowledge. Second, a reductionist understanding of design complexity in theoretical design research will generate and inform limited conceptualizations of design practice.

In this study, we have demonstrated that ICTs like SE and Reddit have already shifted and influenced the epistemological and methodological aspects of design practice. Design practitioners are now able to collectively and dynamically construct the knowledge base for their field and define or shape valid methods for generating pragmatic, experiential forms of knowledge. By focusing on online design practice, we are not rejecting the importance of collocated design practice. Rather, these two types of practices are potentially closely related and complementary to each other. In our study, shared experiential knowledge often originated from collocated design practices in practitioners' company or studio. Our contention is that as design practice expands into online spaces, design research in these spaces must keep up with the evolution of design practice through ICTs. Thus, we call for a "turn to online design practice" as an important step towards bridging research and practice communities, allowing design researchers to identify and document the richness of practice in both collocated and online environments.

6 Conclusion

In this paper, we have reported a mixed-methods analysis, comparing the communication of experiential knowledge in online design communities and academic knowledge in journal articles. We were able to demonstrate both commonalities and differences across the four scenarios, contributing to deeper understandings of experiential knowledge that is expressed by practitioners in online designerly communication. We suggest that researchers should focus additional study on online design spaces as ICTs transform the nature and form of design practice and research. In this study, we have only examined discourse and linguistic characteristics of online designerly communication. Future work is needed to more fully investigate the rhetorical and discursive aspects of this online communication in building knowledge-related argumentation and ultimately supporting community and professionalization practices such as collaboration and socialization.

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Appendix

Journal	Articles
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'One Over, One Under': a dialogue between design and craft

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Focusing on a process where the designer embeds herself in craftspeople's workshops with the intention of 'learning from inside' and 'making together'; this paper proposes pathways for considering collaboration within design. 'One Over, One Under' as the title of the mentioned project suggests, points to the tensions that make weaving possible, also acting as an analogy to collaboration between designers and craftspeople. The project proposes a mode of working and a spectrum of outcomes where the designer has a first-hand experience of production techniques, engages in a serious and continuous dialogue through making, and develops an intervention that also brings forth her own skill set (such as introducing digital manufacturing and structural variations), transforming the conventions and boundaries between established roles and manufacturing techniques. An experiment that resulted in a series of objects considering both the technologies of production and the input of the designer, this process not only increases the potentials that crafts hold for the field of design, but it also offers possibilities of collaboration and further articulation of the design act.

basket weaving, 3D printing, learning from inside, crafts and design

1 Introduction

Understanding how craftspeople work, their personal relationship with materials and the act of making could lead to new perspectives both for designers and the discipline of design. In order to discover the new possibilities that could arise from the collaboration between the designer and the craftsperson, in this paper, we present the project 'One Over, One Under', realised in cooperation with the basket-weavers of Sapanca and Hüsna Budak, a student of the Industrial Design Department at İstanbul Bilgi University, where we, the authors of this paper, were the course leaders.

Through discovering the possibilities that could emerge from the collaboration between the craftsperson and the designer, 'One Over, One Under' aims to intervene into the traditional process of basket weaving via utilising methods of digital manufacturing (Figure 1). The process is shaped by a collective activation of the distinct knowledge and skill sets that each party holds. The project offers a position through clashing the craftspeople' traditional methods of making and the new technologies that the designer is proficient in.

Figure 1. 'One Over, One Under' project (Photo: Hüsna Budak, 2015)[1]

As part of the ID 402 Graduation Projects course of İstanbul Bilgi University University's Department of Industrial Design, students work on a project within a self-defined context, with the supervision of the course leaders, and in close contact with a professional or an academic 'mentor'[2] competent in the subject matter. In examining the project that developed through this process, we develop our propositions through the visual and written reports prepared by the student and our own observations during our meetings with the student throughout the project as course leaders.

Focusing on the 'One Over, One Under' project as an example, our aim is to draw attention to the pathways that develop both for designers and for craftspeople through the act of 'making-together'. Therefore, we first attempt at understanding the nature of weaving and talk about the history of basket weaving in Turkey and its place in local production today. We then discuss the nature of the craft and the way it interacts with the designer through the process of collaboration. As a result, we present further possibilities of production for basketry, weaving and design but more importantly, we aim to demonstrate a working method between the designer and the producer, one that is dialogic and visible in being so; aimed at co-producing, where the forces from both sides are mutually present in the outcome.

[1] All photographs used in this paper were shot by Hüsna Budak during the course of the project.
[2] Gülname Turan was the mentor who contributed to this project.

2 Basket Weaving

2.1 On Weaving

Basket weaving, which is argued to have emerged by taking birds' nests as examples, is one of the oldest artisanal techniques known (Zoran 2013; Neziroğlu 2007). Unlike crafts such as woodworking, pottery or blacksmithing, weaving is not restricted by the raw materials used. It has become a highly flexible method of craft by accumulating various materials and different techniques of production. Throughout history, various uses, materials and applications with differing sizes are encountered. People have used woven products for carrying, storing, house building, measuring, and with symbolic purposes at religious and funerary ceremonies (Zoran 2013; Neziroğlu 2007).

Due to its diversity and the central role it has played in various cultures throughout the years, weaving is a field that is open to several different readings. Ingold (2000) proposes that the nature of weaving has a rhythm arising from the tension between reciprocal forces. In addition to the diversity of materials used, basket weaving is shaped by both the forces that the fiber materials exert on each other and the muscular dialogue with its producer during weaving. Basketry also sustains its existence through this reciprocity between different sources of force. So much so that Plato, in his dialogue titled "Statesman", uses basketry as a structural metaphor, for weaving the state through governance and justice, being reciprocal forces (Danto, 2012, p.207).

These forces and the tension are present both between the craftsperson and the material, as well as the horizontal and vertical elements that form the basket. In weaving, while the craftsperson applies a force on the material to shape the stakes and interweave them through one another, the elements that make the basket also continuously apply forces on each other, becoming tighter and building the form. Thus, the activity of weaving is a continuous process of to and fro between different actors (Ingold, 2000). Ingold (2000) further underlines a difference between making and weaving, and states that while making comes to an end with a final form, weaving is a process that is constantly in motion and that lasts a lifetime, "punctuated but not terminated by the appearance of the pieces that it successively brings into being" (Ingold, 2000, p.348). The weaving of a basket is not the concretised form of a preconceived idea in the mind of the craftsperson; instead, it emerges as a product of the active and sensuous engagement and the force field generated between the craftsperson and the material in the weaving process. The craft is a pattern formed by the rhythmic and repetitive movements of these reciprocal forces. Therefore, basket weaving involves no automation, and it is a process of development that requires constant attention and the instantaneous decisions of the skilled craftsperson (Ingold, 2000).

The 'One Over, One Under' project adds a new ingredient to this "field of forces" (Ingold, 2000, p.345), which is the dialogue established between the craftsperson and the designer. Before we start talking about the project, we shall look at the place of basketry in Turkey to better understand basket weaving and the current conditions of this craft.

2.2 Basket Weaving in Turkey

Through archaeological excavations, we know that it is possible to come across traces of basketry from the earliest periods onwards in various parts of the World. Contemporaneous with different regions throughout the world, traces of early basket weaving techniques found in Anatolia go as far back as 10,000 years. The earliest examples of basketry uncovered in archaeological excavations belong to the Neolithic period, and we come across a wide array of different techniques and materials that change according to the place of production throughout Anatolia (for example, findings from Çatalhöyük excavations indicate that weaving had a central role in the daily life of that period) (Neziroğlu, 2007). A variety of products with many different functions, to be used in areas such as agriculture, storage, measurement and transportation, were produced by weaving. In addition to the common basket, a wide variety of products such as "fish traps and pots, bird cages, weighing pans for balance scales, saddlebags, prayer mats, hats, umbrellas" (Neziroğlu, 2007, p.53) have taken their place in daily life.

Today, however, production capacity is getting smaller day by day, compared to the variety it had back in the past. We could see basket weaving still present mainly at “Konya, Kastamonu, Kocaeli, Trabzon, Rize, Edirne, Kırklareli” (Neziroğlu, 2007, p.53) today. Although the raw material used in these places varies according to local vegetation, we still come across similar techniques in terms of weaving. The most common production process involves an initial stage of softening the collected material by soaking it in water, followed by cutting it to length according to the size of the basket that will be produced, forming a central base by horizontally arranging these stakes in the form of a cross, and then weaving the horizontal elements one over, one under (hence the title of the project) through the vertical stakes standing upright from the central base (Neziroğlu, 2007).

Figure 2. Weaving of the base

2.3 Basket Weaving in Sapanca

During ‘One Over, One Under’, our student Hüsna worked with the basket weavers in Sapanca, one of the main sites of local basket production. There exists limited sources of information about basket weaving in Turkey, and especially less regarding the practice today. There are no detailed research on techniques and master craftspeople, even about the regions such as Karamürsel and Aydın, where basketry is promoted as a touristic value. Due to this lack of reference material, the information about basket weaving in Sapanca had to be gathered first hand, during the weekly visits of the designer to the weavers’ workshops. In addition to learning the techniques of weaving, she also gathered information about factors that surround production, like procuring raw materials, everyday lives, and sales networks of craftspeople.

Sapanca is one of the regions where basketry still remains as a fundamental source of livelihood. The area is rich in raw materials used in basketry (such as willow, wicker, cane and reed) due to its climate and flora. While some craftspeople permanently reside in Sapanca, others migrate to Sapanca seasonally from nearby regions, following the flourishing of the plants, and spend winter months here, weaving baskets. The most common raw material is wicker, which they collect from the forests and trim, for preparation. It is also possible to obtain cut and trimmed raw materials from the market places in Sapanca. However, instead of buying, most of the craftspeople our student Hüsna has spoken to prefer to forage the raw materials themselves in order to reduce costs. A lot of the craftspeople in Sapanca also prefer the above-mentioned most common technique of weaving in Turkey; ‘one over, one under’. The baskets are generally produced as vessels to be used in carrying various kinds of goods (Figure 3).

During the project, Hüsna worked with four different master craftspeople in Sapanca and paid weekly visits to their workshops, where they were also dwelling, and she weaved baskets with them. Masters Erol and Nurdan are married, and they are seasonal labourers normally residing at Biga in Çanakkale, and coming to Sapanca during winter months to collect raw materials and to weave baskets. Hüsna first started working with Masters Erol and Nurdan (Figure 4) and learned the basics of basket weaving from them. Later on, she met and work with the siblings Masters Sabahattin and Pembe (Figure 4), and she tried to acquaint herself with the unique and individual relationship each one of them has with weaving. From the middle of the project onwards, she continued working with Master Pembe, with whom she could communicate the best. Master Pembe’s habits in weaving were open to try new forms, she had an attitude that enabled her to share Hüsna’s excitement and participate in forming ideas.

Figure 3. Examples of some of the basket models produced in Sapanca

Figure 4. The artisans with whom the collaborations were carried out: Erol, Pembe (top), Nurdan, Sabahattin (bottom)

The craftspeople usually collect their materials from Akyazı, the nearest forest. After cutting and trimming the sticks they have collected, they split each stick into three strands and get these ready to be woven. As it is a very difficult task to split a stick into three by hand, Masters Erol and Nurdan have designed a tool especially for this purpose, that they call ‘the juniper’ (Figure 5), which they have produced from juniper tree. With this tool they could easily split the sticks into three equal strands. Masters Pembe and Sabahattin, on the other hand, were cutting slits in the upper part of the sticks with the help of a knife, and then splitting the sticks into three strands by hand.

Figure 5. Unprocessed sticks, 'the juniper' and the way it is used

All four masters that Hüsna worked with were fundamentally using similar basket weaving techniques. They were using stake and strand technique (Neziroğlu, 2007) on the main body. In the stake and strand technique, after the base is woven, sticks are added perpendicular to the base. These vertical elements remain stable during the weaving process and also assume the role of the main skeleton. The horizontal elements are woven, intertwining the vertical elements layer upon layer and lock one another in place to form the body. After the body is completed, additional elements such as handle, lid and border (Figure 6) could be added.

Figure 6. Various phases of weaving, from left to right; base, body, border.

3 An Unexpected Encounter

3.1 Crafts Learning

Hüsna, as an industrial design student, has obtained knowledge on mass production methods and on recent technological means of production, such as the ability to use 3D modelling programs, and is accustomed to utilizing this know-how in developing forms that embody her ideas. Craft, on the other hand is a way of making things via thinking and sensing through hands so much so that making becomes an intellectual process (Sennett, 2008). With her material engagement, craftsperson thinks through her hands and convey her knowledge through material experiences. Since knowledge of the craft is not necessarily available with words and instructions, it requires material performances to reveal knowledge (Nimkulrat, 2012). Similarly, some part of the designer's knowledge is embedded in her practice and it can only be disclosed through design activities (Cross, 2001) such as, sketching, modelling and later embodied in the artefact. To further contextualize design education in Turkey, it is important to emphasize that during the historical formation of Industrial Design departments, there has been very limited attention given to crafts and small-scale production (İngin & Altay, 2014). Thus the profession (or field), by way curricular discourse has either undermined or disregarded an essential mode of product-making.

Sharing knowledge through making together, the 'One Over, One Under' project aims to intervene traditional basket weaving through the use of design knowledge and skill-set with current means of production. It involves an enquiry into the opportunities of collaboration that could be achieved between the craftsperson and the designer. In order to establish this dialogue and collaboration, the designer weaved herself within the workshop of the craftsperson, where craft knowledge, i.e. the embodiment of skills and relations with materials were unveiled.

The methods that the craftspeople demonstrate at their workshops guide the apprentice in learning the craft through practice (Sennett, 2008). Crafts involve tacit sets of information that could not be transmitted in any way other than practice. This situation creates a “communication gap” (Schön, 1987, p.101) between master and apprentice, where talking seems futile, and only making together could help bridge this gap. In fact, during the act of making the master reveals a lot more than she actually could say or was even aware of. By making together (which includes observing and emulating), the master could teach more than she explicitly knows, and the apprentice learns much more than she can explicitly claim to understand (Kaya 2011; Polanyi 1966). In İngin and Altay’s studies about the craftsperson-apprentice relation in the context of design education, it is emphasized the benefits of a designer (student) entering the craftsperson’s realm of production and having a first-hand experience of the work would yield both a profound understanding of techniques, and a sense of responsibility towards the producer (Ingin & Altay, 2014).

Polanyi defines tacit knowledge as personal knowledge that is internalized so deeply that it is “ineffable” (1962, p.88); that it cannot be expressed in words. It can only be acquired through making (Kaya, 2011; Rust, 2004). According to Sennett, in acquiring a skill, the individual constantly repeats and follows a series of procedures, and so builds her own method of making. Following a routine so internalized through repetition, the work proceeds “instinctively” (Sennett, 2008, p.50), without having to think about it. All the knowledge and experience acquired to fulfil this skill is then transformed into tacit knowledge within the process. Performing a sophisticated skill, like gaining mastery in a craft, functions as a set of practices interwoven between tacit knowledge and explicit critique (Sennett, 2008). Thus, practicing a craft arise from the unspoken dialogue between the explicit awareness of the master and tacit knowledge acquired from repetitive experiences. Although the craftsperson knows how to perform her craft to the finest detail, because of the silent nature of this knowing she cannot be sure how to put her knowledge into words/instructions (Nimkulrat, 2012; Wood, Rust & Horne, 2009; Sennett 2008). Hence, to be able to learn a craft from a craftsperson it would be necessary to observe the act of making within which this silent dialogue is embodied, and work along to be able to recognize the “decisive moments” (Sennett, 2008, p.95) within practice. Due to the nature of tacit knowledge, which only becomes accessible through making, this knowledge could only be acquired through “a discussion grounded in a context of practical activity” (Ingold, 2013, p.9).

By means of the weekly visits to the workshops throughout the project, Hüsna was able to create that “grounded discussion” with the craftspeople. She aimed at grasping the tacit knowledge of basket weavers through “learning from inside”; not just by talking, nor by observing alone, but by “doing together and thinking through observation” (Ingold, 2013, p.11). Here we would like to emphasize that the places where this relationship could be formed were also workshops where the activity (that is, the craft) was shaped in the form of a dialogue. Workshops have been places where “learning becomes local” (Sennett, 2008, p.178). The weekly visits to the workshops and the weaving experiments jointly carried out by the designer and the craftsperson on these visits formed the basic structure of the ‘One Over, One Under’ project.

3.2 ‘One Over, One Under’: A Dialogic Process between Designer and Craftsperson

Hüsna made weekly visits to the masters’ workshops to intervene into a traditional method of production by establishing a dialogue between the different skill sets of the designer and the craftsperson, and to be able to understand the craftsperson’s relationship with the materials and the act of weaving, which could only be acquired through making together (Figure7). Hüsna observed through weaving, and was able to establish a common ground for discussion through the baskets they had weaved together. The excerpts included here are taken from Hüsna’s study notes and reports:

> *I found the opportunity to weave a basket together with Master Erol at the workshop. He taught me the basic method of weaving, which is the weaving technique used in almost every*

basket, on a basket that he had started when I was away. When it was finished he gave the basket to me as a gift, saying that we made it together. (Hüsna Budak, 2015 project report)

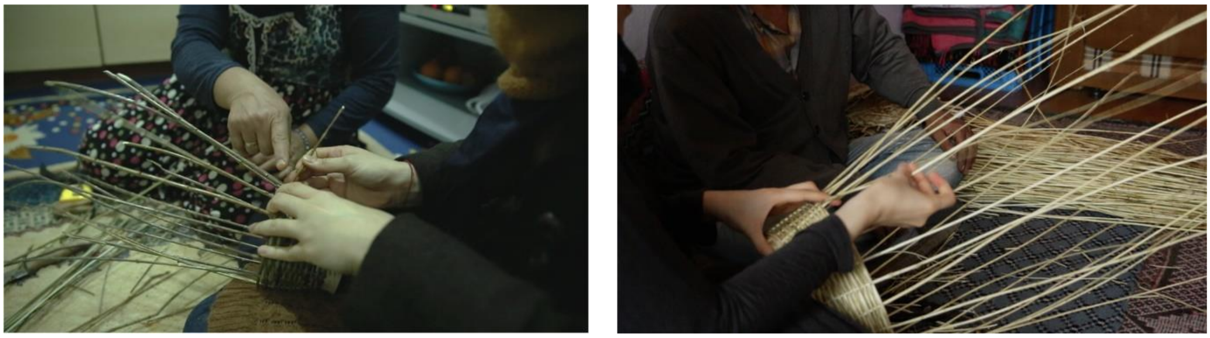

Figure 7. From the visited workshops

Instead of starting with a specific idea or a preconceived final product, the project was initiated as a process of enquiry and an investigation aiming to establish a collaboration between the designer and the craftsperson. And at each step, it proceeded as a process of growth/development that embraced new discoveries that would emerge from this collaboration with the craftsperson. As Hüsna became acquainted with the practice of weaving and managed to establish a relationship of mutual trust with the craftsperson, she began to form her own ideas, to share them with the craftsperson, and to discuss these, again, through practice. They tried to see the possibilities, the pros and cons of new ideas through weaving together, and together criticised how different interventions related to basketry:

To improve our communication with Masters Sabahattin and Pembe I asked them to weave something different than what they are accustomed to. I asked Master Sabahattin to weave a basket with a base that has three centres, and Master Pembe to weave a spherical shell. Master Pembe told me that she needed a mould to be able to do this, so I gave her a metal bowl. (Hüsna Budak, 2015 project report)

Figure 8. Various experimentations, from left to right; with mould, three-centred, with different materials

During the project, in addition to the examples depicted in photographs they carried out various other experiments together, and each one of these experiments was essential in establishing a common ground (Figure 8). These experimentations involve actions that help establish communication and confidence between the designer and the craftsperson by enabling a discussion within a context of practical activity. In addition, these experiments that are carried out together also function as a means to acquire tacit knowledge embedded in the practice of the craft. As mentioned earlier, the knowledge regarding the craft exist tacitly, internalized through its own practices, and it is not possible to access it through verbal spoken instructions (Nimkulrat, 2012; Sennett, 2008). Similarly, the design discipline too is a practice-based field, in which a certain portion of the knowledge of design is inherent in the act of designing, and could only be observed when revealed through various activities within the design process (Cross, 2001). By means of investigation of knowledge through practice, the designer plans her each following step by evaluating her knowledge that becomes observable through action, and by learning from it (Tung, 2012; Schön, 1983). Therefore, the designer does not follow a predetermined route or a systematic method within the design process, but establishes her own path for each project within the necessities of the design process (Visser, 2006; Schön, 1983). Design becomes a process where the practitioner reflects on each step and plans each following step accordingly, albeit in a nonlinear fashion, often constituting a route through experience (Schön, 1983). That being the case, in the 'One Over, One Under' project, design and craft evolve by learning from one another -through multiple repetitive experiments made together- and meet again and again on the common ground of discussion through making.

Within these innumerable experiments there were moments of leaps forward: realisations that helped the project to proceed to the next level. One of the most significant of these was the realisation, arrived at after many experiments, that at the bottom of each basket there is a base (Figure 9), which acts as the centre and is the starting point of the act of weaving.

> *Almost every basket is woven like this, starting from a centre. This is the first base I had woven with the help of the master. It was really hard to make. (Hüsna Budak, 2015 project report)*

Figure 9. An example of a finished base

Although they are woven in different sizes, forms and for various functions, the presence of a central base is a common characteristic in all baskets. Due to the difficulty of its production and the precision required in making these, Hüsna thought that concentrating on the centre could yield favourable results. Proceeding from this common centre could lead to a result that could be applied to every basket, as well as aiding the production of the craftsperson. Together, the craftsperson and the designer carried out a number of experiments on this idea:

> *I brought the two wooden pieces that I prepared to Master Pembe, to test the idea of incorporating different materials into the centre of the basket. We used the square one at the centre of the base, and the circular one as the base itself. Placing a rectangular piece at its centre, the base of the basket had the same form too. If we were to weave the sides of the basket we would have ended up with a rectangular basket. The shape of the piece placed in the centre also determines the form of the basket. (Hüsna Budak, 2015 project report)*

Initially, considering it is a plant-based raw material like the materials used in baskets, various forms out of wood were produced to exercise different ways of intervention at the centre of the basket (Figure 10 and Figure 11). Hüsna would bring the wooden pieces she had produced to the craftsperson at her visits, and they would discuss what to do and how to weave with these. Various experimentations were carried out with wooden pieces that would be utilised as part of the base or that would become the base itself:

At first, I had in mind to place the wooden piece in the centre of the base and weaving around it, but after the trials with the rectangular piece I had the idea of using this piece as the base itself. As a small experiment, we wove a basket with a wooden base. After the base was put in place, I wove the body of the basket. Master Pembe said that it would be better if there were more holes around the wooden cylinder allowing more vertical stakes. (Hüsna Budak, 2015 project report)

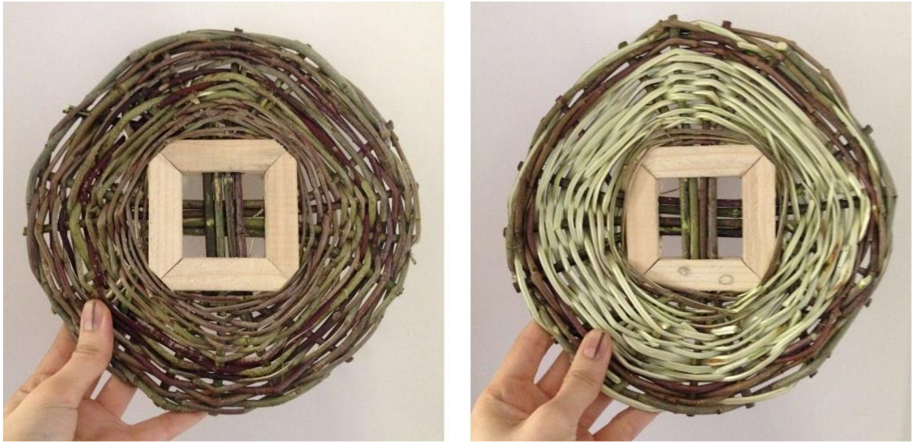

Figure 10. Examples of bases woven around an additional square wooden piece

Figure 11. Basket woven around a wooden base

Through these experiments and discussions by way of making Hüsna was able to get feedback from the craftsperson as well. As the production of the perforated form in wood was expensive and difficult, other materials were also tested. She experimented base interventions with many different materials like clay, rubber, Styrofoam (Figure 12) that she was familiar with from her design education:

Working with wood was not really appropriate for reed baskets. The wooden pieces had to be drilled at particular axes and angles. And this was both a difficult and an expensive process, so I decided to try out different materials like Styrofoam and clay. After many attempts, I decided that none of these were suitable for reed and for a basket. As a result, I decided to work with a 3D printer offering a flexible method of production, and the material used in these printers, PLA. (Hüsna Budak, 2015 project report)

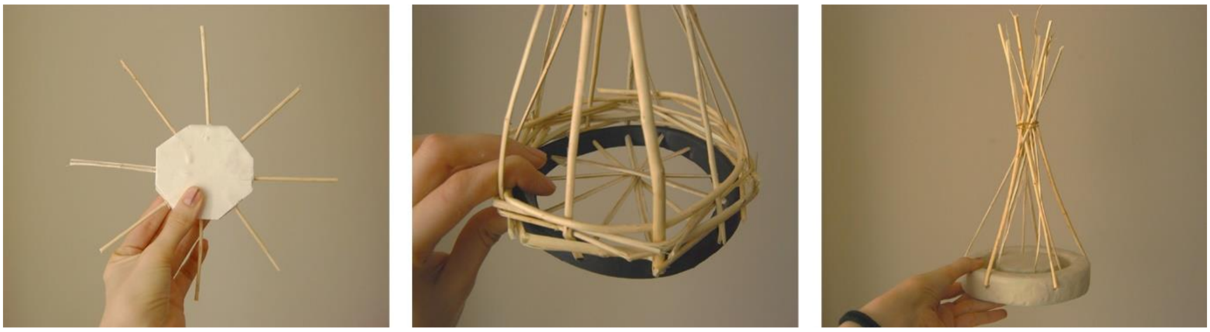

Figure 12. Experimentations with different materials, from left to right; rubber, Styrofoam covered in putty, clay

3.3 The Contribution of the Designer

Another important leap in the project was realised when the designer incorporated the three-dimensional (3D) printer method -that belonged to her knowledge set- into the production relationship. Compared to wood and other materials that have been tested before, 3D printing, as similar to weaving is a much more flexible method of production, and it is a lot easier to produce the perforated forms required at the base with this method. In an effort to discover the possibilities that might arise from the use of the 3D printer, various attempts were made to establish a functioning dialogue between weaving and the printer.

In the first experiments (Figure 13), a number of different 3D parts were shared with Master Pembe. The designer and the craftsperson began to weave together and figure out what could be done with these, and in keeping with the advice of the craftsperson, many issues such as the placement and number of holes necessary were discussed. Another point that was raised in these discussions was concerning the stakes, which had to be bent too much, rendering them weak and causing a worn-out look. Based on these feedbacks, the designer created a new set of parts (Figure 14). Another important point that was noticed in these experiments was the flexibility of the 3D printer production and the variety of forms it could produce, as well as the ease with which the craftsperson could relate to these alien parts:

> *Master Pembe thought that the weaving technique was made easier by some of the parts I brought. For instance, she was really excited about weaving with one of the plastic parts because she could start weaving a basket immediately, without weaving a base, which is very difficult to weave and mandatory in the traditional method. (Hüsan Budak, 2015 project report)*

Figure 13. Initial trials with bases produced by a 3D printer

Figure 14. Various experiments produced by 3D printer

From this point onwards, they would leave the traditional form of the basket behind and begin experimenting with new possibilities together (Figure 15).

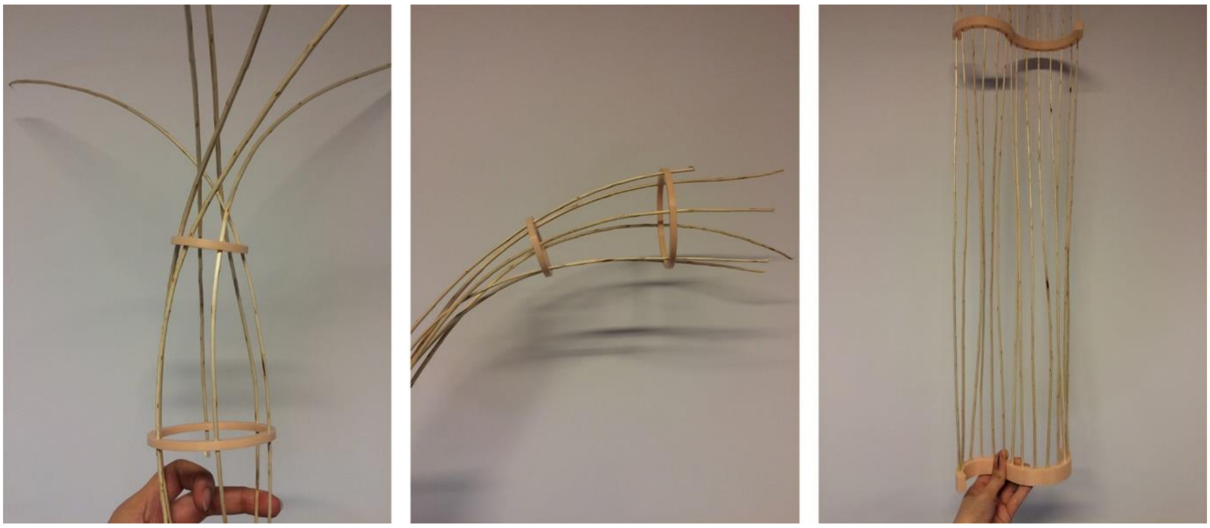

Figure 15. Experiments in new forms

The 3D parts were designed both as a tool for production and as a part of the finished product. On one hand, these parts allow the craftsperson to weave different forms that she could not have woven without them, and on the other hand they become an integral part of the end product. As a visible component of the final product, the 3D parts manifest the possibilities that the dialogic process between designer and craftsperson generate.

A hybrid situation emerges out of two different methods of production, two different materials and two different practices, and through a collaboration between craft and design. Resulting in a series of products that have their own presence, with a distinct formal and structural language. Within the scope of the project, a set of 9 products consisting of 3D parts and woven reed emerged, revealing a spectrum of possibilities (Figure 16).

> *Each part constituting the One Over, One Under project points at a different potential of the combination of basket weaving and the 3D printer. The experiments show the flexibility of the basket weaving and the 3D printer. The two methods could easily accommodate one another. (Hüsna Budak, 2015 project report)*

The combination of the 3D printer and basket weaving forms a negotiation between two seemingly opposing modes of production. The 3D printer and basketry belong to different moments along the historical development of the methods of production. While basket weaving is one of the oldest known methods of production, the 3D printer is one of the newest. Both forms of production are incorporated in the project by containing a knowledge set specific to respective participants /

collaborators. But when these converge in a production process, the interplay between their differences, and the revealed tension manifest possible modes of co-existence.

Figure 16. The 9 parts constituting the One Over, One Under project

4 Conclusion

In In this paper, we present two principal propositions by way of discussing 'One Over, One Under', an industrial design student's collaborative project with basket-weaving craftspeople in Sapanca, Turkey. The first one of these is how a situation of 'learning from inside', where the designer has a first-hand experience of production techniques, could shape the thought and the act of design. Our second proposition is that the knowledge sets and the technologies accessible by the designer and the craftsperson could be interwoven through mutual fostering and a certain tension. As this example illustrates, field experience could be combined with competence in contemporary digital technologies, with the ability of modelling three-dimensional complex geometries, and more importantly with establishing a dialogue with a critical outlook on products and production processes. Such an approach can lead to various possibilities for designers, producers, and potential users.

When the cost-effective and flexible structure of new production technologies is combined with crafts in a certain manner, the exchange could present extensive possibilities of production for craftspeople, as well as opening up further possibilities for the act of design. The 'One Over, One Under' project brings together one of the oldest and most flexible production methods, basket weaving, together with one of the newest and most flexible methods of production, three-dimensional printers. This intervention, developed by the concrete and physical parts produced by the designer, provides a tool that aids the craftsperson in her act of weaving, acts as an input that diversifies the forms and geometries that could be produced in basket weaving, and presents elements that eventually become part of the final object. Thus, a dialogical process is at work, rather than a consecutive design-production-product sequence.

The designer and the craftsperson, the fields of design and crafts reinforce one another by applying forces over and under, just like the reciprocal forces inherent in basket weaving. Such a method where the designer's contribution to production is both an outcome of learning from the inside and having a physical presence, the 'consecutive' and 'hierarchical' relationships between design and production are undermined. Instead of such distinctions, a positive and favourable tension and dialogue makes possible new products and modes of production.

The 'One Over, One Under' project offers an experiment considering both the technologies of production and the input of the designer. Apart from an approach that increases the potentials that crafts hold for the field of design, it offers potentials for elaboration and further propositions about the nature of the design act.

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Combining Practices in Craft and Design

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Combining practices of craft and interaction design opens up new opportunities for both domains but structuring such cross-domain collaboration poses challenges. How to set up a crafter-designer collaboration to utilize the different fields of expertise and include separate practices? We address this question through a co-design research approach. First, we present an overview over existing approaches. Then, we propose our perspective that builds on an initial distinction between the collaborators, repositions the construction of the brief, and culminates into a collaboration through the shared object. Finally, we describe a successful collaboration between an interaction designer and a ceramic artist to support our model. We present a collaboration model that builds on distinct expertise, evolves through a design-based brief, and realizes through a shared dialectic object. We present this through a case study in pottery but we argue that the model is not tied to a particular craft technique and transferable to other collaborative settings in this field.

craft; physical computing; design collaboration

1 Introduction

Craft theory and craft practices have become important reference points for interaction design. New technologies allow the inclusion of physical making practices in digital prototyping and the socio-technological history of craft offers a rich context for interaction design that emphasizes phenomenological approaches and/ or addresses our changing relationships to materials. Yet, the challenge remains to balance this meeting of craft and design practices in a productive way. As successful as many of the craft-related individual projects are, they largely present unique case studies. They do not offer a model for structuring this domain encounter. An overbearing of new technology that merely utilizes craft is as flawed an approach as setting a new agenda for interaction design on a romanticized perception of craft. How can we structure a collaboration of interaction design and craft in a successful and balanced way?

Here, we apply an action research methodology to suggest a structured collaborative practice that ultimately emphasizes the shared object in a new way. The argument builds first on a review of background work done in this field, then it describes the approach chosen, followed by a case study that describes the collaboration between an interaction designer and a potter. Finally, it summarizes the resulting model and the lessons learned.

1.1 Craft as Reference in Interaction Design

Craft has always been indispensable for interaction design but its place is shifting as new technologies open design opportunities. Ehn suggested already in 1998 the idea of the "Digital Bauhaus" to fulfil a "third culture in the digital age" by combining science, art, and craft based on "a critical and creative aesthetic-technical production orientation that unites modern information and communication technology with design, art, culture and society" (Ehn, 1998). The promised blended model implies a multi-talented and –educated crafter-designer-maker. It largely remains an ideal, though. Gaining mastery levels in both, craft as well as the interaction design requires extensive dual training and copious amounts of talent.

Individual projects (see e.g. (Buechley & Perner-Wilson, 2012; Goodman & Rosner, 2011; Peppler & Glosson, 2013)) demonstrate the potential in this field. But just as the Digital Bauhaus remains an ideal, the question of how to achieve this combination through a structured design process remain a challenge. The hybrid does not simply emerge. In fact, the notion of hybrid crafts itself has been questioned (Devendorf & Rosner, 2017).

Ratto's concept of "critical making" provides one methodological entry point encouraging a shift away from an object-focused production and toward "shared acts of making rather than the evocative object" (Ratto, 2011). This process-oriented approach emphasizes a reflective encounter with technology through the materials at hand. In that way, it references the "reflective practitioner" suggested by Schön (D. A. Schön, 1987) in a workshop setting. The practice of critical engagement through material can also be traced in craft research, but here is it more based on a "thinking through craft" (Adamson, 2007) approach that heavily relies on the exceptional skills of the craftsperson. Unlike critical making exercises, where the resulting object is seen as a trace of the process, the object in a craft-centered approach has value in itself. That is why the material quality and condition of the object are defining components in an ensuing creative collaboration.

1.2 Related Work: Craft and Design

For the purposes of this argument we can divide existent approaches relating craft to interaction design into three main approaches.

Technological/ artistic approaches target novel combinations of crafting and digital interaction to either produce new technological combinations or individual projects that exemplify certain approaches through their unique expressions. The former is prevalent in the area of prototyping and it often combines craft practices such as fiber arts or paper craft with novel materials such as conductive thread and/or ink and new technologies like the Lilypad (Buechley & Qiu, 2014) or ePaper (Karagozler, Poupyrev, Fedder, & Suzuki, 2013). Craft and prototyping techniques are combined to explore a richer technological vocabulary. They present a blended practice that combines traditional craft methods with novel materials and tools. Initial frameworks are emerging – set within the frame of such a technological perspective (e.g. (Zhu, 2012) for paper circuits, (Berzowska & Bromley, 2007) for soft circuits). But the area is dominated by a plethora of individual projects that combine craft and digital components to explore individual forms of expression.

Ethnographic/ educational approaches build on the social context of craft to explore novel practices. For example, Buechley and Perner-Wilson observed 40 crafters to inform their hybrid designs (Buechley & Perner-Wilson, 2012). Goodman and Rosner build on their ethnographic work with gardeners and knitters (Goodman & Rosner, 2011). Peppler investigates the overlap of crafting and digital media to inform novel educational approaches (Peppler, 2013). These works emphasize learning from existing craft traditions and projectiong these lessons onto the digital. However, at the same time, craft itself had to adjust to new digital production techniques and this complicates such a perspective.

Craft-based approaches consist of modifications to existing crafting practices. They are often transformative but focus less on the development of new technologies and more on the application of existing ones to traditional practices. For example, long-held traditions of craft face changes triggered by personal fabrication and digital tools that often simplify and speed up processes (Gershenfeld, 2005). This can lead to a collision “and through this collision a new value for craft thinking, processes, and knowledge is beginning to emerge” (Press, 2007). This emergence originates in the workshop not the lab (Bell, 2012) as crafters adopt digital technologies into their practices. Depending on the constellation of the participants, these three approaches often overlap and occasionally allow for novel approaches. But their success often depends on the dual-identity of a crafter-designer or a close collaboration that is noted but its nature and structure remain largely unclear. Here, we will focus on this form of collaboration.

1.3 Approaching Collaboration: Separating Practices

Our approach toward a structured craft-design collaboration emphasizes material and critical processes (like Ratto and Adamson) and aims at inclusion of specific craft practices (like Rosner and Buechley). However, it differs in its lay out through a co-design informed approach. As a result, it provides a differently weighed model for structuring collaborations between crafters and designers. Co-design manifests in a creative collaboration of different practitioners. Those processes are not easily structured and the initial phases of collaboration is described as an uneasy “crumple zone” (Stappers, 2005). It is, however, in this “zone” that the collaboration of craft and interaction design anchors itself. It is also here that the balance between partners needs to be struck.

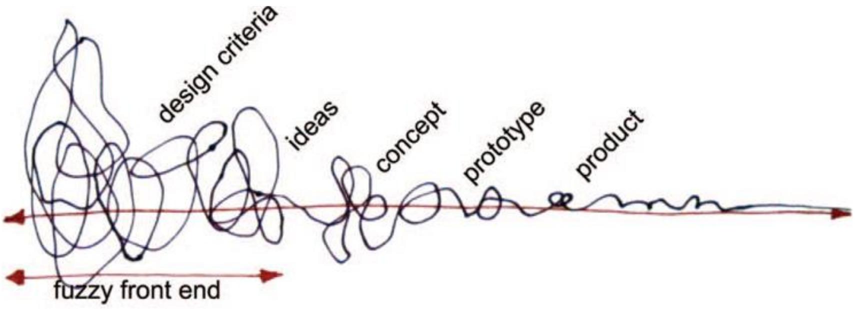

Figure 1. The “fuzzy front end” in craft and design collaborations as identified by Sanders/ Stappers (Sanders & Stappers, 2008).

Few projects target such a structured combination of specific local craft traditions with designers. Tung (Tung, 2012) structures the collaboration toward a commercial revival of craft in Yuan Li, Taiwan. Other case studies include participatory design approaches to support Indonesian bead crafts (Zulaikha, 2013). The here proposed model starts, like Tung’s, from the designer’s perspective. However, it differentiates itself through a focus on the material and the shared object. This object becomes a key component of an emergent practice without turning into a pre-conceived product upfront. Our approach abstracts a model that relates to existent concepts like Tung’s but is itself not directly aimed at commercial deployment, focusing instead on the creative partnership between crafters and designers.

As a couple that includes one practicing crafter (a blacksmith) and an analytical STS scholar, Keller & Keller’s provide another fitting reference for our approach. Their activity system traces an “umbrella plan” from an initial brief to an experientially informed encounter with the material and emergent object design (Keller & Keller, 1994). This approach informed the analytical first stage of our proposed approach. Because we remained interested in the encounter with the material, aother key concept was that of the “surprise” encounter with these material qualities during the production. Herein we relate to Ingold and Hallam, who outline creative practice with materials as *generative*, *relational*, *temporal*, and ultimately *improvisational* (Ingold & Hallam, 2007). Their concept of practice as a process of bringing-into-being shaped by in-the-moment encounters with others and with the material influenced our own design of the collaborative process between crafter, designer, and material.

Ingold further proposes to look at “real” objects as constantly coming into being through relational networks wherein all participants collaborate and the human ones “*follow the materials*” (Ingold, 2009). He emphasizes objects not as finished constructs but as dynamically unfolding of forces. The thing, here, is not a proof or even a trace of the collaboration–but an active ingredient of a larger dialogue contextualized far beyond a single manipulation. Craft engages with the materials en route to the object. Ingold’s particular focus on materials suits our approach for a material- and practice-based collaboration. It establishes the thing as an active part of an emergent dialogue between all partners involved. As the agency of objects increases we see their role in the design process becoming ever more important in a participatory design process. This physicality of materials has been outlined by Hansen and Dalsgaard as “framing” as well as “transformative” (Hansen & Dalsgaard, 2012) for participatory design events. Both are encountered only in a process-based approach.

Our approach differs from the ideal of a holistically educated crafter-interaction designer. It builds on a model that involves a designated designer and a crafter, wherein the two do not directly collaborate from the beginning, nor do they blend their fields of expertise into one. We argue that this space for dialogue is not an emerging shared practice but a dual one that includes the object in the unfolding discourse. The following will outline an example implementation of this approach as well as a discussion of results.

2 Creating an Interactive Ceramic

The project started in spring 2015 and continued into the next year, in the production labs at Georgia Institute of Technology on the one hand and the ceramic workshop of the crafter on the other. It consisted of a collaboration between Clement Zheng, as a designer in the field of Industrial Design, and Amy Roberson, a ceramic craftsperson. Its goal was to structure their collaborative process in a way that would harness the creative input and individual practice of both partners without diluting either one’s expertise in the process. The project originated as a challenge to Zheng to explore a craft practice and apply the found knowledge to digital media design. Ceramics as the target practice was chosen by the designer personally, inspired by his lack of expertise in this field. This initial distance to the craft practice was seen as beneficial for the set up of the project as it supported differentiating between the two experts involved. The transactions with the craftsperson evolved from an initial *investigative* phase to understand craft and craftsperson, to an *exploratory* phase of discussing possible collaboration opportunities, to an *implementation* phase to prototype the interactive artefact. These phases manifested from the broader principles outlined above. The collaboration included Zheng but excluded co-author Nitsche who had no direct contact with the crafter. The analysis and discussion was based on a shared review of the process and its results.

2.1 Investigation: Mapping Craft and Crafter

The designer, Zheng, is trained in the fields of industrial design and interaction design, specializing in designing tangible interactive products. His practice typically involves designing, building, and programming electronics, often with the help of digital fabrication tools.

Zheng had no prior experience with ceramics in his work. The first phase of the collaboration involved an approach from the designer to the crafter. The explorative first encounter comprised of a series of informal interviews and observations of the crafter at her workplace, as well as personal encounters with the craft itself.

2.1.1 Combining Creativity

Definitions of creativity vary depending on the context they are applied in (Sawyer, 2012). Amabile’s micro level looks at how immediate surroundings and social context might affect creativity and proposes a “Consensual Assessment Technique” (Amabile, 1996) based on subjective shared criteria. Amabile’s method is included in the later stages of our model. In addition, Csikszentmihalyi differentiates a three layered creativity system model of *domain*, *field*, and *individual* (Csikszentmihalyi, 1996) useful for understanding Roberson's practice: Roberson produces craft objects within the *domain* of ceramic arts and has been a practicing artist in residence at the Mudfire gallery in Atlanta since graduating in 2012 from a Fine Arts program specializing in ceramics. She describes this gallery not only as a working but also as a social space, one that is "great for idea sharing and brainstorming." Her attraction to ceramics stemmed from the utilitarian and tangible nature of the clay pieces; what she calls an "interactive three-dimensional canvas of expression." She is interested in pottery for its tradition of producing not only beautiful objects but also objects of utility. This balance of form and function remains important to her practice, and evident in her pieces.

Figure 2. Examples for Riberson's ceramic work; combining function and her personal aesthetic.

Roberson is an active contributor to the local craft scene in Atlanta, which can be seen as a *field*. As an artist in residence in a city gallery, she teaches and assists amateur and professional ceramic artists in the community. In addition, she participates in art festivals around the city. Her work is sold through those art festivals and through the online craft marketplace Etsy. Within this *field*, Roberson has established an identity for herself, especially for her use of simple, functional forms coupled with playful and vibrant glazes.

Roberson's work is influenced by her *individual* interests and passion. In particular, she is attracted to the Electronic Dance Music culture and tries to imbue her work with the same fun and playfulness through her use of glaze and colour. This establishes a unique signature in her work, even as she claims a much wider overarching influence of the Mid Century Modern ceramics. In line with her attraction to playful and vibrant visuals, Roberson is also attentive to color trends. In her repertoire of tools is a set of Pantone colour swatches which she refers to in choosing glazes for her pieces.

2.1.2 Exploring Process and Materials

Our approach sets out from the designer to the crafter. It started with an exploration of the crafter's identity and creative stance and continued into a look at ceramics as a creative material practice. Roberson's craft process could be divided into two distinct methods that either fall into a relatively structured "umbrella plan" (Keller & Keller, 1994) supporting a precise planning and effective performance, or into a more "improvisational" (Ingold & Hallam, 2007) crafting that embraces elements of surprise. Roberson deploys the latter method typically when exploring a new form on the wheel or with new glazes and colour combinations. The more top-down former method is used by Roberson, for example, when producing a series for a collection. It features a strong initial brief and a set procedure – what the Kellers termed an umbrella plan – with few improvisations or surprises allowed in the process.

2.1.3 Encountering the Craft

The designer had no experience of working with ceramics but experimented with the practice to experience the basics of working with clay and pottery tools over multiple sessions working on own (mostly flawed) ceramics. This experiential approach was carried out in tandem with the interviews and discussions with the craftsperson.

Limited as such a preliminary encounter with the craft was, it allowed the designer to discuss basic materials and processes with the same language as the craftsperson, even though their quality was far inferior. The conversation can now emerge over a shared experience, albeit between an expert and an amateur. In addition, this first-hand experience increased the sensitivity and empathy towards the craft. Experiencing the practice was not meant to turn the designer into an expert potter but to encounter the material and the practices as active components to prompt questions about them. As the collaboration gained specificity, the flow of ideas shifted away from generic issues towards Roberson's unique crafting practice and her identity as a craftsperson.
The tension between form and function stood out as a recurring dilemma throughout Roberson's work. As a craftsperson, she creates her pieces with the intent that customers will use and interact with the pieces. This is evident in a signature colorful detail that she creates at the base of each vessel, a detail that is only revealed through interacting with the object: one has to pick up the cup and turn it around to see her signature glazing on the bottom. However, many of her pieces end up not as functional objects but as gifts and display ornaments. Roberson recounts her own grandmother, who would not use the pieces as she deemed them "too pretty". In contrast, Roberson intends others to see and "use" her objects, uncover specifics, and manipulate them.

2.2 Exploration: Developing the Brief

If the investigative approach of the craft and crafter is a phase of research *into* craft, then the brief is the hinge which turns the collaboration to a research *through* craft and design (Frayling, 1993). As with most design briefs, it consists of a goal, constraints to work within, and is formulated between "motivation" and "creation" phases (Cross, 2008). However, some important aspects of the brief stood out in our case.

2.2.1 Role of the Brief Development

Up to this point, the perspective was that of the designer approaching the craft. The brief is developed by the designer as a concluding response that forms a turning point. We observed that the designer stands on fertile middle ground; the designer has gained insights on the craft practice and the practitioner and understands the motivations which drive the crafter in her work. At the same time, the designer is conscious of his training to integrate other, often diverse fields into a cross-disciplinary process (Owen, 1990). In contrast, crafters are trained on a specific material manipulation processes first and foremost. This difference of breadth versus depth between the design and craft practitioners was observed also in other collaborations (see (Tung & Chen, 2013)). Thus, the integrative nature of the design process supports the role of the designer as the developer of the brief. This brief should not only bank on the opportunities identified in the previous phase, but also exploit the strengths and motivations of both designer and crafter to drive a successful collaboration. This focus on process differs from the more uni-directional client-to-designer problem statement that defines a typical design brief (Cross, 2008).

In practice, the brief should be anchored in a shared object that is able to connect both practices and create opportunities for the collaborative object-making process. Besides anchoring the collaboration to a type of object, the brief also divided the work between crafter and designer. Neither crafter nor designer were experts in the other's domain. Consequently, the goal was to provide sufficient constraints, yet leave enough room for crafter and designer to explore within their own domain.

Lastly, our brief follows Amabile's consensual assessment - evaluating the outcome based on the judgment and expectations of both crafter and designer. This differs from a more formal, criteria driven evaluation approach found in a typical design brief (Cross, 2008). The brief had to be accepted by both collaborators and serves as a catalyst setting a new trajectory for craft and design to collaborate. Building on Ingold and Hallam's emphasis on improvisation in craft practice, we propose that the brief affords a process, which is malleable to the "surprises" that might emerge.

The brief marked the start of the task-driven and object-focused collaboration between crafter and designer.

2.2.2 Brief: Building an Interactive Lamp

In our case, the brief called for the creation of an interactive lamp. We were less concerned about the novelty of the object as a product (commercial interactive lamps exist) but about the appropriate framing of the next collaborative steps and the connection to the various creative practices. Its targeted outcome was not seen as a product but instead as a shared common ground for engagement.

The nature of the lamp object relates to Roberson's interest in electronic dance music and use of vibrant glazes as well as playful trademark details within her ceramics. It specifies a tangible user interaction with the lamp, where the movement of the lamp affects the hue and colour of the light. While this interaction model via object manipulation is fairly typical of tangible interaction design, it was included to support features which were personally unique and important to Roberson. The fact that a lamp needed to be picked up to function related to her concerns about the detachment of the objects from their function.

2.3 Implementation: Sharing Lamp-Making

The lighting component of the lamp was based on readily available RGB LEDs but the sensing system proved to be more challenging. It is impossible to embed electronics in clay that will be fired at around 2,300 Fahrenheit. This meant that the electronics had to be assembled onto the finished ceramic. It also meant that the ceramic needed to be constructed with this later assembly in mind. Both are non-typical conditions for the crafter as well as the interaction designer.

Figure 3. Lighting component design and implementation.

In the implementation, this led to the choice of accelerometers to sense the interactions, as they can be connected to the ceramics without disrupting the craft process. The accelerometers in turn informed the first interaction model of the lamps—the hue of the light is affected by the lamp's tilt direction, while the saturation of the light is affected by the tilt magnitude. This also allowed for gradual improvements of the interaction through reprogramming. The interaction design addressed a key concern of Roberson with her existing objects. She had complained about the non-use of her objects as they had been deemed “too pretty” to be touched. Yet, the interaction design required users to “pick up” the object.

The implementation went through iterations of divergent and convergent phases. During the divergent phases, the crafter and designer engaged in individual exploration, developing their respective components. During the convergent phases, the prototypes were assembled and evaluated.

2.3.1 Divergent Phase I: Independent Development

The housing and assembly of the electronics to the ceramic lamp body was the focus of the designer. Prototypes iterated through initial breadboard models, to more robust packages encapsulated with a custom-made chassis. Eventually, a clamping method was devised to secure the electronics to the ceramic body. This required a small hole to be introduced at the base of the ceramic lamp body, a standard procedure in ceramic craft.

Figure 4. throwing the first ceramic lamp shade prototype.

The form, size and texture of the ceramic body was the crafter's focus during this phase. The exploration began with paper sketches for possible forms of the lamp, as a reflector of light and as a form for users to hold and interact with but also as an object in itself with its presence in a room. A few forms were eventually shortlisted and turned in clay. These pieces were then fired with different colour glazes.

2.3.2 Convergent Phase I: First Assembly of Object

The assembly of the first prototype met the initial expectations of both crafter and designer. The lamp can be comfortably picked up, and the form afforded the interactions of tilting and turning. The electronics functioned inside the body and responded accurately to the interactions.

Figure 5. Assembled first prototype at work.

However, new considerations emerged through assembling and interacting with the first prototype. The glaze used was glossy and smooth and it raised the issue of the user's hands slipping during interaction. With respect to the electronics, the exposed LEDs were too bright to look at while interacting with the lamp. This critique of the prototype involved both crafter and designer and often reversed their roles. The designer would argue about the glaze and the crafter critique the light fixture. The object involved both participants in a shared reflection of the decisions made in the divergent phase and enabled both to engage in a better understanding of the collaboration process.

2.3.3 Divergent Phase II: Improvement and Iteration

The second divergent phase focused on addressing the areas of improvement identified in the first prototype. If the first divergent phase was based on the brief, then the second was based on the object (see Figure 5) and its shared discussion.

With respect to the ceramic lamp body, the crafter began experimenting with a new glaze which fires to a matte finish and mitigated the slipperiness of the first prototype. As for the electronics, a custom circuit board was fabricated to organize the wiring, while the code was modified to dim when a user interacts with the lamp, minimizing the glare experienced.

2.3.4 Convergent Phase II: Changes based on the Object

The crafter produced a ceramic lamp body with a different size and form for the second iteration. The electronics and ceramic lamp body assembled seamlessly and the new matte glaze provided an improved friction to the touch. However, the lamp's new form (that of an overturned cone) and its slightly larger size, made it difficult for a user to interact with the lamp in the same way as the smaller first prototype.

Figure 6. Different interaction methods explored with the second prototype.

Instead, the second prototype encouraged the user to pivot the lamp on the edge of its base, which then enables it to roll along its circumference. The designer had been unaware of this weight change, and the crafter had been unaware of its possible impact on the electronics. This new affordance required an improvisation of code optimization, which was quickly adapted to support the new interaction model. This surprise that emerged during the second assembly, and the improvisation that followed, gave rise to a different interaction concept. At this point, both designer and crafter had become more familiar with each other's process and domain. With the two prototypes as reference, the discussion went beyond improvements of the existing models. New approaches to develop interactive ceramic lamps, as well as innovative ideas for the different lamp components were raised.

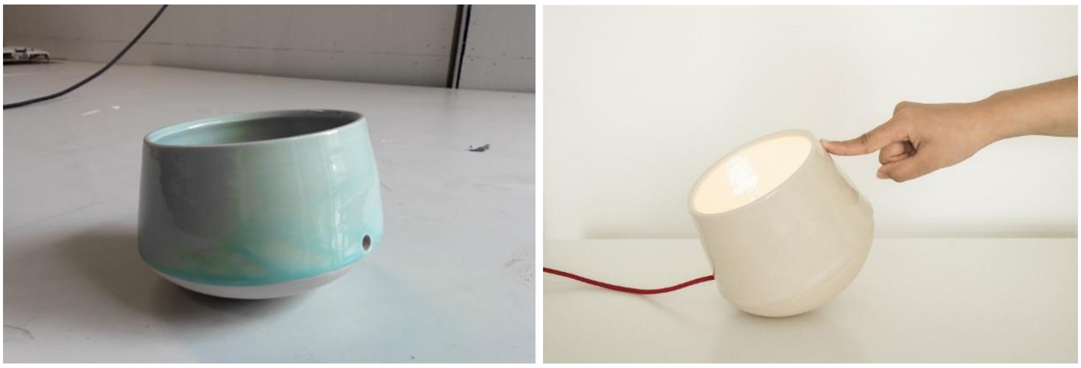

Figure 7. "roly-poly" variations; reflecting the manipulation technique in the shape of the lamp shade.

The collaboration between crafter and designer continued and more ceramic forms and interactions were explored, including the ‘roly-poly’ form as well as a new method of organizing the cables and electronics with the ceramic lamp body. We interpret these later steps toward the development and optimization of a possible product as signs for a successfully initiated collaboration. As establishing this collaboration was our declared goal, we exclude further development and iteration of the lamp and instead look back at the example project to combine craft and design as separate practices.

2.4 Evaluation: Consensual Assessment

The outcomes of each iteration were evaluated against the emerging expectations of the crafter and designer. Amabile’s consensual assessment technique argues that “a product is creative to the extent that expert raters independently agree upon this judgment” (Amabile, 1996). This serves our goal of establishing a collaborative practice as it depends on shared engagement with the object. The *personal* and *domain* impact of this collaboration both provided evidence in support of such an assessment technique. Roberson varied her *personal* crafting and glazing techniques in reaction to the outcomes of each iteration—“This rounded form is good to hold, but I want to see how an open form will change the quality of light”, and “I want to try a more neutral glaze to see its effect on the different color hues”, were quotes in direct relation to the interaction design and exemplify her engagement with the collaboration through its objects. The collaboration pushed the designer to continually reassess the interaction design and programming of the embedded electronics. He reflected that “the variation in weight, texture and form of each ceramic piece presents a different set of affordances” and pushed him to consider “new tangible interaction models consequently different electronic behaviors in response to Amy’s [Roberson] pieces”.

Figure 8. Facetted variation; inspired by responses from peers.

Furthermore, the outcomes of each iteration catalyzed discussion and idea generation among Roberson and her peers at Mudfire gallery (her *domain*). Roberson reported on an impromptu discussion with her peers about “incorporating electronics into ceramics” while she was working on her part at the studio, resulting in several new ideas, one of which was a “faceted lamp body that changes the lighting effect as it rests on different faces”. These were conceptualized without the designer and indicate possible extensions of the model to reach wider collaborating partners within the targeted craft *domain*.

3 Developing the Synthesis Model

Tung et al. offer a helpful designer-crafter collaboration model (Tung, 2012; Tung & Chen, 2013). Their case studies outline four stages, namely a “fuzzy front-end stage”, where crafters and designers got acquainted and designers explored the craft, a co-creating stage, where directions and concepts were established, a co-prototyping stage, where the concepts were implemented, and a feedback stage, where stakeholders evaluated the process and outcomes of the collaboration. Much of this corroborates with our case study. For instance, we also find the initial investigative phase to be important in establishing a common ‘language’ between both parties, easing the differences in practice as well as concept explorations.

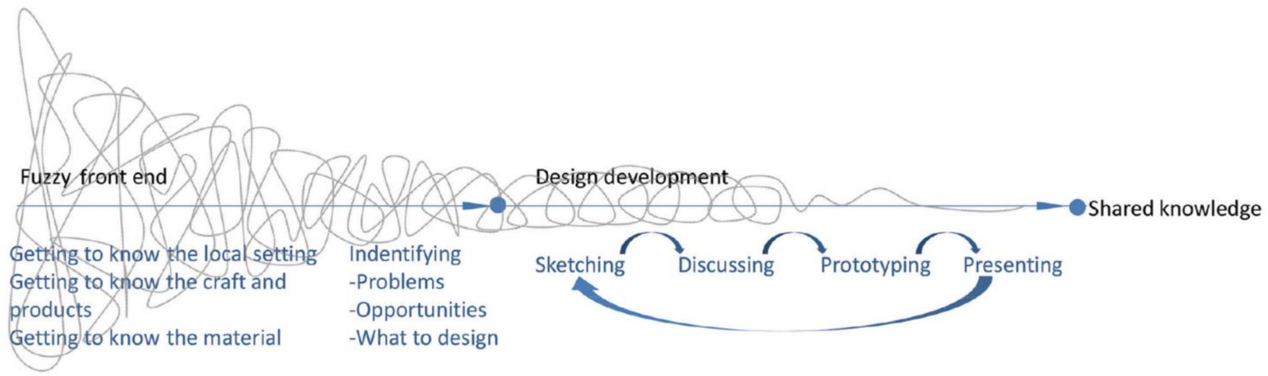

Figure 9. Tung’s craft-design collaboration model [28] based on Sanders/ Stappers

While the process and themes were similar, there are notable differences. This paper outlines a model for fairly long-term collaborations between crafter and designer. This poses numerous challenges when compared to a shorter-term ‘workshop’-style collaboration. Rather than a co-prototyping phase, which tightly couples the design and craft processes at an early stage, our case study revealed a need for individual exploration leading to subsequent assembly and evaluation. We observe that these individual explorations were also helpful in pushing designer and crafter to innovate on a domain-specific level, while keeping the shared brief in mind. In our case, the designer had to develop various physical joints to attach the electronics to the ceramic, without actually having the ceramic part yet; while the crafter explored additional techniques beyond turning to create forms that respond differently to the accelerometer. This cyclical process of co-investigation, individual exploration and assembly may prove to facilitate a longer-term craft-design collaboration beyond a single project. We can summarize these phases to our model for collaboration across craft and interaction design domains:

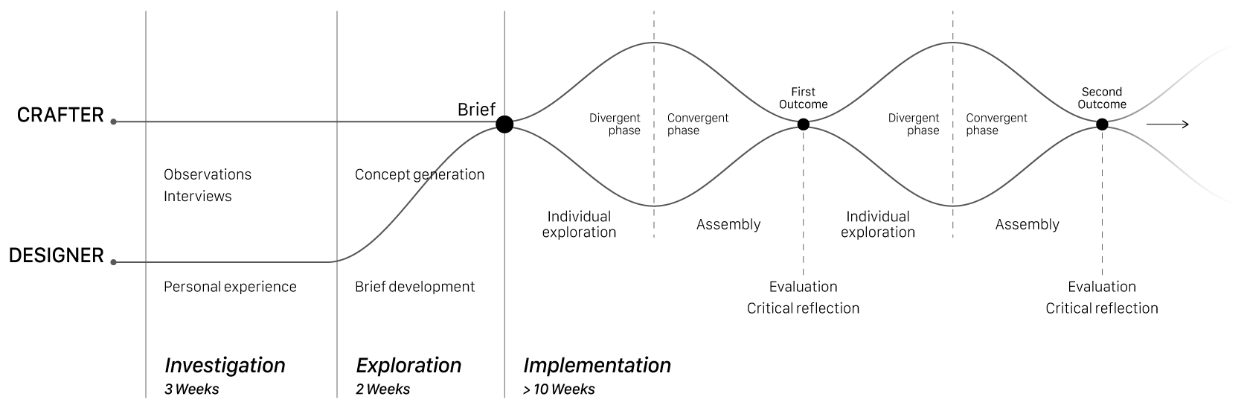

Figure 10. Collaboration Model

Our approach leverages the separate fields of expertise of crafter and designer as distinct and operating at times in asynchronous practices. The “fuzzy front end” appears less “fuzzy” and more distinct yet divided, whereby the initial division is not a problem but the basis for later creative

collaboration. This approach is both critical as well as experiential and enables the designer to formulate the brief. This brief stands out as a distinct focal point for both collaborators.
The brief is a turning point and establishes a collaborative feedback loop between crafter and designer. This dialogue continues over and through the emerging objects. These objects can neither be classified as speculative prototypes, nor as finished products, but as Ingold's things. The thing carries the qualities of a crafted object – including the weight, tactile affordances, and light properties. At the same time, these emerging qualities converse with its interaction design – including the code, the sensors, and the light emitters. As the designer noted in reflection: "I am accustomed to specifying every aspect of a 'product', from measurements to materials to color and texture. For this collaboration however, I felt like I was designing a system to work with the craft." The result is a process that assembles both practices over the evolution of a dialectic object. Notably, the thinking is not "*embodied in the artefact*" (Frayling, 1993) but the object itself offers active surprises that contribute to the shared development process.

Herein lies another difference between the collaborations outlined in Tung and our case. Unlike the collaborations discussed by Tung & Chen, commercial viability was never a consideration in our set up. Instead, we focused on the process as critical practice to combine creative collaboration. In this regard, our model responds to the notions of "critical making" outlined earlier. Here, the object serves as a stepping-stone for a critical engagement. *Making* is foregrounded with the objects providing reference points for the critical production and discourse work (Ratto, 2011). While we agree with the role of the shared object as part of the critical process, these shared objects stood out not only as traces but also as actors. They are reflective as well as creative. The object, as Mäkelä argues, can become "a method of collecting and preserving information and understanding" (Mäkelä, 2007). But while it is a collection method for Mäkelä's "artist-researcher" it becomes an operational tool for separating crafters and designers in our case. Scrivener suggests the term of a "knowledge artifact" that is "intended to inform" (Scrivener, 2002). Through the prevailing differences between crafter and designer, this "information" is no single message but a conversation that allows for the necessary divergence and convergence to develop. These developments have all the traits of a possible learning process, however the set-up of our study was not directly aimed to prove learning but explore collaborative options. The three stages of investigation, exploration, and implementation situate the key elements of our model: approach and brief, divergent and convergent phases centred around critical objects, that foster a dialogue instead of a merger of design and craft.

4 Conclusion and Outlook

Our model builds on existent concepts such as the Kellers' umbrella plan (Keller & Keller, 1994) but realizes them in a distinct dual approach. As a collaborative model, it allows to bridge the three identified approaches of craft and interaction design work: *technological*, *ethnographic*, and *craft-based* approaches. While the *technological* side is largely covered by the interaction design and the *craft-based* side by the collaborating crafter, the *ethnographic* approach realizes through practice: the initial approach of the designer to the crafter, the emerging collaboration, the focus on the object itself, and its settling in the community, as seen in the domain adjustment of the crafter in her gallery.
The challenge gains an anthropological perspective (notably Janet Dixon Keller and Tim Ingold are anthropologists) and builds on existent work that leans into that domain (e.g. (Goodman & Rosner, 2011)). We present a model for a constructive collaboration between the two domains that does not attempt a direct merger. Diversity between craft and electronics has already been noted as a defining quality criteria (Buechley & Perner-Wilson, 2012) and in our case, diverse practices realize through maintaining a collaborative but distinctly dual process. We did not attempt a teaching exchange, nor did we test for pre- or post-knowledge levels. But a benefit that emerged from our approach is the change of perception of the "other's" practice. The crafter was able to comment on

and contribute to the interaction designer's work and the designer reflected that "this relationship with the craftsperson removed the possible biases" on his side.
This paper outlined the underlying conditions and approaches, presented a sample realization of the model, and captured the underlying model that emerged from this work. Key components are the initial approach of the designer to the crafter, formulation of the brief, and the creative role of the shared object as a platform for discourse to unfold. We propose our current model to researchers as well as practitioners who work in the converging (and at times clashing) fields of interaction design and craft. It suggests an alternative to the proclaimed merger of craft and design into a new creative practice and offers a model to support this emerging area.

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Co-creation in Professional Craft Practice

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Design practice involves several disciplines, and when the manufacturing process demands special skills, designers outsource the work to craftspersons. Traditionally, craftspersons make a living by taking orders and delivering handmade artefacts according to the designer's prescriptions. In this paper, we ask the following: What are the essential issues emerging when designers outsource the manufacturing of their designs to professional craft practitioners? We present a case study in which aspects of sharing and experiential knowledge are analysed both from the point of view of the designers and the craftspersons involved in the making of artefacts for an exhibition. We found that having experiential knowledge of various materials benefits the designer and that material agency is an important issue in this process because the properties and production processes play a large role in the aesthetics of the final artefact. Multiple questions of authorship are raised in this context because of the aspect of outsourcing, and we suggest that this could be better reflected in the presentation of the final artefacts.

co-creation, design research, experiential knowledge, authorship

1 Introduction

Co-creation is gradually being promoted in several research contexts, such as in recent evaluations of EU research that recommend that collaboration should be more enhanced in future EU projects (Lamy, 2017). There is a need to focus more on interdisciplinary collaboration (Clapp & Jimenez, 2016) because over an extended period of time, research has been focusing on expertise from a monodisciplinary perspective. Since the design philosopher Victor Papanek promoted political ideas in design, a more holistic and ecologically inspired view on design practice has been reflected in design research (Papanek, 1971) forwarding the designer's role to contribute toward a responsible change of society as a whole (Melles, de Vere, & Misic, 2011).

Now, as we need to study expertise from an interdisciplinary perspective (Gibbons, 1994) it is of general interest to see the pros and cons of collaboration and to try to identify the various potentials and pitfalls of relationships in different contexts.

In recent studies of co-creation, it has been emphasised that the relationships between the people in the project are decisive for success, such as in, for example, community-based health services (Greenhalgh, Jackson, Shaw, & Janamian, 2016). Greenhalgh et al. (2016) demonstrated the potential of co-creative research as an approach that can have a real impact in society because the research can adopt to local cultures. In orthopaedic engineering of prosthetics for children in the Cambodian countryside, the need for co-design emerged (Hussain & Sanders, 2012), and a fusion of horizons of understanding was aimed for (Gadamer, 2004).

As people's emotions and presence are central to human collaboration, it is especially interesting to look at this interaction in professional areas where sensitivity is of vital importance, such as in the art, design and craft contexts. In co-design practices in service design, shared motivations and responsibilities together with mutual trust and shared making practices have been pointed out as the enabling factors for successful collaboration (Pirinen, 2016). In the current paper, we will discuss co-creation processes between craft and design practitioners. We look closely at this issue through two cases and discuss emerging elements through the lens of experiential knowledge, material agency and authorship.

1.1 Literature review: Co-creation in craft practice

Craftspersons have traditionally been educated in craft guilds through apprenticeship and in communities of practice (Sennett, 2009). Recently, craft practitioners have also entered academic research environments, giving an insider's perspective of professional craft practice and studio-based processes (Groth, 2015; Groth, Mäkelä, & Seitamaa-Hakkarainen, 2015; Heimer, 2016; Mäkelä, 2016; Niedderer, 2012; Nimkulrat, 2009, 2012; Pedgley, 2007; O'Connor, 2005, 2007; Riis, 2016). However, few studies have reflected on the collaborative aspects of making and learning in a professional craft practise.

Thus, co-creation is a subject less studied within the field of *professional* craft practice. Together with her research group, design and craft researcher Pirita Seitamaa-Hakkarainen has extensively studied co-design within craft–design processes (Härkki, Seitamaa-Hakkarainen, & Hakkarainen, 2016a; Härkki, Seitamaa-Hakkarainen, & Hakkarainen, 2016b; Lahti, Seitamaa-Hakkarainen, Kangas, & Hakkarainen, 2016; Lahti & Seitamaa-Hakkarainen, 2005); however, these studies were mostly in educational contexts with student participants designing in learning environments.

Other examples of studies utilising collaborative processes in material arts and design are textile designer and weaver Anne-Louise Bang and Ceramic artist Arild Berg. Bang (2010) studied participatory processes in the textile design industry, and through a structured and systematic approach, she explored how to design textiles by using a textile-based conversation and game-inspired design methods. Later, she explored how material objects can enable actors in a network to articulate and discuss topics that otherwise would have been challenging to identify (Bang & Christensen, 2013).

Similarly, ceramic artist Arild Berg (2014) studied collaborative processes in ceramic art practice. The central finding in his study was that collaboration enhances the topic of artistic integrity, but also the integrity of the collaborators, both personal and professional (Berg, 2014, p. 212). Participation and collaboration can therefore be more encouraged in ceramic art making, and even in other disciplines, to further investigate communication in co-creative activities.

1.2 Outsourcing and multidisciplinary collaboration

Although product design, as well as industrial design, has often been strongly linked to the knowledge of making and materials, it is only natural that the product designer or industrial designer cannot be expected to have practical, or even initial, knowledge of all manufacturing processes in the different disciplines that they work in. When manufacturing processes demand special skills, designers sometimes outsource the work to craftspersons. In this process, the designer has varying knowledge of the processes of production. There might be a steep learning process for both parties;

the designer needs to become familiar with the different affordances and constraints of the material in relation to the intended design, and the craftsman has to internalise the designers' idea, as well as the atmosphere and style of the intended design.

1.3 Experiential knowledge

Experiential knowledge is an important aspect of any craft practice and deals with the longitudinal embodied experience and knowledge of materials and processes that have become automatized and that form the basis for skilful performance (Molander, 1993; Niedderer, 2012; Niedderer & Reilly, 2010; Niedderer & Townsend, 2014; Nimkulrat, 2009, 2012; Wood, Rust, & Horne, 2009; O'Connor, 2005, 2007; Sennett, 2009). This *a priori*, personal and tacit (Polanyi, 1958, 1966) knowledge cannot be taught; instead, learning in the field of arts and crafts happens in communities of practice (Paavola, Lipponen, & Hakkarainen, 2004) through scaffolding (Wood, Bruner, & Ross, 1976) and active engagement with materials and peers (Wood et al., 2009).

In this process, the affordance (Gibson, 1986) and agency (Malafouris, 2008) of the material is physically tested and evaluated (Groth & Mäkelä, 2016), creating a practice-based knowing that may be linked to the theory of embodied cognition. According to this theory, we build our minds through our experiences, and the more experiences we have of a certain action or interaction, the better we can anticipate and predict the possible outcomes from future similar actions and interactions (Lakoff & Johnson, 1999; Johnson, 1987, 2007; Noë, 2004, 2009; Thompson & Stapleton, 2008; Varela, Thompson, & Rosch, 1991).

This tacit, personal and bodily knowing is utilised also in the craftspersons' *planning* of the processes and techniques to be used in the making of the designers' artefacts. In this process, the craftsperson considers the material properties' affordances and constraints. Often, these 'feeling based' calculations are already communicated to the designer or other collaborators in the making of a contract or offer, where they are sometimes even written in text. However, more detailed communication on the restrictions of the materials and techniques happen verbally in the studio or after the process, as we will see in the presented case studies.

1.4 Material agency

Restrictions related to the studio or technical aspects are more easily communicated than the constraints that deal with the material properties because these are partly tacit and too vast to be communicated in a few sentences. In the case of using *new* materials, the craftsperson is taking the risk of the material behaving in unexpected ways. A theory in new materialism introduces the idea that material has agency (Bolt, 2007, 2013; Malafouris 2008) or that materials are *vibrant actants* (Bennett, 2010). Thus, we are invited to re-think our hierarchical attitude toward materials (Coole & Frost, 2010; Bennett, 2010) and to consider material as an equal actor in the making process (Bolt, 2007) and that affects the aesthetic outcome to a large degree.

Through the current study's co-creation project in craft practice, there was an opportunity to explore this further, and we present a design and making process that took place over a year's time, following the preparation of two designers who intended to create a joint exhibition in a craft gallery. The research question was as follows: *What are the essential issues emerging when designers outsource the manufacturing of their designs to professional craft practitioners?* Through a case study approach (Yin, 2009), we will learn the story from both the perspective of the designers and the craftspersons who were involved and discuss the different aspects of experiential knowledge and exchange that emerged. Next, we present the methodology used for the research and describe the two cases. The different aspects encountered are discussed in more detail in the discussion chapter, where we touch on essential issues such as the experiential knowledge exchange, mutual trust and authorship in co-creation.

2 The craft studio as a design research environment

A ceramic workshop and a glass studio are the two settings for the current research. Two designers initiated a collaborative project because they planned a mutual exhibition at a local gallery space. The designers had worked together previously, they knew each other since studying together at the same design school, and they shared a similar style and vision. Although being educated as Masters of Arts (MA) in a practice-based design school, learning hands-on techniques for manufacture, both designers have continued their design profession choosing to outsource the making of their artefacts to either industry or professional craftspersons.

The exhibition date was set one and a half years ahead, and the work on sketching the designs was started through a mutual discussion between the two designers. The idea was based on making unique artistic pieces that built on functional shapes while highlighting the different material qualities of the pieces. The designers wanted to push both the aesthetic and physical boundaries in their art, bringing the material to 'the edge' of collapse. The materials, colours and main idea was agreed on mutually while the actual shapes were developed individually.

When the manufacturing of the intended designs started, craftspersons specialised in the chosen materials were contacted. The two designers were both present during most of the making sessions to continue the negotiations on the mutual direction that the pieces should follow. One of the designers, designer 1, opted for ceramics as the main material but also designed a range of objects in glass. The other designer, designer 2, opted for glass as the main material but had some details in ceramics. The division of labour thus was split into two studios: the ceramic workshop and the glass studio. To facilitate the description of this research setting, we gathered the data into two cases, as described below: Case 1 for describing the ceramic processes and Case 2 for describing the glass-making processes.

2.1 Knowing from the inside

The qualitative methodology utilised for the current research draws on ethnographic methods in which autoethnographic reflections (Ellis & Bochner, 2000; Mäkelä, 2003) are supported by interviews, e-mail communication and documentation from the co-creation process. One of the participants, the ceramic craftsperson, collected the material and conducted the interviews, while also reflecting on her own experiences. Because the authors are familiar with the process of this case and the processes generally involved in the described craft practice, we draw on personal and experiential knowing, a perspective described by anthropologist Tim Ingold (2015) as *knowing from the inside*.

A total of 51 e-mails were exchanged between the two designers and the glass workshop, 21 and 30 separate e-mails, respectively. These e-mail messages were analysed through a data-driven and thematic content analysis by colour coding according to the emerging themes present in the messages and reflected in the interviews. Three interviews were conducted, one each with the two designers and one with the main glassblower. The interview data totalled 2 h and 54 min of audio recordings. These were analysed through transcription and colour coding in the same manner as the e-mail communication. All communication was originally conducted in the Finnish language; therefore, transcripts and quotes from this material were translated into English for the purpose of the present paper.

3 Case description

3.1 Case study 1: Co-creation in a ceramic process

The designer first approached the craftsperson in early March 2016, showing initial drawings and discussing the designs and proposed making process (Figure 1). Meetings then took place over the period of 1 year on 9 days, which involved 45 hours of work, including loading the kiln and other smaller tasks. The last making session occurred in late April, 2017.

Figure 1 Initial plans and sketches for the ceramic pieces drawn by designer 1.

On each occasion, the process of making the ceramic pieces followed the same structure: the designer visited the ceramic studio with a certain shape or object in mind. The material and technical challenges related to the making of each object were first mutually discussed and then tried out in clay on the potter's wheel. Three different types of clay were used: white porcelain, black porcelain and a red coarse stoneware clay (Figure 2). Two of these clays were new to the craftsperson, and all three types of clay had very differing properties, affording the implementation of the ideas in different ways (Figures 3 and 4).

Figure 2 The ceramic craftsperson throws three different types of clay on the potter's wheel. Photo by the authors.

Figure 3 Newly thrown black porcelain pots. Photo by the authors.

Figure 4 Pots ready to be fired in the kiln. Photo by the authors.

The work in the studio was conducted in a way that allowed for the designer to sit down in front of the craftsperson and the potter's wheel. The shape was then sought for together while referring to the 1:1 drawn images that were placed in the studio. The designer reflected over this process in the interview:

> *Making with you (the craftsperson) is in a way like sketching through your hands. I can see how you kind of are drawing the shape for me in the clay, and I can say when it is good or when it is going in the wrong direction. You then also make suggestions and often we both know when the shape is just right.*

Also, the craftsperson agreed on this seamlessness in the making process: "I felt like my hands were extensions of the designer's eyes. Our minds were working simultaneously, and we both fed into the process of making". Although there were problems that caused disappointments and unexpected changes to the plans, the mutual learning process was experienced positively by both the designer and maker. The designer reflected on this in the interview:

> *The results were not what I had expected, but it was better than that! All the processes that influenced the making made the pieces surpass my initial drawings, and in the end, we threw the drawings away. But still I feel that the pieces became just the way I had*

wanted them, they carry the same spirit in them even if they are not exactly like the drawings.

The ceramic craftsperson felt it was a pity that the chosen materials had some problems with cracking and that the coarse clay was not suitable for making the pieces as large as imagined. However, the final pieces that came out of the process were expressive and challenged the aesthetics and material properties in an interesting way. The maker also felt she had challenged herself as a maker and knew she had worked on the edge of her physical ability.

3.2 Case study 2: Co-creation in the glass-making processes

The two designers initially contacted the glass studio with their ideas by e-mail. Designer 2 made the initial contact on behalf of both designers, sending the intended designs as images (Figures 5 and 6). The title of the initial e-mail message was: *Art glass project: glass blowing, tests and consultation; are you interested?*

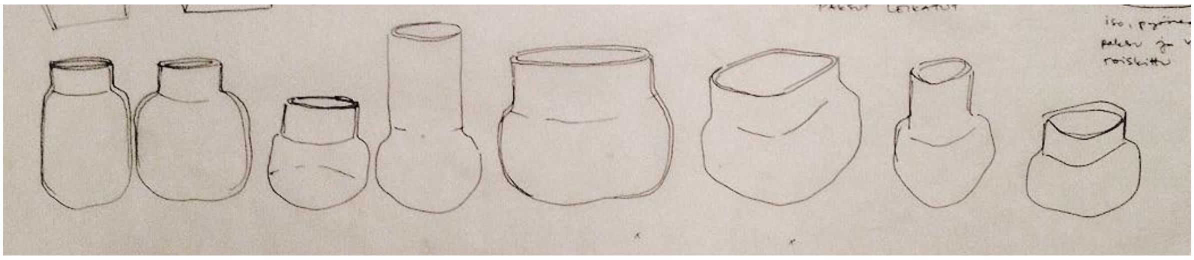

Figure 5 The initial ideas for the glass pieces by designer 1.

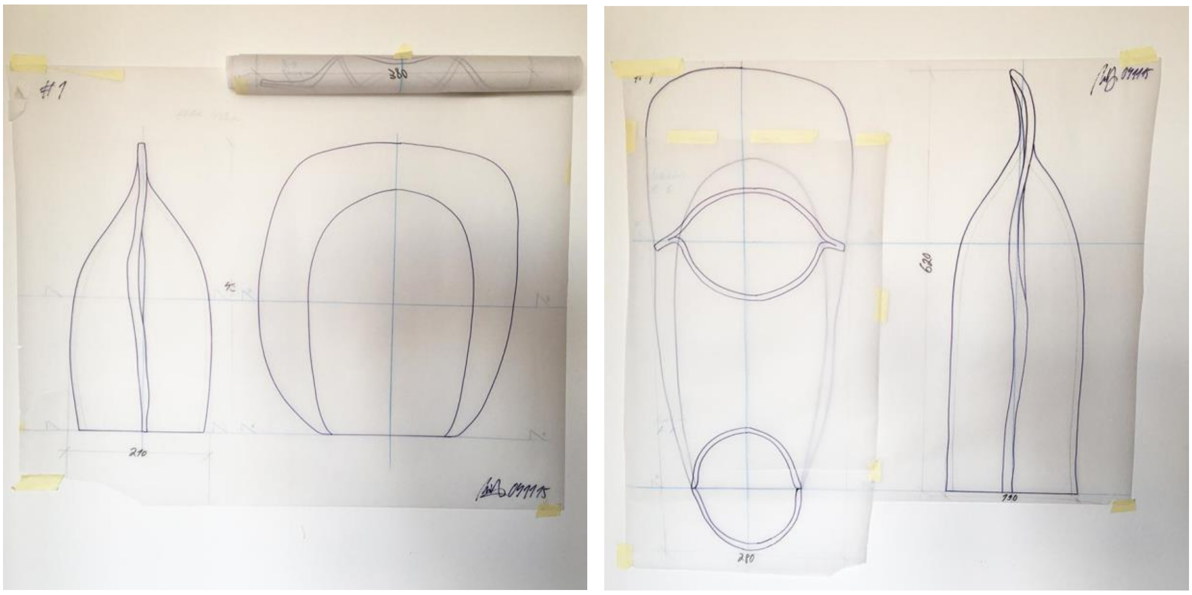

Figure 6 The initial ideas for the glass pieces by designer 2

The actual making process was proceeded by an agreed upon 'prototyping day' that would last for 7 hours. During the prototyping day, the designs were modified according to the results of the testing. The shapes were very unusual, and the glassmakers had never done something like this before; it was a learning process for both the designers and glassblowers, and the main glassblower said: "We have never done anything like this, great, let's go for it!". Through the tests conducted on the prototyping day, it was agreed that moulds were needed for the glassblowing. The moulds were then designed and communicated via e-mail and made by a separate mouldmaker prior to the actual glassblowing day.

Figure 7 Blowing hot glass into a wooden mould. Photo by the authors.

The final pieces were made over the course of a whole day of working in the glass studio, half a day for each designer (Figures 7–10). Because glassblowing is comparatively expensive, the timetable was very tight. The pieces of designer 1 demanded the need for two glassblowers and two assistants; therefore, four people were involved.

The pieces were also ground and polished in the cold workshop after cooling down, by yet another craftsperson specialised in grinding. The coldworking process was monitored by one of the two designers because the aesthetics of the pieces are much enhanced by the different coldworking options. Designer 1, who was not present in the cold workshop, said in the interview: "The cold worker made the suggestion to sandblast one of my pieces, and I hate sandblasted glass! But the piece turned out great and it was the most liked piece in the exhibition. I would never have come up with that idea myself". Designer 1 also appreciated the friendly advice given by the glassblower in the choice of colours because the glassblower knew how the colour affected the behaviour of the glass.

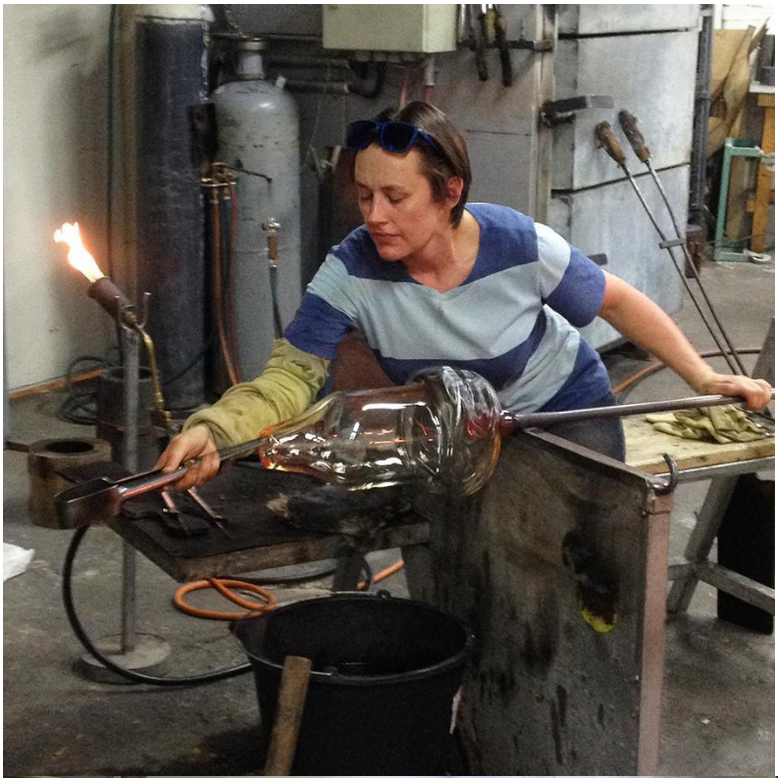

Figure 8 The glassblower is shaping the hot glass using metal jacks. Photo by the authors.

Figure 9 Several craftsperson's collaborative blowing and shaping of the hot glass piece. Photo by the authors.

Figure 10 Shaping the blown glass by pressing. Photo by the authors.

In the end, the pieces were modified away from the initial design to a large degree. The addition of moulds and grinding made it too costly to use more time in the studio and to make additional try-outs of the larger pieces. However, the glassblower was generally happy with the process and the outcome, as she knew the restrictions that were present.

3.3 Exhibition opening

The pieces were finally exhibited in the *Lokal Gallery* in June 2017. The exhibition was promoted with a concept text that described the making process and underlined the two designers' intentions and mutual visions as a collaborative endeavour. One of the designers gave a speech on the opening night, describing the collaborative nature of both the designers' work, as well as the manufacturing processes and collaboration with the craftspersons. The glassblowers, the glass grinder and the ceramic craftsperson were all mentioned by name in the speech.

Figure 11 Exhibition opening. Photo by Katja Hagelstam.

Figure 12 'Äärillä' (on the edge) pieces. Photo by Chikako Harada.

Figure 13 'Äärillä' (on the edge) pieces. Photo by Chikako Harada.

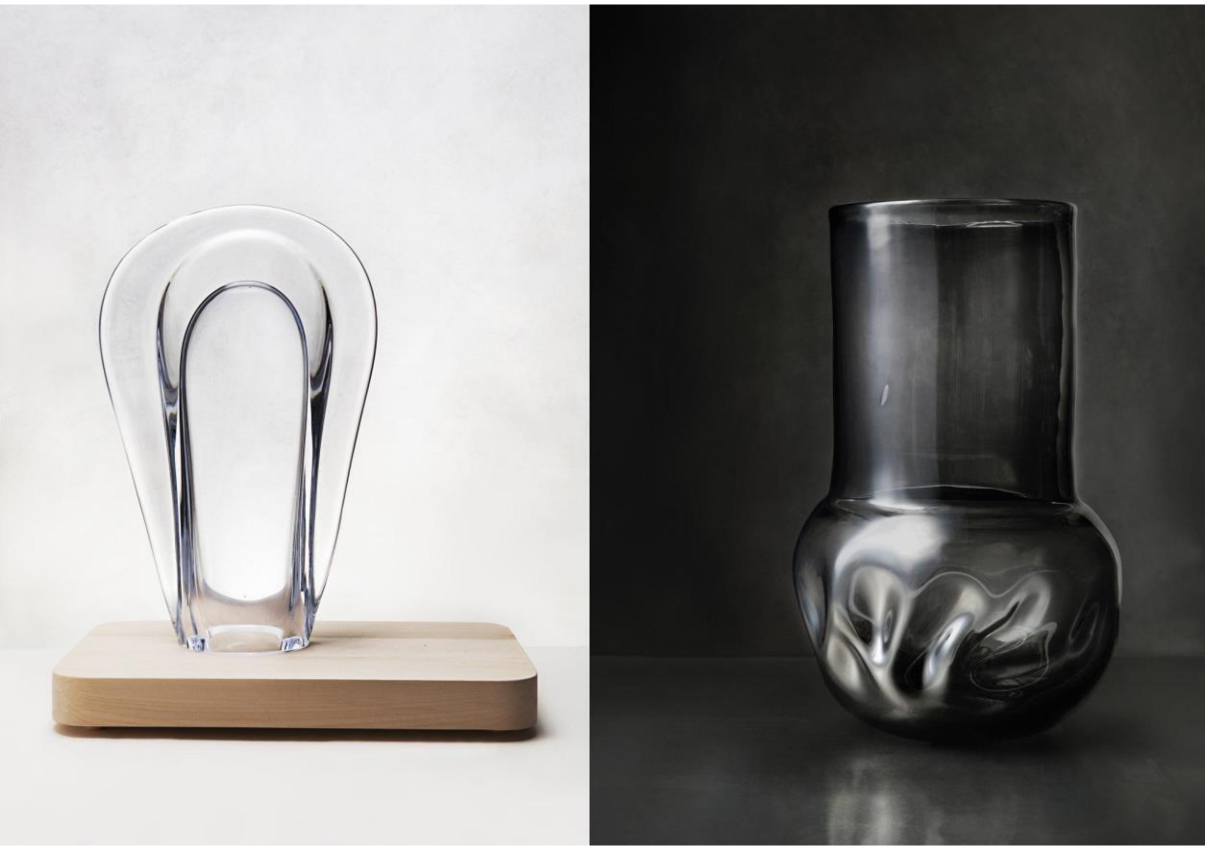

Figure 14 'Äärillä' (on the edge) pieces. Photo by Chikako Harada.

4 Discussion: issues rising from co-creation in design and craft

The project unfolded in a typical manner: the craftspersons materialised the ideas of designers. The final produced artefacts were not exact copies of the initial designs; instead, many factors played a part in the artefacts' final conception, and all together, nine people were involved in the making process. The materials and techniques utilised also had a say in how the designs turned out in the end. In this section, we look closer at what happened in the process, from drawing to exhibiting the artefacts.

4.1 Co-creation: mutual trust and distrust

The process followed the common procedures of outsourcing labour: the designers asked their designs to be manufactured by craftspersons according to the designers' instructions. However, their mutual input during the process made the project attain co-creational features. The analysis showed that the word *together* was mentioned 26 times in connection to making activities in the e-mail communication between the designers and glassblowers and was mentioned 73 times in the interviews. The 'making together' in this context refers to being present together, looking together, evaluating together or commenting on the process of making together. The verbal and bodily communication between the designers and glassblowers is seen as *the form of making* that the designers bring to the process.

Both designers expressed worries that their *making* in this respect would not be good enough or could be more skilfully conducted and that this has a direct effect on the successful or unsuccessful outcome of the hands-on making process of the craftsperson. In the interview, designer 1 said: "I was really nervous before going to the glass workshop. I worried that I would not be able to describe what I wanted well enough, and I was afraid that the pieces would not turn out well because of that". The two designers had discussed the issue during the project: 'We talked about how important it is to clearly explain and to speak up when things are going in the wrong direction. We cannot expect anyone to get into our heads'. Designer 1 said further: "It's important to create trust between the designer and maker so that the craftsperson dares to make suggestions that she thinks are good rather than just following the drawings blindly". From the glassblower's point of view, the collaboration went smoothly, and in the interview, she said:

> *It was good to work with such experienced designers because they are used to collaborating with others and they dared to ask questions and were thinking a lot about the process beforehand. In this way, we were ready to start working straight away.*

The glassblower also highlighted the fact that in experimental processes, it is important that the designers are present so that they can better understand what challenges and constraints lead to the change of plans: "Some aspects can be planned for, but most decisions are made very quickly in the course of the making".

The two designers represented two different attitudes toward the manufacturing process. They especially expressed differing opinions on the issue of trust and reliance on the craftsperson's ability or willingness to collaborate and produce the intended designs as ordered. Designer 2 was unhappy with the defects in the finished glass pieces that came from the use of handheld tools and the manipulation of the glass via secondary materials, such as the gas flame, cold marks from the pressing of wood or air bubbles inside the glass. As a professional designer, she aims for the best of quality and does not want to settle for second best. This has a direct influence on her credibility as a designer because she feels that she wants to stand behind her designs 100% in the exhibition. She recognised the professionality of the glassblowers and said, "They are really super professional glassblowers!" But designer 2 reflected over what she had learned in the process:

> *I try to learn from each of these projects and be humble over what mistakes I have done and where I could become better, and I really think I should be clearer in my briefing of the project and in my descriptions of how I want the pieces so that they really*

> *understand what I mean. But I guess glass people are really much 'in the moment', and they might not plan ahead in the same way as we designers do. They just try out things and see what comes out.*

Designer 1 expressed another view: he fully trusted both the glassblower and ceramic craftsperson to do their best in times of difficulty. He said: "Of course I was disappointed, but hey, what did I expect? I had imagined that I could achieve all those different kinds of designs and so many of them, of course it was not possible!"

In the mutual interview, conducted 5 months after the opening of the exhibition, both designers reflected on this difference in attitude and connected this to the different type of design education they had received. Designer 1 is educated in the ceramic and glass department and after graduating has specialised in ceramic product design. In the interview, he said:

> *An industrial designer has to use many different materials and is used to designing, for example, metals and plastic. Most such materials do not change or move very much during or after the process, not like clay that moves and changes a lot during the firing in the kiln for example. In contrast, someone educated in ceramics and glass expects these materials to change in the process of making, and they might therefore be more accepting of this process.*

Designer 2 is educated in the applied arts and design department and after graduating has worked in various materials. She said in the interview:

> *I see myself as somewhere between industrial designer and product designer and admire craftspersons, and I wish I could make things too. My making consists of designing and drawing, the computer is an important tool for me because I have to be clear in the communication with both industry and crafts people, the ratios and the centimetres have to be exactly right so that there are no misunderstandings.*

Essentially, the two designers had different scales for what was meant by quality in the craft process. Also, the glassblower described this aspect in an e-mail soon after the first prototyping day:

> *One has to make decisions about quality on the axis prototype-finished piece. Unique prototypes carry the process of making in them. Even if the result is something else than what was originally designed, the piece is a result of that process and a similar piece might never be made again. In such cases, the price of the artefact is made up of other qualities than perfection.*

In the interview, designer 2 reflected that "well in the end it was supposed to be an artistic collaboration, so we should not have expected it to be so precise as we did. It would be great to learn to be so flexible and relaxed as the glassblowers were".

According to Patel, Pettitt and Wilson (2012), successful collaboration is achieved through the complex interplay of several factors and situational features, for example, the characteristics of the individuals and their interaction processes, the provided support they get and the characteristics of the context. However, some values can often be different when people collaborate, and conflicts might emerge from this. If this challenge is overcome, original, new ideas might rise (Berg, 2014, p. 218).

4.2 The voice of the material

The aspect of knowing the material and its affordances make up the experiential knowledge of the craftsperson. But to what extent is this knowledge useful for the designers? In our cases, the material properties played a part in the process that led to the change of the aesthetics of the finished pieces. When the designer's expectation of the material properties was not met, there was disappointment. However, these disappointments were overcome by a gradual process of acceptance. This process happened in stages, mostly in the form of a learning process of the designer that was facilitated by the craftspeople explaining what is possible and not.

We tie this process to the acquiring of experiential and embodied knowledge through the act of physically manipulating material and learning what the material affords. Through this process, the mental image of the intended design is subsequently shifted toward a more realistic direction because the designer 'makes sense' of the affordances and constraints of the materials and techniques. This process is visualised in Groth's (2017) model of embodied sense making (Figure 17).

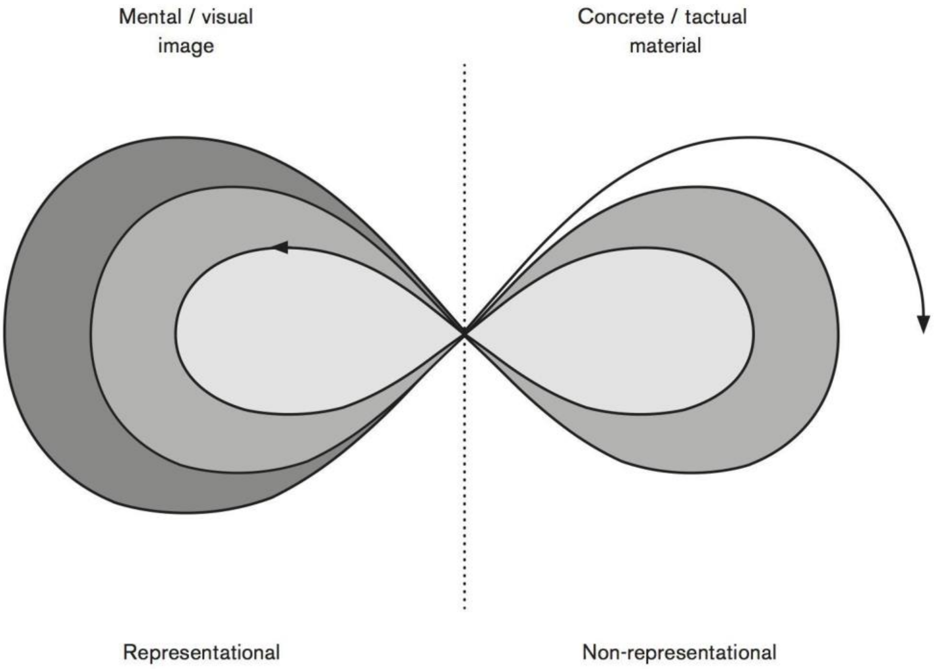

Figure 15: Model of embodied sense making in design and craft practices. Source: Groth, 2017, p. 64.

Here, the two modes of making — the conceptual and immaterial planning on the left and the material and concrete testing in reality on the right — are displayed. The designers' process is visualised as a loop starting at the creation of a mental image or idea of a design, and this is tested in concrete material and readapted again in the mind of the designer until the idea of the design and the possible material outcomes have merged. This process is more thoroughly understood when experienced personally and physically rather than observing this process. Because the designers in the current case study also tried out manipulating the material themselves in some details, they could better accept the change that their design had to take because they experienced the material limits and understood on a concrete and embodied level the constraints of the material.

4.3 Authorship

The designs of the artefacts were negotiated from the start of the process until the very end. What was imagined was not practically or materially feasible, and the design was changed in the making process. In the case of ceramics, the initial designs were negotiated millimetre by millimetre as the shapes were thrown on the potter's wheel, and the opinions of the craftsperson were asked and accepted. In contrast, the glassblowers were keen not to add any personal dimensions to the finished product and did not claim any authorship of the process at all and said: "We try our best to find and enhance the style of the designer we work with".

However, when designer 2 was asked in the interview whose ‘hand print’ the pieces carry, she answered: “I would say that the pieces are 70% the glassblowers and 30% mine because they are not what I drew in my design studio”. Saying this, she acknowledged the fact that there is always hand marks and signs of the makers when outsourcing the design, and she further said that a 50%-50% ratio is what she strives for rather than 100% her own design: “But I was very happy with the exhibition in the end, when all pieces came together they fulfilled each other, and it looked very good”.

According to Hennessy and Murphy (1999), collaborative teamwork contains the challenge of actively communicating and coordinating the team’s accomplishments, but it also offers the incentive that the end results can be much more than the totality of individual contributions. As seen in this case, the pieces were altered through the making process, and authorship was blurred in the process; however, in the end, all the participants agreed that the pieces were now *more* than what they would have been if made individually.

There is a difference in the disciplines of unique glass and ceramics practice regarding how the authorship is perceived in cases where a unique art piece is made to meet an order. In the discipline of glass, it is more common to order a design to be made by a glassblower; although in the end, the piece might be signed solely by the designer. In this case, the glass pieces were not signed at all by either the designer or maker.

In the case of the ceramic collaboration, both the designer and maker signed the pieces with their name stamp while the clay was wet, a proof that the name was not added at a later point but that both were present during the making of the piece (Figure 18).

Figure 16: The ceramic pieces were stamped by both the designer and maker of the pieces. Photo by Chikako Harada.

This practice was initiated by the designer, who insisted on the use of both stamps. The craftsperson found this a natural step because her hands had marked the piece in every aspect, and although the design was not hers, the shapes were the fruits of a mutual understanding on how to best interpret the 2D drawn designs and form them into 3D clay shapes. The glassmakers in this collaboration did not make any claims of authorship; however, they did say that seeing their company name mentioned next to the pieces that they had manufactured for someone else made them happy.

The glassblower also said that she would never convey any opinion regarding the style or aesthetics of a design by a customer but instead always tries to do exactly as the designers wish: “There are so many different types of good, we cannot judge what is good for someone else”. However, in her own practice, when designing and exhibiting her own work, she admitted to being very critical of what she chooses to display.

Shared authorship has been identified as a motivator and enabler for co-creation (Bhömer, Tomico, Kleinsmann, Kuusk, & Wensveen, 2012), but as in this example, the authorship is given up by the payment of a salary; the designers may not entirely trust the makers to have intrinsic motivation in the project, and they might not trust them to carry the same responsibility or ‘worry’ about the successful outcome.

This is of general interest in co-creation processes in other fields. One example is from film production and the relationship between a screenwriter and director (Pelo, 2010); here, the constitution and sharing of authorship are identified in both gathering ideas, sketching, building the story structure, writing drafts, rewriting and completing the final draft. Authorship in film production can be used as a model also in the designer and craftsperson relationship. In a film, the contributors and their role are listed at the end of the film. This resembles the references in an academic text, where it is a standard to refer to those who have contributed to the product and the common effort to expand knowledge on a topic.

In a similar way, in production processes in design and craft, the list of contributors could be listed as co-creators. Another general example is the rising demand from consumers to know about the production line in the food or clothing industry, where qualities such as ethical standards in the production and knowledge of the country origin are seen as a part of brand attachment and brand experience (Nguyen, Dadzie, Davari, & Guzman, 2015). Nguyen et. al (2015) claimed that this eventually contributes to the consumers' perceptions of the firm's intellectual capital and the corporate social responsibility of the company.

5 Conclusions

In the current paper, through an inside perspective, we analysed the process of co-creation in professional craft practice. The outsourcing of labour that involves monetary aspects and services is similar to how co-creation happens in other professional fields, such as in film making (Nguyen et al., 2015) and service design (Greenhalgh et al., 2016).

The designers calculated for the costs arising in the process of testing the designs and making prototypes. However, the limitations of the studio environment, the craftspersons’ physical abilities, the materials changing properties or agencies and the influence of the mouldmakers’ and glass grinders’ work affected the initial designs to quite an extent. In product and industrial design practice, where the products are manufactured in production lines and by machines, this is naturally not the case, but in manufacturing involving handmade processes, this aspect is often present; sometimes, this is experienced positively and sometimes negatively.

Also, the complex question of authorship surfaced as an essential issue in the current investigation. Authorship is affected by the relationship of a paying customer and service provider and the setting of the collaboration. In an intended co-creation project, the authorship is naturally shared, but in a customer–service provider relationship, the authorship rests with the customers. Different disciplines, such as glass and ceramic practice, have different customs in this respect. The question of mutual respect and authorship is of emerging interest in co-creation projects and also in a wider perspective both in cross-disciplinary practical projects and the emerging amount of interdisciplinary research projects (Lamy, 2017).

In this case, it has been shown how pride and professional identity are at stake when outsourcing the manufacturing process to craftspersons, where the authorship stays with the designers. The outcome must meet minimum requirements of quality, but these are subject to internal and external negotiation because there are multiple types of qualitative standards. In the end, it is an issue of mutual trust between the collaborators and the recognition of the co-creation activities.

Because of the current study, we can say that co-creation is a sensitive collaboration in which it is important to build trust and respect for each of the collaborating partners. The communication of intentions and abilities, as well as informing each other of changed plans due to internal or external constraints, preferably needs to be done in real time because distrust easily builds in these situations. Therefore, it is advisable that designers take part in or attend the making process if possible because they are then able to better adjust to the changes made to the artefacts that may arise because of unexpected events, hence being able to see why these changes had to be made and sharing the experiential knowledge and sense making of the processes.

In addition, we propose that the authorship of the artefacts is more readily shared if the collaboration is extended to the making process. Therefore, it can contribute to the designer's corporate social responsibility and strengthen the brand value by ascribing shared authorship to the craftsperson in cases where the artefact is made by hand. These research perspectives might, however, still be in contrast to many design practices in the co-creation process, ones where the craftsperson is paid for the work; here, the payment often is seen as a compensation of the loss of authorship. Another perspective is that there might even be situations in which the craftsperson is not interested in the shared authorship of the product, especially if the craftsperson takes on jobs that might stand outside his or her sense of good taste. However, the current study might contribute to a change of craft practice toward more shared authorships. More research is needed in this topic, especially the opinions of professional craftspersons from different domains should be heard.

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Embodied Knowledge in a Community Adaptive Practice

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This paper aims to understand experiential knowledge in a community practice of making by expanding the definition of a designed-object, and design-authorship. It seeks to do so through an enquiry into the making of an object-tool used and made by a community of manual load-bearers in Delhi's vegetable and fruit markets. Tool-making requires an understanding of the task and body's capability. These load-bearers, over decades, have devised two distinct object-tools from understanding contextual differences in material-forms of load being carried, their bodily limitations and available material constraints. The repeated sensorial, kinaesthetic and embodied experience of carrying loads gives raise to a collective body of experiential knowing from individual knowing. It is a form of an open-authorship knowing. Any user-maker can try new iterations, if it eases the task of carrying loads; the adaptation becomes a standard and permeates through the community. Design iterations are made with availability of new raw-materials, change in task of loads to be lifted, thus, the experiential knowledge in object-tool is ever changing.

open authorship, materiality, tool-making, experiential knowledge

1 Introduction

The experiential knowledge used in disease diagnosis, sea navigation or animal paw-print readings for hunting (Ginzburg and Davin 1980) is different from the tacit embodied knowledge of handling materials and object-making (Ingold 2013) like that of making earthen pots or bamboo traps and baskets. Resource and technology scarce communities learn ways of need fulfilling that are extremely contextual; through use of hand-skills they optimise available local resources to craft object solutions. Their making practices are transmitted through generations by sensorial, kinaesthetic and experiential interaction of hand-skills with their body and available local materials (Marchand 2007, Sennett 2008, Pallasmaa 2009, Ingold 2013 , Niedderer 2013). These communities develop experiential knowledge around survival, resource management and livelihood. The making of object iterations in these community practices span generations thus community members continually add and remove aspects forming a dynamic knowledge repository that is accessible unevenly within the community.

This is a case study of embodied knowledge used in a practice of making; the knowledge is openly shared and added to in a unique kind of maker-user community. More than a finished object or even the act of it being used, it is in the act of its making that the experiential knowledge held by its makers is most tangible and best articulated (Niedderer 2013). A unique space to study this is offered in practices of making and doing that are necessary for the survival of a practicing community. The knowledge of these practices is possessed by the whole community, and is treated like an open resource. Cumulative knowledge added by individuals is transferred over generations. The practice continually adapts to the social, environmental and economic changes faced by the community in its context through optimising use of material resources in its direct control.

This paper identifies and tries to fill the gap in frameworks to articulate experiential knowledge in community practices because standard frameworks of scientific knowledge do not allow for an appreciation and understanding of a community's experiential knowledge (S. Marglin 1990, 232-256). It is at the site of transmission that experienced practioners make their knowledge made most explicit for novices, but even so the master-makers do not (and can not) articulate all their experiential knowledge, which is often second nature to them, hence a novice must become part of the practice to learn nuances from her own embodied immersion in the practice (Sennett 2008).

2 Object, people and context

A handcrafted object that reflected a contextual understanding of solution finding from available material resources was found in the vegetable and fruit markets of Delhi. This object helps the users undertake their livelihood and is shaped by the users themselves. The object is hand-made through materials found in the market context, it was also an articulation of the experiential knowledge the makers have of their bodily limitations, material constraints and the physical function/task that needs to be accomplished. There are two variations of this object and a comparison of these two similar yet highly context specific back supports demonstrated that the makers and users possess a unique embodied understanding of material, male human body, ergonomics, motion and weight.

The user-makers are male manual labourers who store goods inside the vegetable and fruit market from trucks bringing these goods and take goods out from storage on purchase. These men have over many generations, fashioned a jute-gunnysack back-supporting object-tool that cushions their backs and helps them ease their burden during this work by reducing abrasion on their body. This handcrafted object-tool is called a '*pitthia*' in Daryaganj vegetable market and '*pitthu*' in Azadpur cold storage market.

Table 1 Functioning aspects of the two market and the communities.

LOCATION	DARYAGANJ – VEGETABLE MARKET	AZADPUR – FRUIT MARKET
Timings and Seasons	All year-round work, Summer till 10am; Winters till 12 pm	Lean season Monsoons June–August Productive season October –March
Loads/ Products	Sacks – Jute gunny, plastic sacks Length more than width or thickness	Cardboard cartons, Plastic Crates Equal component of width and thickness, varying height of loads
Distances, terrain and weights	Walk over uneven ground Usually 200 meters, up till 1km, 50-100 kgs	Climb Staircases 4-7 floors, 15-20 meters 35-60 kgs
Process cycle And Temperatures	From 12am(or 3/5am) till 11am(or 1pm) Summer 25°C-40°C; Winter 5°C -20°C	All day/night in high season Off-season 6am – 10am & 4pm – 10pm 8°C to 4°C to –4°C
Age	20-65 years	16-40 years
Livelihood Time	3 years – 30/40 years to lifetime	6 months – 15/20 years
Posture	Walk bent Support the sacks with hook and hand	Walk almost upright Sometimes hold ropes attached to *pitthu* arm straps
Built	Usually malnourished and slight in built	Usually well built
Object-Tool	Lower back support	Upper-mid back support

The Daryaganj vegetable market is located within the walled old city of Delhi since 16th century. Azadpur is a wholesale fruit and vegetable market established in 1970s when large cold storage facilities were relocated to northern edge of Delhi by the government. In both markets the labouring men belong to a particular region but are not related by kinship. The men in the Daryaganj vegetable market are mainly from the eastern Gangetic plains of North India and those in the Azadpur Cold Storage facilities are from Nepal and neighbouring Himalayan region of Northern India.

Pitthia/pitthu and its parts are named from human body parts that they support in Hindi e.g. *peeth* means back or spine; for the straps *baju* means arms. *Pitthia/pitthu* as back support covers/cushions and protects the length of the back. They are made from jute gunnysacks stitched with plastic rope and are held onto the body with shoulder straps for passing arms through. There is an extra firmed-up support, at the lower back or upper back, to rest loads of either sacks or cartons. A difference in the loads to be carried has lead to a difference in support, which has led to the development of two different variations in the object-tool, which weigh about four to five kilograms. The making of this object is only known within the collective of load bearers, who are the users of the object. This object does not have an existence in any form including name, reference and visibility outside this market space. Figure 1 and 2 show variations in the loads, and carrying postures in the two markets; while figure 3 and 4 show the differences in the object-tool in the two markets.

Figure 1 Two sacks being loaded onto the loadbearer in Dariyaganj vegetable market total weight is approximately hundred kilograms; Figure 2 A labour in Azadpur fruit market needs to walk in a rhythmic balanced manner to carry four half cases of about ten-eleven kilograms of mango, each. Source: Author

Figure 3 A pitthia and Figure 4 A pitthu; notice the relative height difference between the two object-tool, the position of the support and variation in material, wood in Daryaganj, and rubber belt in Azadpur; also obvious the variation in the joinery of the strap to body of the pitthia and pitthu; Notice the variation in the use of plastic in the two locations. Source: Author

3 Method: Making tells more than the Object

An object is the articulation of knowledge (Zimmerman, Stolterman and Forlizzi 2010), yet observation of a finished prototype or even use of an object-tool cannot tell what the user and maker tacitly knows about materiality and body abilities (Polanyi 1966, Niedderer 2013). This research was aimed to understand tacit knowledge in collective design action and the dynamic nature of this knowledge, especially when the user is also the maker and is constantly exploring the making of an object-tool. The reason for selecting a making practice that is not formalised into an expert craft is that only in a still open-ended and adapting practice that the points of trial and errors, as well as form changes in the object being made can be observed. To be able to understand this collective design process required being a part of this community. It was decided to temporarily be a part of the community by participation in the making of the designed object-tool as well as spending time in the working and living space with the members of the community. The research was conducted in-situ in both market sites, where all members of the load-bearer community were using the object-tool and where as user-makers they periodically replace the object-tool.

The research was carried out over a period of seven months from July 2015 – January 2016, with the first few months focusing on the Daryaganj market and the later focusing on the Azadpur market. Simultaneously analysis of the process of making the object tool, of the task of lifting loads as well as the bodily experiences of the load bearers was conducted till February 2016. A case study approach inspired from ethnography was used along with involvement in making. The users themselves were unable to articulate how this object making improves their world and its particularities of form, material and strength except in and during the act of making. The study of two similar yet distinctly different object-tools in the two markets allowed for a comparative study for understanding the knowledge and the making process.

During the research period, the researcher made the object-tool in both the markets with tangible verbal and demonstrated instructions from the community, besides tacit guidance through bodily experiences of both the material its strength, malleability, tightening and the final object-tool. This process of instructed making was recorded. Digital diaries were made of the task of load lifting while using the object-tool and the making of the object-tool. The researcher was involved in the act of making and using the object as a novice to learn critical junctures in making and using. The object as a tool was observed for the manner in which it aids in load lifting, but only in its making was the maker-user's knowledge of the body, the task, and materials understood to a certain degree. This making of the object-tool allowed an uncovering of what is crucial to the functionality of the object, thus expanding the definition of a designed object.

Interactions with the users-makers were also recorded, these communications with the makers and involvement in the making process allowed a reflection of the trials and errors explored in making this object-tool and its current stabilised form and materiality. Investigating the making process allowed for an articulation of the experiential knowing the maker has of the object, materials, his load-bearing activity, its conditions and the body (in this case male only). It also helped understand the individual choices the load bearers exercised in making variations in techniques of stitchwork, in their choice of material, or position of the placement of straps. There was a conscious decision to understand the point where the object becomes a standardised template and the scope of customisation individually necessary and available within the object-tool.

3.1 Relevance of Making and Repair

When someone starts working, they need this object-tool, for this they assist the person who can make it, this is where their first observation of its making begins. Not every object-tool is made by the user himself, but most men assist in its making. A relative, who brings a newcomer to the marketplace for pursuing the livelihood, persuades a known maker in the community to make the object-tool for him. A newcomer who cannot get anyone to make a *pitthia/pitthu* resorts to buying. In Daryaganj, this could be an old *pitthia* purchased from someone who is leaving this profession, or a new *pitthia* commissioned from one of the makers, rarely, some men take ownership of another's *pitthia*, if he is not around or has gone to his village. While in Azadpur, anyone who enters the profession pays for the jute gunnysack, at times after a month of working, and gets a new *pitthu* commissioned. This object is much more necessary to accomplish the lifting of cartons than it is to lifting of sacks. In both markets, the payment is not explicitly monetary but can be translated to an economic return, maybe lift some weight for him, feed him something, or buy him drinks, often weeks after the making. There is no exchange for making in kinship[1]. Therefore, economic motives have a lower consideration than the social relationships, in the context of these markets.

In both the markets, all users can repair their own *pitthia/pitthu*, even those who claim to have no knowledge and ability of making one. The object-tool usually lasts about one and a half to two years. In both places, they reinforce a new one after using it for one or two months with stitch-work. In Daryaganj they use running back stitch, which runs through the entire thickness of the folded sack back-support binding it. In Azadpur they use chain stitch, which is only done on the top layer leaving the last layer of the folded sack without stitches, see figure 5 and 6.

[1] Often, kinship in rural India includes anyone who is from the same village/town, besides blood ties.



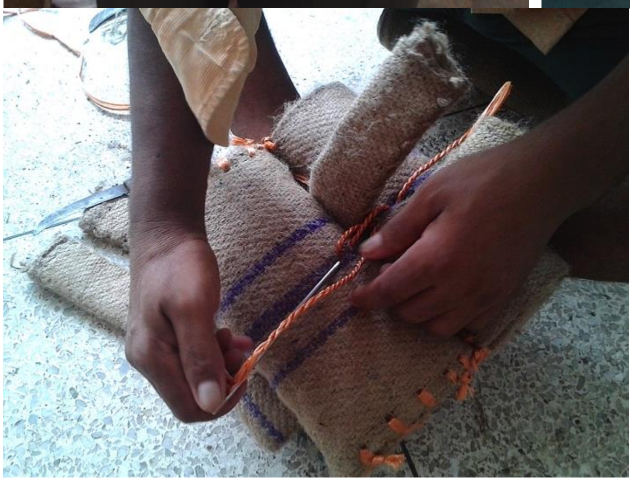


Figure 5 This pitthia has new straps attached in jute atop a plastic sack reinforced body. Figure 6 A month old pitthu, with the user beginning chain-stitch on the straps. Figure 7 Stitching a knot in the middle of the base, which will support the straps. Figure 8 Attaching the wooden support piece. Source: Author

In Daryaganj, most men can clearly define the process and steps of making, but when one wanted to make one was directed to only one specific person. Here, all the men can repair and do so to increase the longevity of the object-tool. Only one man said, he has never made and cannot make one, but even he repairs his *pitthia* at regular intervals of every year or so[2]. He recently used a plastic sack and repaired the strap on one side. In Daryaganj, the men seem to be able to carry sacks with *pitthia* of any shape, size and quality, maybe the load of sack is more conducive to being carried, and quality of the *pitthia* does not really affect much the ability to accomplish work in Daryaganj.

[2] Balram's *pitthia*, Daryaganj is in a very worn out condition. He claims to have been using the same *pitthia* for the last twenty years. The person who made his original *pitthia* is dead, he got this one made by begging the man to make him one, and he would have reciprocated in kind as he didn't pay the man any money. Interview with Balram on 28th September 2015.

In Azadpur, most men claim not to know how to make, but in actuality here most men can make a *pitthia* and usually all of them collectively assist in making. *Pitthu* is essential to the work in Azadpur cold storage if they do not have a *pitthu* or it is in a bad shape they are unable to work[3]. Despite of a *pitthu*, blisters cover their entire backs, during the productive season from October to March.

3.2 Material

Around twenty years back, only jute gunnysacks were available in both the markets. Rice and sugar were packed in jute gunnysacks. The jute gunny used for sugar was of highest quality (strength, weave and softness); this was the preferred raw material for making. Today, it is very difficult to get new jute gunnysacks. Rice still comes in large jute gunnysacks to Food Corporation of India godowns. These jute gunnysacks are purchased as seconds by vegetable farmers are used to pack their goods, and are used for making a *pitthia*. A jute sack is reused many times, often only reused sacks are available in Daryaganj; being second-hand their prices are much cheaper than in Azadpur.

The jute gunnysacks are distinguished by the quality of the jute, and weave. These open structure jute sacks used for onions and potatoes are only used for making filler rolls of in Daryaganj. The rice packaging is considered to be the best for making straps; since shoulders and straps are the point of maximum contact. This jute sack has a denser weave, feels softer and does not cut through the skin.

Until 1980s jute thread was used for stitching, even now, jute thread unravelled from opening side-seams of the jute sack (being used to make the object) is used for tying and wrapping in the making, but for most of the stitching and reinforcing plastic is used now. When it was easier to find jute gunnysacks the object was made and replaced frequently. In 1996, about twenty years ago, they started using plastic gunnysack. Now with easier availability of plastic sacks more ways to protect the scarcely available jute sacks have evolved, either by covering in plastic(only done in Daryaganj) or by plastic thread stitch-work. In Daryaganj, sacks are used as a protection layer to cover and hence reinforce the *pitthia*.

The men in both *mandi* understand plastic for its properties of durability, strength and ability to repel water. They use the plastic sack for its ability to protect the object-tool from wear and tear, as well as moisture. They are also aware that the jute gunnysack that they have been using is soft and moulds itself to the body. They also know that using plastic alone will cause immense slippage and defeat the purpose of having a tool to aid the load bearing. It would also retain sweat and heat on the back. Most men in Azadpur do not prefer the use of plastic sack as covering for reinforcing. While many men in Daryaganj, have started making the inner layer and straps from plastic sack. In Daryaganj, plastic sack is used in sheet form as reinforcement the men describe this as a make-up and reinforcing finish much like plaster on the wall to give a clean finish and strength to the object-tool.

3.3 Body

A man may go through many object-tools in one lifetime with changes in body built over age, the strap length changes most often and usually according to the built and age of a person; if a person becomes heavier in built, he needs longer straps. The straps alone can be removed and changed if required. In Daryaganj, they make very long straps and measure against the person who will use the *pitthia* before attaching. The measure of the straps can be easily changed as it is only stitched on the side. Many men continue to use the same *pitthia* for over five years. Thus, they learn only the making and joining of the straps, and continue to do so while using the same *pitthia* body.

In Azadpur they use a standardised length for making the straps. They adjust the length according to the built of the user by changing the position of the attachment stitch to the upper portion of the *pitthu* body. If a person is very short, the straps are stitched to the upper portion at a much lower

[3]A man from another cold storage in Azadpur took a day's leave from work, wage cut, to get his *pitthu* in order, by commissioning Mohan to make it for him. He was unable to work with his defective *pitthu*, which was hurting him physically and not allowing him to work.

position. If a person is very tall, his straps are attached by an adjustable method, where the straps are knotted together at the bottom, this allows slightly more play of length, see figure 7.

3.4 Task and user

A comparison of the making of two similar yet highly context specific back-supports reflects the user-maker's understanding of differences in market architecture and goods being carried in the two markets by designing two kinds of back-supports. In Azadpur, they carry fruit in cardboard or plastic cartons on vertical stairs, while in Daryaganj; the men carry about sixty kilogram vegetables sacks over horizontal distances. The cartons have larger width volume, while sacks, are longer than wider or thicker. The men walk bent down when carrying sacks on a horizontal plane, and men walk upright to climb while carrying cartons therefore, the centre of gravity in both sites is different. The *pitthu* in Azadpur has to support the upper back, while in Daryaganj *pitthia* supports the lower back. These two iterations of the object-tool have further evolved with the availability of new materials to reinforce the structure.

4 Making tells what the object cannot

The final object does not tell the observer which part of the object needs to be most flexible and which part needs the most strength. Since the user is the maker here, he is careful about these aspects during the act of making and checks them most often. Thus, making as a process helps identify information that would otherwise be inaccessible for research (Niedderer 2013). The making of a tool also reveals what is crucial in the practice, a tool helps accomplish a practice better, and therefore the toolmaker is most particular about those aspects in tool-making. While observation of making one can see particularities and ask reasons for the same, and gain some experiential knowledge that is lost in a final designed object. In this object-tool making, the makers are most conscious of not having any creases and folds in the sack. They also try to do the stitching as evenly as possible. This stress on evenness is essential to make a well-made object tool, as even the slightest of crease can hurt the body when supporting a load of 50-80 kilograms on it.

However, it is only in making with them can one know other particularities, like one learns the excessive strength and pressure they exert in rolling the sacks or in pulling the stitches. The tightening is essential to making a *pitthia*/*pitthu* well, if loose the sack will have gaps to become lopsided or take shapes other than intended. Thus, experience in making reveals details about the object that cannot be known by just observing either the object and its use or its making[4].

There is a difference in the knowing of instructions like, a step-by-step guide, which any observer who has seen a *pitthia* being made a few number of times will be able to describe; and a knowing that arrived at through the practice of making a *pitthia* for oneself (Sennett 2008, Ingold 2013). Only then does he understand the body pressure and movement that is needed to get the tightest possible roll of the jute sack or the stresses the hands need to experience in pulling and stitching the thread, to understand the quality of tightness required. A crucial characteristic of experiential knowledge gained through the act of making is that it can only be understood through experience (Berkes 1998, Scott 1998, 330, Marglin and Marglin 1990, Lansing 2006, Harris 2007, Sennett 2008, 181-193).

4.1 Embodied Knowing

Many materials properties are understood only through bodily practices like the softness of a gunnysack or the strength in the plastic stitchwork, or the rigidity of the back-support on which the load has to rest. The men engage in a dialogue with the object and its materiality on a daily-basis through repeated experience of working with material, using the tool and body. This leads the

[4]After making a *pitthia* and a *pitthu* one can tell that the roll has to be rolled very tight, the tightness can be told and qualified by phrases from experience like 'you will need to tighten till your hands get blisters stitching' but without experience of making how will you ever know!!

makers to develop an intuition that allows imagination and anticipation of future innovations within the object guided by the materials, tools and body (Sennett 2008, Ingold 2013). The maker develops a knowing that is embodied through his hands; in the way he handles material and through his previous experiences of making as well as using the object-tool.

In this particular context the maker also has access to certain experiential understandings by simultaneously being the user and experiencing the object-tool. Being the end-user allows him to imagine further future possibilities of changes in the object-tool. The material is understood for its properties and is combined to enhance its strengths. The material choice is guided by interaction with the body, through the body and judged by the body. The men understand the material not through abstract nomenclatures, but through concrete material properties like softness, wetness, openness in weave, strength that are perceived by experience through the senses. (Ingold 2013 , 29).

4.2 Materiality, Choice, Customisation and Adaptation

The materials used are all located in the context itself, the makers collect raw material that would otherwise be discarded. The makers constantly look for relevant material, like in Azadpur increased use of cardboard cartons has led to lack of wood from the old wooden crates; thus, they started using the rubber machine belt, which is a waste material for the cold storage, see figure 8 and compare to figure 6. They chose the machine rubber tube realising that it was hard and stable; and thus added a rigidity and strength to the *pitthu* to support cartons. It is not a form of reuse; they are actively looking for material that can be put to use. The men exhibit an understanding of the properties of the material they use as they do not use any or all materials available but specific materials.

In the last twenty-five years, plastic sacks have become more easily available than jute sacks in the *mandi*. This availability of the material in their proximity and close interaction with plastic helped the men understand its materiality. Only after prolonged exposure and interaction with a new material during which the users become aware of the physical properties of the material is it put to use. With plastic the men brought changes to the *pithhia/pitthu* structure and finish that allowed them to use the same object longer. Use of plastic sacks and thread has changed the aesthetic look of the *pitthia*/*pitthu* and how the object-tool is used, kept and preserved. The realisation of plastic's water resistance and durability, the men started using plastic sack as direct covering, but at the same time being aware of its non-breathable nature they do not use it next to the skin. In Azadpur realising the high abrasion the cartons cause, they use plastic thread to create a protective covering from chain-stitch thread-work structure instead of direct plastic sack covering, the stitchwork has higher resistance to abrasion than flat woven plastic layer. Previously, the makers would use the running stitch reinforcement, which does not cover the surface entirely. Nowadays, in Azadpur they use chain-stich, which has evolved firstly, due to the change in material from jute thread to bulkier plastic thread and secondly, due to an exercise of imagination. Now, it is difficult to tell when and who started the plastic chain stitch, but once the men realised that it reinforced and protected the *pitthu* well, it caught on[5].

4.3 Open Authorship and Collective Knowledge Building

These trials of a new material like plastic, the use of a new stitchwork for increased reinforcement are constant minute adaptations in the making of an object-tool. All innovations in the object-tool have started as individual trials, when the functional advantage of an innovation becomes apparent to others around it gets adapted as collective knowledge. Since the community shares the ownership of an adaptation, the original initiation of any innovation remains anonymous. The situated understandings about the body, the livelihood task and local materials get shared and diffused in the

[5] Interview at the Azadpur cold storage with Mohan Singh on 22nd August 2015 and interview with Diwan Singh and Vineet Sharma, Manager on 29th November 2015.

larger collective on adaptation of a particular crafted iteration, creating a scenario of open authorship.

Each user-maker is able to add or remove any aspect of the object, therefore modifying it according to his need, understanding and functionality. The practice is malleable and incorporates new insights from individuals and continually adapts to changing materials. Being relevant to livelihood survival, each generation transfers what they already know. This transfer of 'learning's helps avoid another round of trial and errors for the next generation. The practice of knowledge building is cumulative. It diffuses within the community, at times unequally. The next generations add further to the already known, in form of tool, material and form responses[6]. This object, its making as well as the knowledge of its making has a collective and open-ended aspect, due to constant modifications by individuals in material, in stitchwork, in structure and reinforcements.

5 Lessons from a community shared creative practice

Innovation is thinkable when one thinks of new possibilities with known materials and tools. This understanding of a material and its properties, possibilities and limitations, can only be internalised through experiencing the material. An experiential knowing opens up experimentations in a practice of making. In this case study a maker knows about the durability of plastic and its ability to cut and scrape his skin from his personal experience. Through his individual experience of a material, he informs others about its potentials and limits. Since it is an equality-based community with similar diffused knowledge, everyone in the community need not cut their shoulder with plastic to realise its harshness or to realise for themselves its durability. The material has its own forces that challenge the imagination. For example jute deteriorates with moisture easily, hence durability of plastic opened new possibilities, but plastic does not lend itself to cushioning hence limiting a makers ideal of making a wholly plastic *pitthia*/*pitthu*.

Besides materials one also needs to know the abilities of the making tools and the act of lifting loads. Even after knowing a material intimately well, a maker needs to exercise his imagination to be able to innovate and create. The ability to innovate is based on individual sensitivity and ability to imagine. Thus, one needs to imagine before one creates. This imagination is informed by experiential knowing, and is essential to creative process of making new possibilities. The object-tool is made and reshaped by the imaginations of the users, and their first-hand findings based their observation and experience.

[6]Jacquard weaving evolved from the laborious processes of hand-lifting to inlay patterns in weaving.

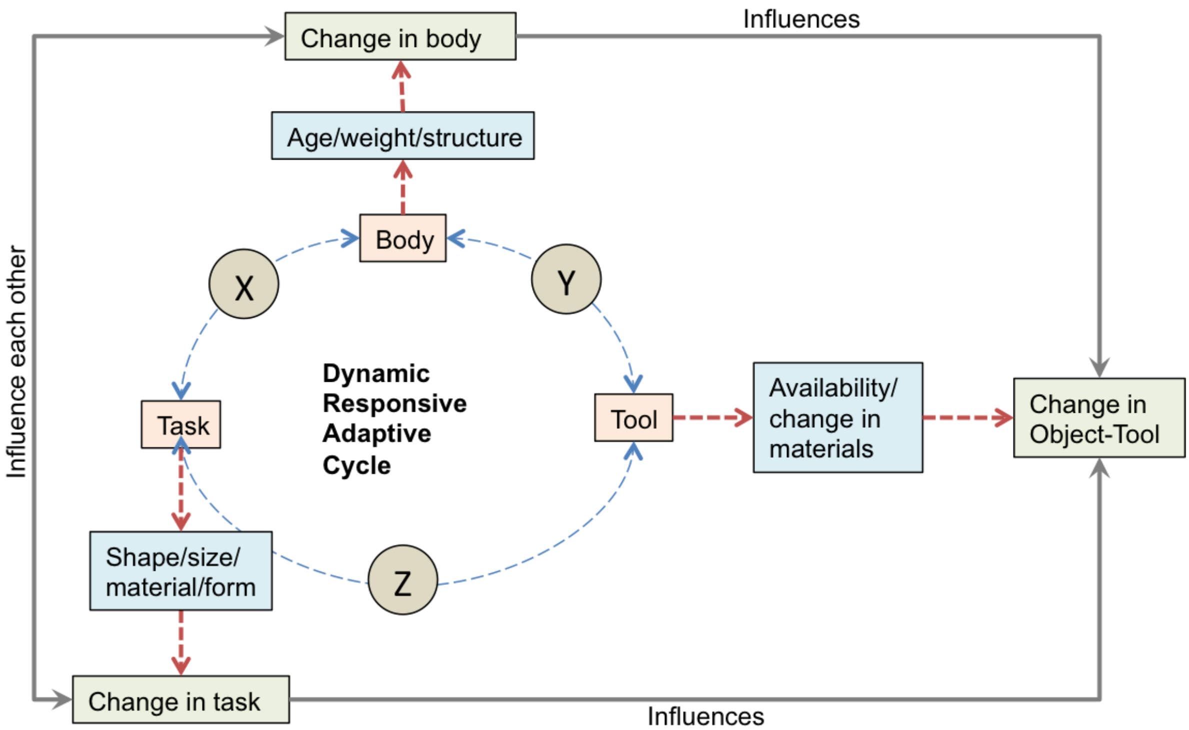

Figure 9 Variations in materiality of the object-tool, the task, and the body of the user form a dynamic responsive and adaptive cycle, where changes in body such as age and change in task such as lifting of different sizes, and introduction of new materials, lead to changes in object-tool. The sites of experiential knowledge (X, Y & Z) are located in this cyclic relationship between the variables of body, material (tool) and task.

There is a circularity of knowing for the user-maker between using the object-tool for the task, its support to the body and material properties that leads to make changes in the design of the object-tool. At the same time, the act of making of the object tool informs the user-maker of what is happening to their body, the task and the material used. This ever-changing object is a continuous dialogue that the maker-user has with material and environment that he is shaping as a maker and that as a user he is being shaped by. Figure 9 illustrates the iterative relationship between the availability of materials, the ageing of the body and the changes in the task itself and their influence on the designed object as well as the sites of experiential knowledge. Being in the context as both the user and the maker allows them to imagine and create what might be; and discard on immediate testing that which does not satisfy the purpose.

Each maker is a problem solver who is creating and adding knowledge to their collective design action through his object iterations and each user is testing the object-tool through use in real-time and space. They are not able to explicitly define this bodily experiential knowledge that they create, use and possess in the making and remaking this object, except when in the act of making. Being the maker-user they understand the user's point of view inherently, by using the object-tool. The functionality of any changes in the object-tool is understood through bodily action experientially.

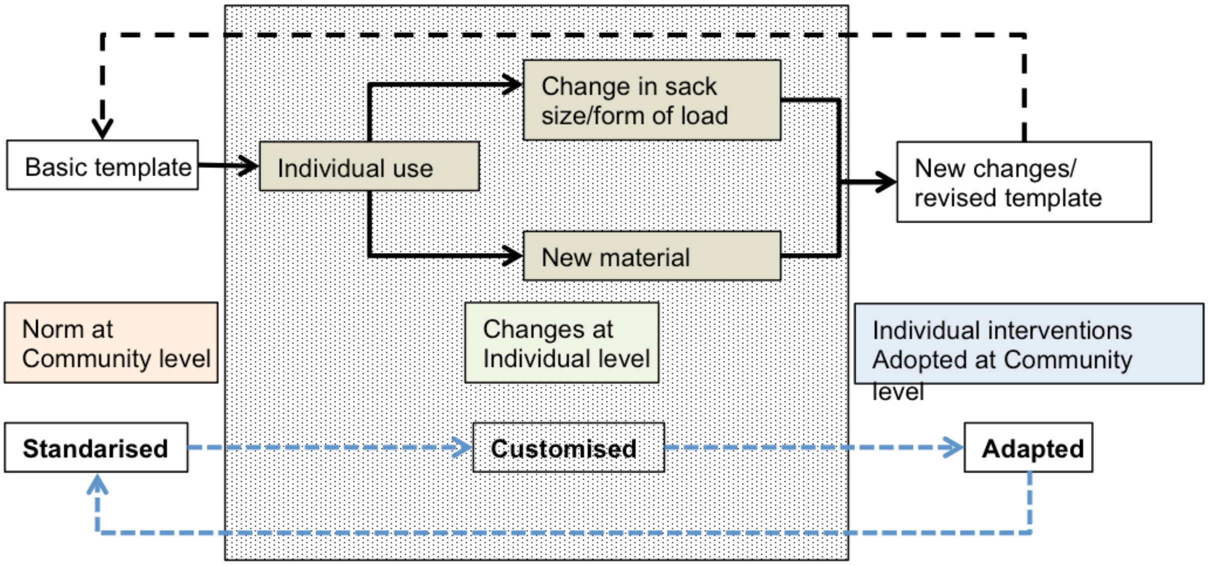

Figure 10 Customisation on a basic template for individual use, and adaptation in the basic template over time due to changes in changes in raw-material and changing market loads types, from sack size changes to kiwi fruit crates.

The object-tool is a standard template that is customised while being made to order for a particular person on a standard template, it is not a standard object that is customised by use. The users being makers allows for modifications and new innovations from their individual experience and according to his body need and material comfort, e.g. more cushioning, denser stitchwork. The men also incorporate adaptations and iterations in the object with changes in the body due to ageing, like increase in strap length, or more cushioning on straps. The customisation within the design standard template is a continuous cycle between these two aspects, what is originally a customisation becomes a standardisation if the larger community accepts the functional benefit of that particular customisation, till a future customisation and its standardisation brings a change into the standard object tool. Figure 10 describes this continuous cycle of standardisation, customisation and adaptation that follows due to the shared nature of knowledge in a community of making.

This object-tool is a constant enquiry amongst the men as it is continually being tested and thus redesigned due to the participatory nature of design in the making of this object. This example of collective action is unique since being the user himself the designer-maker understands implicitly the difficulties that the product has to cater to, and hence the strengths that should be incorporated in the object. The iterative nature of this design activity begins from being the user as well as the maker. This object study tries to articulate the dynamic nature of tacit knowledge in a crafting activity, as explained in figures 9 and 10.

The defining of this user-maker object-tool as a designed object extends the definition of design to include in its purview material objects created in-situ from appropriately chosen surrounding materials by end-users themselves. This is a review of design that begins from being located in a particular situation. The study illustrates collective action in generation of new shared embodied knowledge, as well as intuitive and experiential interaction with materials that gives rise to future possibilities of such design activity.

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Designer's Emotions in the Design Process

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This is a position paper towards the establishment of a research network to address the impact of tacit experiential knowledge, emotion, and cultural perspective on a designer's decision-making during a design process. With this network, we are aiming to start a focused discussion across geographies and cultures regarding the role and impact of designers' emotions within their own design process. The function of this is to foreground the experiential and emotional domain of designers' practice and examine the role of tacit experiential knowledge in design decision-making. The paper sets up the basis and context of discussion, exploring the three key areas to be addressed by the network: designers' emotions as key drivers in decision-making; tacit experiential knowledge; and addressing emotion in culturally-situated design practice. This is followed by our proposed methodology and network objectives and expected impact and outcomes.

design process, emotion, culturally-situated practice, tacit experiential knowledge

1 Introduction

This position paper outlines the proposal for an international research network of design academics and industry specialists to highlight the importance of non-textual, narrative, qualitative methods and forms of expression to represent as well as foreground emotional and experiential aspects of designers' engagement within a design process.

There are two key questions driving our research. Can we explicitly account for designers' emotions during a design process? And can we demonstrate any links between designer emotion and decision-making in a design process? If we can, as designers, access this type of tacit information—belonging in the informal realm, characterised by complexity and ambiguity, and expressed as emotion—then its impact on rational decision-making can be acknowledged.

We are focussing on the designer's emotions and experience within a design process as the designer is often considered a neutral person within the process. However, from our teaching experience, design students have complex relationships with their project especially when they tackle "wicked problems" (Buchanan, 1992; Rittel & Webber, 1973). Some of these projects generate strong emotions and feelings in the designer, such as empathy, sadness, anger or a feeling of empowerment, and this has a bearing on the project outcomes. We are drawing attention to qualitative methods because they allow for gathering information, such as tacit experiential knowledge and emotional states, that would not be visible in data set analysis, however, has impact on project planning, engagement and outcomes. The research work we propose aims to help the designer identify key emotions at play at different stages of a project or activity. In addition, we will examine how designers' emotions play a role in how the project is structured and delivered and how the findings are collated and interpreted.

We are building our approach to the network and its methods from an understanding about cultural transmission of information (formal, informal, technical; Hall, 1959), the impact of our data-driven reality on human communication (Boorstin, 2012; Marshall McLuhan, 1994) and how that has a direct effect on our sense of embodiment (Dewey, 2005; Laing, 2010). We connect the difficulty to base decisions on qualitative forms to a lack of trust generally in the informal realm—particularly emotions—to impart useful information in regards to decision-making (Belfiore & Bennett, 2008; McGilchrist, 2009). An appreciation and respect for the tacit dimension (Gill, 2015; Ingold, 2000; Polanyi, 2009; Schön, 1985) is a key aim of the work we propose for this network.

The project is proposed with a short-term (first phase) and long-term engagement plan. The research network will form the first phase of the longer project. In this first phase we will be inviting participants to two discovery workshops and one dissemination event. These workshops and events will be held in London over the course of 18 months, from Summer 2018.

The diverse participant group draws knowledge across disciplines and geographies to get a more rounded picture about emotion and its impact on the design process. The initial call for interest has drawn a group of 20 participants from Pakistan, Brazil, U.S.A., Israel, Finland, Spain, Denmark, and the UK. Adopting a democratic and participatory structure to the network sessions will, as much as possible, seek knowledge from sites of experience outside of the UK. Participant expertise spans across different subject areas and contexts, including academics and industry representatives in service design, product design, British Council Pakistan, workshop facilitation, graphic design, fashion, business and management, innovation, transdisciplinary art, teaching and learning, and IT.

The first workshop will address the three main themes: emotion, tacit knowledge and cross-cultural participation.

Designers make tacit experiential decisions at every stage of the design process. Emotions such as empathy, anger and fear in relation to a particular topic, circumstance, or grouping can trigger responses that influence a design process. The role designers' emotions play in this process is not often made explicit, despite the important function emotions play in decision-making. This has implications for the role of the designers' emotions in design decisions. Human-Centred and Emotional Design (Forlizzi, 1997; Hassenzahl, 2010; Jordan, 2000; McDonagh, Hekkert, Erp, & Gyi, 2003; Norman, 2003; Sanders & Stappers, 2008; Wright & McCarthy, 2008) often focus on end users' emotions, however the emotions of designers and facilitators within co-design situations are not acknowledged as often. The informal, the non-textual, the narrative and the emotional that exist in the liminal space between formal analysis of data and formal design decision-making are not accounted for qualitatively and/or made explicit.

Qualitative design and art based methods have a particular value for accessing informal, non-textual, narrative, and emotional elements and making them tangible. These qualitative design methods are often applied to researching the end users' emotions, but rarely are they used to look inwards towards the designers themselves.

Emotion is in the informal domain and accounting for its role in a decision-making situation requires an acknowledgement of embodied experience. There is a current bias towards quantitative forms of collecting and analysing experience in order to make the case for making decisions which omit findings from the informal experiential range, as they are so difficult to quantify.

Through the research network, we will draw knowledge across disciplines and geographies to get a more rounded picture about designers' emotions and their impact.

2 Emotion, Tacit Knowledge and Cross-cultural Participation in the design process

2.1 Section 1: Designers' emotions as key drivers in decision-making

Emotions have a troubled history. Within western contexts, emotions have been for centuries contrasted with reason as two separate driving forces of human nature, with an implicit or explicit value judgement about which force holds more value (Damasio, 2000; Lutz, 1986). From a cultural point of view, emotions have been used as a way to judge "others" whether those "others" are women, or people from different cultures, or from different classes. "To look at the Euroamerican construction of emotion is to unmask the ways in which that schema unconsciously serves as a normative device for judging the mental health of culturally different peoples" (Lutz, 1986, p. 288). Within this context, this dichotomy also allows to maintain a system of power relations based on this ideological distinction (Lutz, 1986).

Because of this distinction, the studies on emotion from a scientific perspective are still at the beginning. There is a clear gap in the study of emotion between Darwin's studies in 1872 (Darwin, 1998), widely considered the first scientific studies on emotion, and the 1960s, in which very little was written about emotions from a scientific point of view. This can be attributed to the fact that emotion was not considered, for most of the last century, to be a worthy subject, and was left in the background in favour of reason. Emotion was "relegated […] to the lower neural strata associated with ancestors whom no one worshipped. In the end, not only was emotion not rational, even studying it was probably not rational." (Damasio, 2000, p. 39). This view still dominates the scientific framework for the study of emotions, and there is still very little study of emotion from a scientific perspective. With the advent of psychology and psychotherapy (the thinking of Freud and Jung dominating the development of thinking into the 20th century), other sciences started to advance theories about emotions and viewing them as inseparable parts of our mental process, working in symbiosis with the part we call reason.

Antonio Damasio is a neurologist who pioneered the study of emotion and their effect on human consciousness by studying patients with brain damage in the emotional areas of the brain. He has shown that emotions are necessary to run a regular life and have particular implications for decision-making. Individuals who have brain damage in areas of the brain related to emotions seem unable to make 'rational decisions' and will make "personal and social decisions [that] are irrational, more often disadvantageous to their selves and to others than not." (Damasio, 2000, p. 40). This clearly challenges the cultural idea that emotion and rationality are two contrasting forces, and in fact theorises that emotion is necessary for rational decisions to take place.

Scientifically, emotions are chemical and neural responses to stimuli from the outside or from memory, and they have a regulatory function within the body. This function has a number of implications for the physical state of the person and for the person's state of mind. By changing the mental state of a person, they make the person experience what is around them in a different way and make a mental association between the particular stimulus (object or event that caused the emotion) and the emotion felt (Damasio, 2000, 2006). The emotional state that was associated with the stimulus will be remembered whenever the person is thinking of that particular stimulus or whenever this is encountered again.

This has implications for the decision-making aspects inherent in tacit knowledge. One very interesting study looks at the decision-making of a psychotherapist in a consultation with patients who have attempted suicide. 6ge of designers within a co-design situation, and in relation to designers' roles within an organisational context.

2.2 Section 2: Tacit experiential knowledge

As the world of work evolves to make room for robotic components and algorithmic computation to input into decision-making and realise more 6

3 Proposed methodology

As part of this research network will be inviting participants to two discovery workshops and one dissemination event over the course of 18 months. The participant group draws knowledge across disciplines and geographies to get a more rounded picture about emotion and its impact on the design process. The makeup of the group is detailed in the introduction; we invited researchers and practitioners who we knew had worked in the field of emotions, tacit knowledge and cross-cultural participation, and who, from previous conversations and previous collaborations, we thought would have an interest in this topic. In particular, we tried to draw people who had worked on emotions, tacit knowledge and cross-cultural participation in relation to problem-setting and wicked problems.

The first workshop will address the three main themes: emotion, tacit knowledge and cross-cultural participation, making use of qualitative art and design methods to:

- Test various spatial and relational configurations that allow embodied experience to emerge as key finding from informal experience. Evolving methods for accounting for the informal in a situated experience.
- Note and capture tacit experiential emotional responses in our research network in tandem with the capture of data of network participants' personal values and attitudes. Analysis of this data will be conducted to evolve a means of understanding the relationship between what is expressed as personal value and attitude and what is textually recorded as personal values and attitudes.
- Note and capture emergent human narratives: discovering what people think and know provides us with their perceptions of experience.
- Test methods of documenting and visualising emotional experience throughout the design process and its possible links to decision-making.

At this stage, we hope to identify 'where, when and how' within design process are significant points of interests for designers accounting for their own emotions. This process of learning shall evolve valuable insights and identify challenges within existing and new design practices.

The second workshop will provide spaces for contributions by participants around the themes of the project, as well as methodological contributions to gathering and analysing data. The aim of the workshops is to construct a democratized design space to engender an open mind set. In addition, opening up the workshop to methodological contributions will help to assess the validity of the methods used, and test innovative methods coming from culturally and geographically diverse regions, and different disciplinary contexts.

The exploration is perceived as valuable in terms of identifying emotional triggers, challenges and recharging points within design practice for designers' emotions as design confidence and wellbeing. This in retrospect impacts the collaborative project outcomes operationally. Accounting for designers' emotions can lead to balancing stress, facilitating the feeling of being in charge of things, and identification of motivators to push into action. Enquiring from a socio-cultural perspective, the aim is to realise a comprehensive database as baseline to work up from. This shall help ascertain effective design tools to map designers' emotions and develop a rich repository of perspectives. This can lead to effective working and collaborative initiatives where the designer's wellbeing is accounted for as central to project sustainability.

The dissemination event will then broadcast the findings as well as provide a platform for more voices to shape a future project.

4 Network Aims, Objectives, Impact and Outcomes

The proposed aims, objectives and impact address 5 main thematic areas: The role of emotions in the design process; Qualitative methods to record emotions; New discourse about the design process; Application of tools to understand users’ emotions to the understanding of designers’ emotions; Representing the diversity of participants.

Table 1 Network themes, aims, objectives and impact

THEMES	AIMS (what?)	OBJECTIVES (how?)	IMPACT (who cares? What happens? So what?)
Role of emotions in the design process	• Specify the role of emotions in decision-making within design processes. • Define what is valuable information in the design process for the designer.	• To create a clear link between design process and emotion • Provide templates for designers to map and track their emotions against a project timeline.	• **Develop an index** of potential tools and techniques to help the designer account for type, timing and sequence of emotions during a project, not just for participants but also for him/herself. • **Provide templates** for designers to map and track their emotions against a project timeline. • **Provide tools to address difficult projects** and how to advise people to account for difficult emotions during a decision-making process that is in blockage, stasis or breakdown.
Qualitative methods to record emotion	• Highlight the value of qualitative design methods to access and record emotions, and make these tangible. • This can help identify qualitative methods to access the non-textual, the narrative and the emotional forms of expression to represent and foreground emotional and experiential aspects of designers' engagement with a design process.	• Draw knowledge across disciplines and geographies to get a more rounded picture about emotion and its impact. Towards that end, we have put together a team of 20 participants from Pakistan, Brazil, U.S.A., Israel, Finland, Spain, Denmark, and the UK:	• **A new index of qualitative methods** that can address designers' emotion and are design specific.
New discourse about the design process	• Identify a new discourse about design process that takes into account the designer's emotion as a focal point • The project doesn't have to be instrumental. It aims to identify designers' emotions and the impact on their own design practice, in terms of decision-making within a process.	• The project will provide case studies to visualise the designers' emotions mapped against time on the project, with points in the graph identifying key points of confusion/stress as well as design tools to address those. • To account explicitly for what is valuable information in the design process for the designer	• **Re-map the double diamond** to account for the designer's emotional experience at each stage. • **To make tangible the tacit, experiential decisions** made at each stage of a design process. • **To identify the emotional blocks** at key points in a decision-making process. • **Build capacity and resilience for designers** by accounting for the designer's emotions in the design process.

Application of tools to understand users' emotions to the understanding of designers' emotions	• Account for the informal, the non-textual, the emotional, that exists in the liminal space between formal analysis stage and formal decision-making, that cannot be captured through quantitative methods. In other words, the thoughts, feelings, and actions that cannot be recorded or captured in quantitative form. The capture of emotions does not need to be instrumental. It can simply allow designers the right to account for their feelings during a design process. • Improve understanding of designers' emotions in the design process, currently under-represented. For example, human-centred design and emotional design focus mainly on users' emotions, while designers are seen as neutral. • Address the gaps in human centred design and emotional design, which are always focussed on users', not designers', emotions. Designers are seen as neutral facilitators. This references Bruno Latour's notion that nothing and no one can be seen as being completely objective.	• Identify the tacit, experiential decisions made at each stage of the design process. What role do informal, non-textual, narrative and emotional elements play in the design process?	• **Define a framework for evaluating** the impact of emotions for design process decision-making • The project can also be instrumental and **identify/develop tools to address difficult projects** and how to advise people to account for difficult emotions during a decision-making process that is in stasis or breakdown.
Representing the diversity of participants	• Democratic approach to the research network.	• Draw in expertise from different subject areas and contexts. To that end, we are involving 10 design academics, 6 academics across business and management, innovation, transdisciplinary art, teaching and learning, and IT; and 4 industry representatives from service design, product design, workshop facilitation, graphics and fashion and the British Council PK.	• The outcomes should be **applicable** as much as possible to **different cultural and discipline contexts** and are not UK-centric.

Through the network and addressing the 5 themes above we aim to highlight designer's emotion and tacit knowledge in a cultural context. The capture of emotions does not need to be instrumental. It can simply allow designers the right to account for their feelings during a design process. By not providing an exact methodology for including these aspects, but more a set of possible methods that can be used and modified by the designer, we aim to empower the designer to be confident about including not only their tacit knowledge and emotional experience, but also the tacit understanding that comes from the experience of culturally situated practice.

We see the impact of this research in design higher education as a starting point, partly because of the authors' own backgrounds as well as because of the context in which the project emerged. However, doing this work in education is a way of prototyping techniques that can then be adopted in other contexts, such as design industries, participant facilitation, and design research. By accounting for emotion, we are enhancing the innovation potential of the process.

We envision that the outcomes of the network would be a publication of the research findings, to be disseminated in a public event, including:

- A series of case studies/short piece contributions from the network participants (currently have 20 participants from our initial call) to share knowledge across disciplines and geographies regarding designers' emotion and tacit knowledge. This would provide an initial overview of the current consideration of designers' emotion and tacit knowledge and impact in the sectors represented.
- A collection of potential qualitative tools and techniques to account for designers' emotions in the design process. Providing tools to address difficult projects and allowing designers to account for difficult emotions during a decision-making process that is in blockage, stasis or breakdown.
- The initial steps towards a framework for identifying and evaluating the impact of emotions for design process decision-making, by re-mapping the double diamond design process or adapting other design process mapping tools. To make tangible the tacit, experiential decisions made at each stage of a design process and to identify the emotional blocks at key points in a decision-making process.

5 Discussion and Directions

With this network, we are aiming to start a focused discussion across geographies and cultures regarding the role and impact of designers' emotions within their own design process. The function of this is to foreground the experiential and emotional domain of designers' practice and examine the role of tacit experiential knowledge in design decision-making.

Our intended outputs are: an index of emotional and experiential aspects; a cross-referencing of those with cross-cultural elements; and an index of qualitative methods examined within the framework of emotion, experience, and culture.

With these initial findings, we will seek to model an application of qualitative methods focusing on emotional and experiential aspects of designers' engagement within a design process. We envision this in the form of an index of potential tools and techniques to help the designer account for type, timing and sequence of emotions during a project, not just for participants but also for him/herself.

We also consider it relevant to provide a template for designers to map and track their emotions against a project timeline. The project will provide case studies to visualise the designers' emotions mapped against time on the project, with points in the graph identifying key points of confusion/stress as well as design tools to address those. From those, we will also propose a beginning approach to application of this model within the sequential framework of the double-diamond; seeking to identify points within the design process where qualitative methods are most relevant from the designer perspective.

This initial inquiry is a first step towards a bigger and longer project working with democratic approaches within design decision-making processes. We see the consideration of what is collected for analysis and how it is collected and analysed to be fundamental areas to explore towards this greater aim. This project is not about problem-solving but about taking a wider view into all the elements that play a role in a decision-making process in design.

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Understanding the Evaluation of New Products Through a Dual-Process Perspective

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The development of new products is central to many companies' strategies. However, most studies show that the majority of new products fail to meet their financial targets or fail entirely. To improve the understanding of how consumers evaluate new products, this paper employs existing knowledge of dual-process theories to organise problems related to new product designs. These problems are identified through interviews of 12 designers of consumer products. Through this approach, 24 distinct types of pitfalls for new product designs are identified. Thereby, this paper provides design practice and design research with an extensive and structured account of potential causes of new product failures.

product evaluation; product experience; dual-process theories; product failure

1 Introduction

The development of new products is central to many companies' strategies. This, however, is not a straightforward task. In fact, assertions of new product failure rates as high as 80-90% are common, although possibly excessive (Castellion & Markham, 2013). In this context, a recent study showed that 72% of all new products fail to meet their financial targets, if not fail entirely (Carmichael, 2014; Ramanujam & Tacke, 2016, p. 10). This paper seeks to contribute insights into this topic through investigating how consumers evaluate new products.

The way consumers evaluate products concerns more than the products themselves, but to a large extent also the context in which they are encountered and product-related communication. For such reasons, marketing research has extensively studied consumer evaluation in relation to commercials, shopping activities, and product packaging (Haug, 2016). However, to limit the scope, this paper focuses only on product design-related causes. In this context, maybe the most obvious explanation for new product failure is that consumers do not find a product to have adequately attractive features, e.g., price, appearance, or functions. Another explanation concerns product congruity, i.e., the degree to which a new product conforms to a normative expectation (Noseworthy & Trudel, 2011). In general, new products with very familiar features (i.e., congruent products) may feel comfortable and safe, but do not produce much affective response, while new products with more novel features (i.e., incongruent products) often stimulate arousal that motivates individuals to engage in the act of discovery (Mandler 1975). On the other hand, too many features can make products overwhelming and difficult to use, thereby leading to dissatisfaction (Thompson et al., 2005; Ramanujam & Tacke, 2016, pp. 19-20).

Although the literature provides many insights into how consumers evaluate products, still we do not appear to have the understanding needed to eliminate the high number of product failures. This paper seeks to contribute further insights into this topic by using a dual-process perspective of mental processes to understand consumer product evaluations. Dual process theories of mental processes are a part of the psychology that has received much attention in recent decades (Evans, 2008; Kahnemann, 2011). A common understanding of dual processing is that we have a set of cognitive processes, which are automatic, effortless, associative and rapid (referred to as 'System 1' or 'the intuitive mind'), and a set of cognitive processes, which are controlled, effortful, deductive, and slow (referred to as 'System 2' or 'the reflective mind') (Kahneman & Frederick, 2002). Although the use of this type of theory has spread to many fields in recent years, the literature review carried out in this paper did not identify papers in which it is used for guiding new product development. On the other hand, since dual-process theories have been used to understand human judgments, it seems reasonable to assume that understanding product evaluation processes through this lens could offer new insights.

Based on the discussion above, this paper addresses the following question:

> *Can the dual process perspective on mental processes contribute to understanding disparities between design intentions and consumer experience?*

2 Literature review

The present literature review focuses on 'product evaluation' and 'dual-process theory', both of which are topics that have received much attention. On the other hand, literature searches in research databases (Web of Science, EBSCO and DAAI) for 'dual-process theory' in relation to design, product innovation and new product development produced only sparse results. More specifically, although dual-process theories are sometimes mentioned in the literature, no papers in which they are used for guiding new product development were identified.

2.1 Product evaluation

In the design literature, product experience has been described in terms of emotional and cognitive responses. More specifically, Desmet (2003) defined five overall types of emotional responses to products to support designing for emotions: instrumental, aesthetic, social, surprise and interest. According to Desmet, this classification shows that the focus on generalised pleasure, as in Green and Jordan (2002), is too narrow; instead, designing for emotion requires an understanding of several types of emotions. Similarly, based on a literature review, Crilly et al. (2004) described three categories of cognitive responses to products' visual appearance: aesthetic impression, semantic interpretation and symbolic association. As noted by Crilly et al. (2004), several other researchers have developed similar tripartite classifications (e.g., Lewalski, 1988; Crozier, 1994; Norman, 2004).

Product evaluations are related to different dimensions of a product. Table 1 contains some examples illustrating the variety of the classifications of design dimensions in the literature. It should be noted that some of these classifications include marketing aspects, while others focus only on product-related aspects.

Table 1 Product evaluation dimensions

Author	Classification focus	Dimensions
Dreyfuss (1955/2012)	Principles for design	(1) Utility and safety; (2) Maintenance; (3) Cost; (4) Sales appeal; (5) Appearance
Kotler and Rath (1984)	Design for competitive advantage	(1) Performance; (2) Quality; (3) Durability; (4) Appearance; (5) Cost
Roy et al. (1987)	Product design and purchasing decisions	(1) Brochure characteristics (before purchase); (2) Showroom characteristics (during purchase); (3) Performance characteristics (during initial use); and (4) Value characteristics (long-term use)
Papanek (1995)	Environmental design dimensions	(1) Method; (2) Association; (3) Aesthetics; (4) Need; (5) Consequences; (6) Use
Ulrich and Eppinger (2000)	Product design quality categories	(1) Quality of the user interfaces; (2) Emotional appeal; (3) Ability to maintain and repair the product; (4) Appropriate use of resources; (5) Product differentiation
Snelders and Schoormans (2004)	Product aspects important to consumers	(1) Ergonomic; (2) Price; (3) Hedonic; (4) Symbolic; (5) Quality; (6) altruism; (7) Low involvement; (8) Health.
Noble and Kumar (2008)	Design strategies	(1) Utilitarian design; (2) Kinesthetic design; (3) Visual design
Haug (2015b)	Design dimensions	(1) Composition; (2) Performance; (3) Experience; (4) Communication

When developing new consumer products, as mentioned earlier, the congruency of the design is important (Noseworthy & Trudel, 2011). Product incongruity can take different forms; for example, products may be incongruent in form, making them perceptually incongruent, or functionally incongruent, making them conceptually incongruent (Meyers-Levy & Tybout, 1989). A central concept in this context is 'the moderate incongruity effect', which refers to the assertion that consumers typically evaluate moderately incongruent products more favourably than either congruent or extremely incongruent products because a moderately incongruent product is both novel and familiar (Meyers-Levy & Tybout, 1989). However, as described by Noseworthy and Trudel (2011), research has shown that numerous contextual factors can affect the moderate incongruity effect, which led them to question whether consumers truly prefer moderately incongruent products, given the complexity of real-world consumption.

A common approach for enhancing and differentiating a product is to increase the number of features, typically in the form of functions (Nowlis & Simonson, 1996; Mukherjee & Hoyer, 2001; Goldenberg et al., 2003). More specifically, each additional feature, in principle, represents one more reason for a consumer to purchase a product (Brown & Carpenter, 2000). This has been a popular strategy, particularly for consumer electronics. However, an excess of features can make products overwhelming and difficult to use, resulting in dissatisfaction (Thompson et al., 2005). In other words, additional features may be seen as representing "one more thing to learn, one more thing to possibly misunderstand, and one more thing to search through when looking for the thing you want" (Nielsen, 1993, p. 155).

In relation to the number of features included in a product, Hamilton and Thompson (2007) noted that consumers tend to prefer products with many features and capabilities before using them, but then tend to prefer the ones that are simpler and easier to use after trying them. Consumers, therefore, often choose overly complex products that do not give optimal use satisfaction. In this context, Thompson et al. (2005) argued that conducting more market research to better understand consumers may not eliminate the problem, since if companies conduct market research by asking customers to evaluate products without using them, they will put too much weight on capability as compared to usability. Instead, Thompson et al. (2005) suggest that "firms should consider having a larger number of more specialized products, each with a limited number of features, rather than loading all possible features into one product”.

Product evaluations are affected by the evaluation context; prior to purchase, consumers tend to compare products (joint evaluation), whereas when trying a product, they tend to focus their attention on that single product (separate evaluation) (Hamilton & Thompson, 2007). Compared to separate evaluation, joint evaluation increases the importance of quantitative differences among alternatives (Hsee & Zhang, 2004).

2.2 Dual-process theories

In spite of the extensive attention that dual-process theories have received in recent years, such theories have actually been present in cognitive and social psychology since the 1970s (Evans, 2008). In fact, the idea that there are different types of mental processes may be traced back to Plato, who claimed that the soul is divided into three parts: reason, spirit, and appetite. Later philosophers also discussed the distinction between sensory knowledge (or intuition) and reasoning, such as Descartes, Locke, Kant, Bergeson, and Russell (see, e.g., Frankish, 2010). However, the most important pre-modern account of the unconscious, at least from a historical perspective, came from Sigmund Freud, who held that the human mind is composed of a conscious and an unconscious system operating in different modes (Macmillan, 1997). However, the perspective on such systems today is typically different from Freud’s and his strong focus on repressed impulses and memories.

The first use of the term ‘dual-process’ was in a paper by Wason and Evans (1975) (Evans, 2008). ‘Dual-process theory’ has since become an umbrella term encompassing several types of such theories. These theories have developed, to a large extent independently, in four separate areas of psychology: (1) learning, (2) reasoning, (3) social cognition and (4) decision making (Frankish, 2010). Dual-process theories are based on the idea that there are two distinct systems or processes that ‘compete’ for control when humans are involved in reasoning tasks. These are often referred to as ‘System 1’ and ‘System 2’, terms coined by Stanovich and West (2000). The processes of System 1 are typically characterised as automatic, fast, implicit and associative, while System 2 processes are typically characterised as slow, but able to perform abstraction and generalisation (Evans & Stanovich, 2013). Their speed differs because System 2’s analytic processing uses sequential processes that draw on the central working memory, which is constrained by its limited capacity, while Systems 1’s heuristic processes do not require working memory, but operate in parallel through large implicit mental systems (Evans & Curtis-Holmes, 2005).

Kahneman and Tversky (1972) founded one of the important traditions within dual-process theories. This tradition holds that our judgments of probability typically are the product of rough-and-ready estimation procedures (heuristics), which can produce decision-making errors and systematic biases. More recently, Kahneman and Frederick (2002) developed a more explicit dual-process model, according to which the heuristic-based System 1 processes generate default judgments that often involve attribute substitution, i.e., answering a simpler question than the one actually asked. Thereafter, the answer is passed to System 2, which often simply will endorse the intuitive judgment. However, sometimes, if given sufficient capacity and motivation, System 2 may override it in favour of a judgment in line with normative theory. At times, the final answer, which is approved by System 2, is very close to an intuitive answer proposed by System 1. In other cases, System 2 dramatically revises System 1’s intuitive response. Nevertheless, our final judgments are usually highly anchored in the initial impressions generated by System 1.

Some of the clearest examples of conflicts between System 1 and System 2 include phobias and compulsive behaviours like gambling, overeating and smoking; i.e., situations in which the one with the problem may be aware of the conflict, in the sense that the carried out System 1-driven behaviour is considered to be irrational and at odds with explicitly stated System 2 goals (Evans, 2008). However, conflicts typically occur at a more subtle and unconscious level in relation to decision and judgement processes.

Many authors have added to the list of the characteristics of System 1 and System 2 processes. This has led to a range of criticisms, not the least that the set of features associated with each type of thinking process are imperfectly aligned with each other (Keren & Schul, 2009). As a response to such criticisms, Evans and Stanovich (2013) suggested that only a few characteristics should be used to differentiate between System 1 and System 2 processes, namely that System 1 processes are of an autonomous nature and do not require working memory, while System 2 supports hypothetical thinking and does require working memory (see also Stanovich & Toplak, 2012). Furthermore, they suggested that the larger sets of characteristics, previously associated with System 1 and System 2 processes, should only be regarded as frequent correlates as opposed to defining characteristics (Stanovich & Toplak, 2012; Evans & Stanovich, 2013).

3 Research method

Empirical studies were carried out to identify causes for product failures from a product design perspective (as opposed to marketing). Given that the link between dual-process theories and product evaluation had not previously been established, an explorative approach was chosen. More specifically, interview-based studies were conducted with 12 industrial designers. The reason for interviewing designers, as opposed to consumers, is that the focus of this paper is on the gap between designers' intentions with new products and how consumers actually experience these. While consumers typically are unaware of designers' intentions, designers, on the other hand, often acquire information about of how consumers experience their designs. Thus, by interviewing designers it was possible to access many years of experience with designing consumer products and how consumers evaluate them.

The studies were conducted in five steps: (1) analysis of reference projects of the designers; (2) semi-structured interviews; (3) transcription of interviews; (4) analysis of interviews; and (5) additional clarification via email and telephone. The interviews lasted around 60 minutes and were digitally recorded. Furthermore, notes were taken during the interviews to record impressions that were not captured by the recordings. Information about the designers interviewed is shown in Table 2.

Table 2 Interviewed designers

No.	Years of experience	Education	Examples of design experience
1	8	MA Industrial Design	Lamps, chairs, cooling systems, kitchen equipment, experience design
2	4	MA Industrial Design	Kitchen furniture, children's furniture, tables, shelves, kitchen tools, electronics
3	10	MA Industrial Design	Electronic devices for larger installations, loudspeakers, consumer electronics, railway platforms
4	10	MA Industrial Design	Engineering products, household goods, transport devices
5	11	MSc Industrial Design	Furniture, tents, burning stoves, headsets, rack systems, dining ware, loudspeakers
6	8	MA Industrial design	Gaming equipment, movie settings, exhibitions, game backgrounds
7	20	MSc Product Design	Automotive design, computer animations, bike furniture, toys
8	22	MA Industrial Design	Vacuum cleaners, door handles, construction equipment
9	2,5	MA Textile Design	Kitchen textiles, book illustrations, interiors, baby carriers
10	24	MA Architecture	Furniture, lamps, industrial equipment, household appliances
11	7	MA Industrial Design	Medical devices, furniture, kitchen equipment, dining ware
12	9	MA Industrial Design	Tabletop products, home appliances, furniture, outdoor equipment

During the interviews, the designers were asked to share their insights into how consumers experience products by answering questions concerning product responses, product preferences, and product congruency. The terms 'dual-process theory', 'System 1' and 'System 2' were not used during the interviews, as the designers might be unfamiliar with these. Instead, terms such as 'intuitive', 'emotional', and 'rational' were used. Such terms are to some extent synonyms for 'System 1" and 'System 2', and previous studies by the author showed that these are often part of designers' vocabulary when discussing design experience (Haug, 2015a; Haug, 2016). Furthermore, given the semi-structured format of the interviews, clarification were provided to ensure that the designers fully understood the questions given. The transcribed interviews were analysed through coding. More specifically, first initial themes were identified, after which these were organised into categories, representing parts of product evaluation processes (as further clarified in the subsequent section).

4 Product evaluation from a dual-process perspective

Product evaluations can be a result of interpretations of the product's visual features as well as a result of trying or using the product. Such evaluations take place before the purchase of a product, but may also occur after a product has been acquired and is being used. In order to structure the discussion, this paper focuses on evaluation contexts in which new products are evaluated as a basis for a purchase decision.

As mentioned in the literature review, dual-process theories have been used to explain mental processes involved in judgement in various settings. Based on this literature, a model of product evaluation through a dual process perspective is outlined in Figure 1. The purpose of this model is to provide a frame for organising the data from the empirical investigations. On the other hand, it should be emphasised that the model should not be perceived as a new theory about how the mind deals with product experience, but merely as an application of existing knowledge from the field of psychology in the context of product experience.

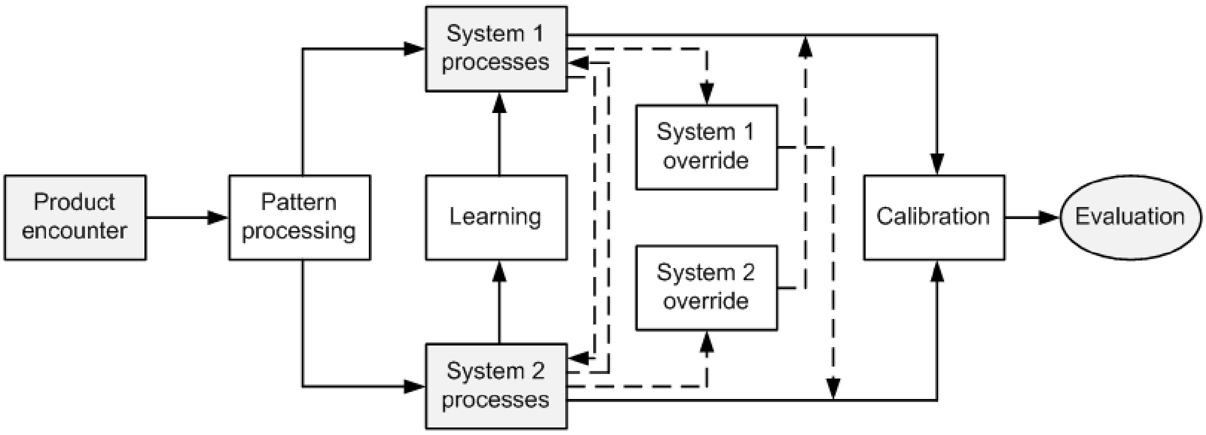

Figure 1 Product evaluation in a dual-process perspective

As seen in Figure 1, the first step in the product evaluation process is the encounter with the new product, in which certain features are noticed, and others are not. Recognised features are processed by System 1, which engages immediately and automatically (Croskerry, 2009). If features are not recognised, if they are ambiguous, or there is uncertainty, System 2 processes engage instead, attempting to make sense of these. If the features do not make sense after reflecting on them, they will at some point be left unrecognised. If features that initially are not found meaningful later become clear, a new understanding of the particular feature develops, i.e., learning. If there are no subsequent modifications of System 1 or System 2 processing, their individual or blended outputs determine the calibration of the evaluation. There are, however, some mechanisms that can alter the result. More specifically, System 2 may override System 1 if it is unsatisfied with its judgement, and System 1 may override otherwise sound reasoning developed by System 2 (Kahneman & Frederick, 2002).

The potential issues related to the design of new products identified in the analysis of the interviews can be organised according to the processes shown in Figure 1. This is summarised in Figure 2 and explained in the following subsections, where the designers' experiences are used to illustrate each issue.

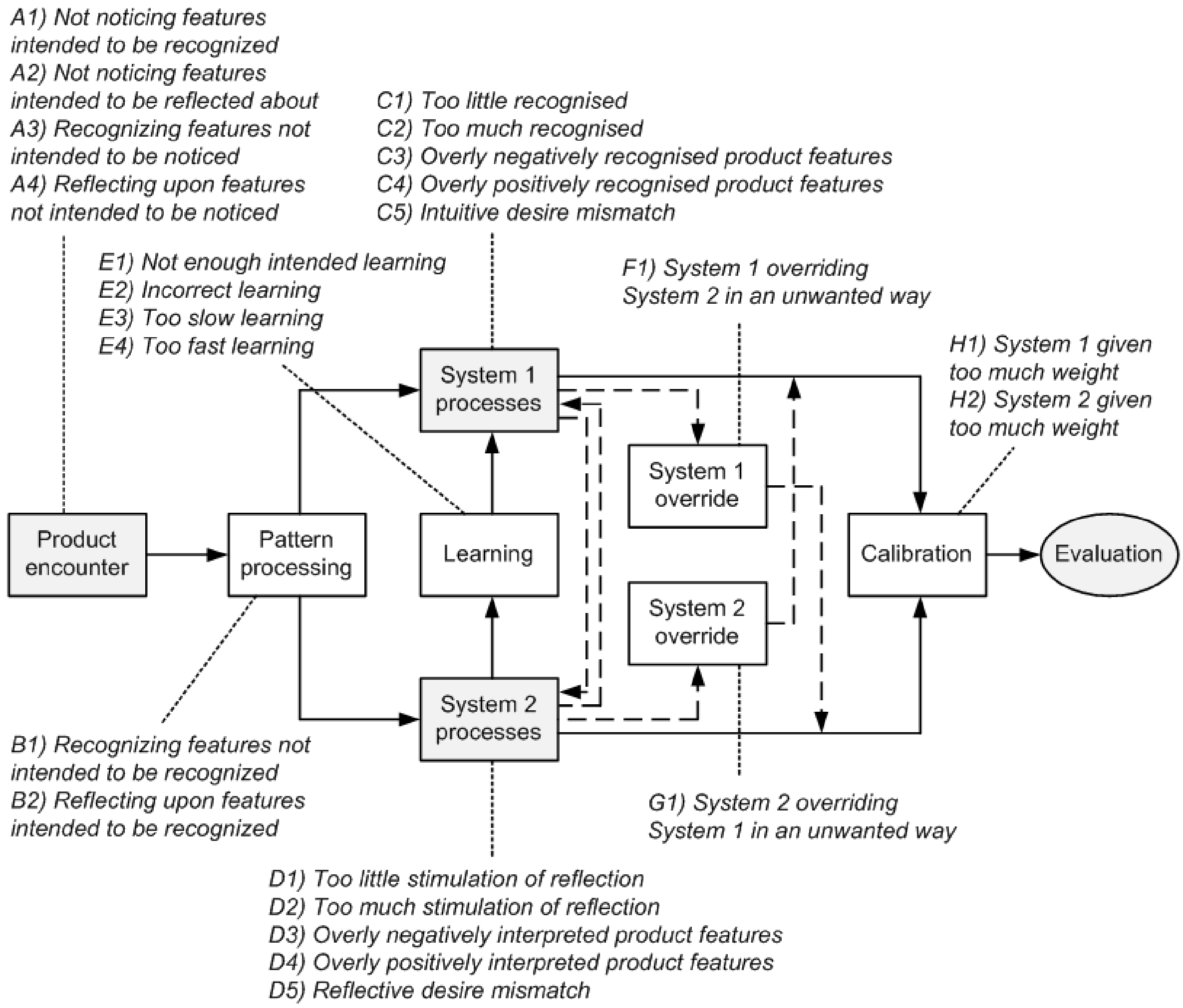

Figure 2 Product evaluation pitfalls in a dual-process perspective

4.1 Product encounter

In the 'product encounter' step, certain product features are noticed, while others are not. In this step, four types of potential problems were identified from the interviews:

A1) Not noticing features intended to be recognized
A2) Not noticing features intended to be reflected about
A3) Recognizing features not intended to be noticed
A4) Reflecting upon features not intended to be noticed

In situation A1, certain product features are intended to be recognised in an automatic manner, but as it turns out, these are not noticed (i.e., failed System 1 activation); for example, in the form of unnoticed visual references that were intended to position the product in a certain manner. This is illustrated by an example, given by one of the interviewed designers, of designing a handbag for an exclusive brand, in which case it is important that consumers automatically notice product features conveying that the handbag is exclusive.

Situation A2 arises when certain product features are intended to stimulate conscious mental processing, but for some reason, these are not noticed (failed System 2 activation); for example, in the form of new functions considered to add value, which, therefore, are indented to be consciously considered by consumers. This is illustrated by an example, given by one of the interviewed designers, of an expensive drilling machine, which consumers may find to be overpriced if they do not notice the features that justify its price.

In situation A3, certain product features are not intended to be noticed, but as it turns out, they are automatically recognised (i.e., unwanted System 1 activation); for example, if a consumer notices some assembly detail, which was meant to be hidden, or experience the product from an unintended perspective. This is illustrated by an example, given by one of the interviewed designers, of a less attractive backside of a closet, not intended to be part of the product impression.

Situation A4 arises when certain product features that are not intended to be noticed, for some reason, stimulate conscious reflection (i.e., unwanted System 2 activation); for example, if a consumer thinks about the functionality of a certain product part that does not have any functionality. This is illustrated by an example, given by one of the interviewed designers, of a chair assembly detail that was intended to be unnoticed but instead gave rise to some consumers thinking about the quality of the design.

4.2 Pattern processing

In the ‘pattern processing’ step, two types of potential problems were identified from the interviews:

B1) Recognizing features intended to be reflected upon
B2) Reflecting upon features intended to be recognized

Situation B1 takes place when certain product features are recognised, although they were intended to stimulate conscious reflection (i.e., failed System 2 activation and unwanted System 1 activation); for example, a product feature that is intended to invoke curiosity, but fails to do so. One of the interviewed designers offered the example of a lamp with a car rim reference. In this situation, one of the challenges was to make the car rim reference obvious enough so that it would be reflected upon, rather than automatically being recognised as some sort of decoration.

In situation B2, certain product features invoke conscious reflections despite being aimed at unconscious recognition (i.e., failed System 1 activation and unwanted System 2 activation). This is illustrated by an example, given by one of the interviewed designers, of a car door with a sound that could make the consumer wonder if there is something wrong with it, rather than automatically recognising this as the sound of a car door being shut.

4.3 C-D) System 1 and System 2 processes

The issues related to the processes of System 1 and System 2 processes can be organised into three overall types:

1. System activity issues
1. Product interpretation issues
2. Desire match issues

7.1.1. System activity issues

In relation to system activity issues, the interviews revealed four types of potential problems:

C1) Too little recognised
C2) Too much recognised
D1) Too little stimulation of reflection
D2) Too much stimulation of reflection

Situation C1 occurs when there are too few impressions for System 1 to form an intuitive idea about the product. The consumer may, therefore, experience the product as being too unfamiliar, in the sense that he/she is uncertain about what to do with it, doubt if it would work as desired, or simply ignore the product. This is illustrated by an example, given by one of the interviewed designers, of a high tech-looking prototype of an injection pen, which some consumers did not recognise as this type of product.

In situation C2, there are too many impressions for System 1 to handle. As discussed in the literature review, this may result in 'feature fatigue'. This is illustrated by an example, given by one of the interviewed designers, of a remote control with an excessive amount of buttons. Although most buttons would be recognisable, the thought of all this functionality would fatigue some consumers.

Situation D1 occurs when there is too little stimulation of reflection. As discussed in the literature review, this could indicate that a new product does not possess adequate novelty; thus, there is little motivation for paying for a new product variant. This is illustrated by an example, given by one of the interviewed designers, of a new type of beer for which there was a challenge in making it appear adequately novel so that it would catch the attention of target consumers while still looking like a beer.

In situation D2, there is too much stimulation of reflection, which could be in the form of a new product that is too difficult to understand. This is illustrated by an example, given by one of the interviewed designers, of a smartphone's user interfaces, which need to be organised in a suitable hierarchy so as not to demand too much reflection on one screen.

7.1.2. Product interpretation issues

In relation to product interpretation issues, the interviews revealed four types of potential issues:

C3) Overly negatively recognised product features
C4) Overly positively recognised product features
D3) Overly negatively interpreted product features
D4) Overly positively interpreted product features

Situation C3 occurs when certain product features are recognised as being worse than they actually are, which may deter the consumer from purchasing the product. This is depicted in an example from one of the designers of a cup that may look interesting and novel, but because of the associations it produces, it may unconsciously be thought of as unpleasant to drink from, although it is not.

In situation C4, certain product features are recognised as being better than they actually are, which could lead to disappointment if the product is acquired. This is illustrated by an example, given by one of the interviewed designers, of a lawnmower with visual references to motorcycles, which later could turn against the lawnmower if it did not perform at an above-average level.

Situation D3 occurs when certain product features through conscious reflection are concluded to be worse than they actually are. This can be seen in an example, given by one of the interviewed designers, of a quality screwdriver that would appear to be an unjustifiably expensive screwdriver if the reflections that it stimulates do not lead to concluding that it has superior quality.

In situation D4, certain product features are through conscious reflection concluded to be better than they actually are. This is illustrated by an example, given by one of the interviewed designers, of a car with a sporting look but with only average driving performance.

7.1.3. Desire match issues

In relation to desire match issues, the interviews revealed two types of potential issues:

C5) Intuitive desire mismatch
D5) Reflective desire mismatch

Situation C5 arises when the product is found unattractive through automatic processing of impressions, as when a product 'doesn't feel right'. This is illustrated by an example, given by one of the interviewed designers, of a lamp with an unpleasant light, which a consumer may dislike without consciously being aware of why.

In situation D5, the product is found unattractive through conscious processing of impressions, i.e., a conclusion as a result of reasoning. This is illustrated by an example, given by one of the interviewed designers, of a high-priced designer ruler, which although being found visually appealing may be considered to be a waste of the extra money.

4.4 Learning

There are several potential issues related to learning, i.e., internalisation of System 2's conclusions about unrecognised product features. Since these System 2 issues have already been described, additional examples from the interviews are not included here. The issues identified in relation to learning includes:

E1) Not enough intended learning (A2, D2)
E2) Incorrect learning (A4, B2, D3, D4)
E3) Too slow learning (D2)
E4) Too fast learning (D1)

In situation E1, the product does not stimulate enough of the intended learning. Obviously, if certain product features are intended to be reflected upon (A2), but this is not happening, the intended learning cannot take place. Furthermore, too much stimulation of reflection (D2) can make the consumer give up, implying that the intended learning does not take place.

Situation E2 occurs when the product stimulates incorrect learning. This occurs if the consumer reflects on features that were not intended to be noticed (A4), and thus internalises some incorrect conclusions about the product. Clearly, incorrect recognition (B2), overly negative interpretations (D3) and overly positive interpretations (D4) all represent types of incorrect learning.

Situation E3 arises when certain product features take a longer time to understand than intended, i.e., when a product demands more reflection than planned (D2). This may result in an unpleasant learning process, or, as mentioned, that the consumer gives up learning how to use it.

In situation E4, certain product features are understood quicker than intended. This occurs when a product is anticipated to be more challenging than it actually is, leading to too little stimulation of reflection (D1).

4.5 Override

In the case of System 1 and System 2 overrides, two potential issues were identified from the interviews:

F1) System 1 overriding System 2 in an unwanted way
G1) System 2 overriding System 1 in an unwanted way

Situation F1 takes place when certain rational considerations are disregarded because of unconscious mental processes; for example, as a result of an emotional response (e.g., in in the form of an impulse-purchase). One of the interviewed designers offered the example of a lamp that is so visually appealing that the consumer forgets to consider if the light it produces is right for the context in which it is to be used.

In situation G1, certain intuitive urges are suppressed because of making what appears to be 'the sensible choice'. However, as System 2 cannot accurately predict the future, it may later be discovered that the consumer's intuition was actually pulling in the right direction. This is illustrated by an example, given by one of the interviewed designers, of a unique sofa that a consumer chooses not to buy, although being attracted to it. Instead, this consumer purchases a more traditional sofa, which he/she later regrets as he/she becomes more accustomed to the thought of the special look of the unique sofa.

4.6 Calibration

The final process is the calibration of the outputs from System 1 and System 2 processes. Two potential issues with this process were identified from the interviews:

H1) System 1 given too much weight as compared to System 2
H2) System 2 given too much weight as compared to System 1

Situations H1 and H2 bear a resemblance to the override situations, the difference being that instead of disregarding the other system, the other system is merely given less weight than it should have, which may later lead to disappointment.

In situation H1, certain rational considerations are undervalued because unconscious mental processes pull the consumer in another direction. This is illustrated by an example, given by one of the interviewed designers, of a chair being found so visually interesting by a consumer that considerations of sitting comfort are not given adequate weight.

Situation H2 occurs when certain rational considerations are overvalued compared to intuition. This is illustrated by an example, given by one of the interviewed designers, of not buying an innovative rack system that he/she finds attractive because of it seeming too special. In this context, the consumer may later regret not having bought the more novel one, as he/she becomes more accustomed to the concept of the novel rack system.

4.7 A checklist for the design of new products

The pitfalls of new product design described in the previous subsections can be transformed into a checklist to be used in design projects, as shown in Table 3. The checklist may be used to test prototypes on potential users, or it may simply serve as a set of dimensions to consider when developing and evaluating design proposals. In order to link to the checklist to the previous part of this paper, the labels used in Figure 2 are stated behind the questions.

Table 3 Checklist for the design of new products

Focus	Potential problem
Product encounter	1. Does the user fail to notice features intended to be recognized? (A1) 2. Does the user fail to notice features intended to be reflected upon? (A2) 3. Does the user recognize features not intended to be noticed? (A3) 4. Does the user reflect upon features not intended to be noticed? (A4)
Pattern processing	5. Does the user recognize features not intended to be recognized? (B1) 6. Does the user reflect upon features intended to be recognized? (B2)
Processing activity	7. Does the user recognise too little? (C1) 8. Does the user recognise too much? (C2) 9. Does the user reflect too little? (D1) 10. Does the user reflect too much? (D2)
Interpretation	11. Does the user recognise product features overly negatively? (C3) 12. Does the user recognise product features overly positively? (C4) 13. Does the user interpret product features overly negatively? (D3) 14. Does the user interpret product features overly positively? (D4)
Desire match	15. Does the user experience intuitive desire mismatch? (C5) 16. Does the user experience reflective desire mismatch? (D5)
Learning	17. Does the user fail to acquire enough intended learning? (E1) 18. Does the user acquire incorrect learning? (E2) 19. Does the user learn too slowly? (E3) 20. Does the user learn too fast? (E4)
Override	21. Does the user's intuition override reasoning in an unwanted way? (F1) 22. Does the user's reasoning override intuition in an unwanted way (F2)
Calibration	23. Does the user's intuition weigh too heavily as compared to reasoning? (H1) 24. Does the user's reasoning weigh too heavily as compared to intuition? (H2)

5 Conclusions

This paper investigated if dual-process theories can be applied to provide insights into disparities between design intentions and consumer experience. To do so, a dual-process perspective of mental processes was used as a frame for organising problems related to new product designs, which were identified through 12 interviews with designers of consumer products. The result of this process was the identification of 24 distinct types of pitfalls to be aware of when designing new products. These 24 pitfalls were organised under eight overall types: 1) Product encounter issues; 2) Pattern processing issues; 3) Activity issues; 4) Interpretation issues; 5) Desire match issues; 6) Learning issues; 7) Override issues; and 8) Calibration issues.

The derived 24 types of pitfalls for new products illustrate how new product evaluation concerns much more than how well individual product features match the preferences and needs of consumers. In fact, a product may include features that are exactly what a consumer desires, but still be discarded if the user fails to notice these, interprets them wrongly, becomes fatigued by them, allows rational (but narrow) thoughts to overrule sound intuition, and so on. Thus, the derived classification provides design practice and design research with an extensive and structured account of potential causes of new product failures. It should, however, be noted that this kind of explanation model only accounts for some of the reasons for why products fail (or becomes successful); for example, product information from producers and other consumers also to a large extent affects a product experience.

For future design research, the developed classification points to areas for further study, not the least in relation to defining design principles to avoid such issues for new products. Furthermore, the classification may provide a frame of reference for studies of new product failures. For design practice, the checklist provided by this paper may be used in relation to prototype tests to determine if new product concepts are experienced as intended, or it may simply serve as a set of dimensions to consider when developing and evaluating design proposals.

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Section 15.

Objects, Practices, Experiences and Networks

Editorial: Material-Enabled Changes in Design Research and Practice

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Over the last decade, we observe an ever-increasing interest of designers in tinkering and designing (with) new materials (Karana et al., 2015, Rognoli et al., 2015). Designers grow materials from living organisms (Myers, 2012; Collet, 2017), create active composites by embedding electronics into materials (Vallgårda et al, 2016). These emerging materials do not only radically change the role of the designer from a 'passive recipient' to an 'active maker' of materials (Myers, 2012; Karana et al., 2015; Rognoli et al., 2015), but also the ways we experience materials in daily artifacts, as *alive, active and adaptive* more than ever (Karana et al. 2017). We argue that practices with and through these emerging materials both in-design and use-time (Giaccardi and Karana, 2015) offer opportunity for achieving positive social (Drazin & Küchler 2015), environmental, economic and even political change.

- How do/will emerging materials advances affect practices around products from the designer and the end-user perspective?
- How is environmental, social, economic or political change activated through these new and emerging materials and "*material-driven design*" practices?

Within this Theme Track we asked authors to prepare articles that collectively address these questions through material and product design cases, examples of methods and frameworks, and theory building, which focus on the following axis points:

- Emerging materials: growing, recycled, bio-based, smart materials and material systems, alternative material resources, self-produced materials...
- Material-enabled cultures around design and production: open science, co-design, customization, democratization of fabrication practices, repair, craft practices, closed-loop systems, DIY approaches, bio-hacking, collaborative cross-disciplinary working practices, resilience strategies, …
- Emerging material experiences: sensory, embodied and affective experience, new material-driven practices, our relationships with nature and technology mediated by materials, new material identities and languages, new material contexts, virtual materials...

We have nine unique contributions accepted for the theme track which provide a wide panorama of topics in relation to emerging materials and design. Common to all, materials are considered as a powerful catalyst for change in design research and practice, as well as design practice as a catalyst for change in materials design. For example, borrowing concepts from social sciences that explore materiality within its multiple environments, ***Damla Tonuk*** and ***Tom Fisher*** draw on conceptualisations of materials as active and as having the capacity to bring about change by proliferating relations and responding to new developments of "biotic materials". Sharing a similar view and a socio-material theoretical lens, ***Marium Durrani*** takes the mending activities of non-professional menders in communal repair workshops in the city of Helsinki, Finland, as a point of departure, identifying these menders as vernacular menders and exploring their dynamic practices to reveal the situated, embodied, routinized yet creative process of mending. She argues that

professional designers are not the only ones experiencing proximate relations with materials and the created outputs by the vernacular menders point towards extending mainstream conceptualizations of design and creativity towards positive environmental change.

More specifically about textile materials, ***Elaine Igoe*** identifies the deepening relationship between textiles and material design practice in the post-digital era by using key examples of contemporary designers. With a quote from the designer Lucy Hardcastle, she draws attention to the diverse techniques used by designers to tailor materials and create sensual aesthetics in design: "Hardcastle uses glass blowing techniques, 3D printing, flocking, hand dyed fabrics, 3D rendering, digital animation, photography and sound effortlessly to create *"real and imagined touch, visual illusions and sensual aesthetics"* (Hardcastle, 2017).

Stefano Parisi and his co-authors accentuate the connected, augmented, computational, interactive, active, responsive, and dynamic features of emerging materials and provide a number of examples to illustrate the potential of these materials for unique experiences. They urge designers to understand these materials in relation to other non-human entities, i.e. the environment or other materials, artefacts and organisms, which they introduce as the 'connected level' of materials experience. Delving into the making of a specific active, dynamic, responsive material, ***Jane Scott*** explores the design space in relation to humidity and moisture levels, using textile fibres with the ability to swell; changing in dimensions when exposed to high levels of moisture. Drawing on her personal experience, she explores how the complex hierarchies that exist within textiles can be used to engineer a unique class of programmable systems. She argues that this challenges conventional smart interfaces that rely on mediated responses via electronic control and demonstrates how an alternative approach informed by biomimicry can generate a new class of smart-natural materials.

Hellen van Rees and her co-authors describe the development of a robotic textile to be implemented in a health & wellbeing context and emphasize the role of a multidisciplinary approach to advance in new material development. The role of collaborative materials development for positive social and environmental change has also been emphasized by others contributing to the theme track. ***Rosie Hornbuckle*** shared her own experience from an EU H2020 funded project for the collaborative development of materials, involving designers, scientists and manufacturers. She argues that for such projects to move forward, at the very least, designers need to understand the material's potential and scientists need to understand what designers want the material to 'be like'. She offers one approach – appointing '*materials liaison officers*' to overcome language barriers between involved parties. To that end, ***Serena Camere and Elvin Karana*** offer a Toolkit to enrich designers' materials experience vocabulary to open up the design space for unique functions and expressions in material (driven) design. They emphasize that when the experiential qualities of a material are probed and mapped alongside the material's technical properties and performances, a thorough understanding of the material is achieved to guide the design process in (collaborative) materials design. ***Maria Engberg*** and her co-authors offer a new perspective to emergent materiality by giving prominence to the visual experience, next to the haptic and performative. The authors illustrate how engaging with phenomenological and computational visuality using mobile AR/MR technologies provides a deeper understanding of how the visual can be designed as part of a complex and re-configurable materiality.

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Experiential Characterization of Materials: toward a toolkit

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Traditionally in science and engineering, materials are characterized *technically*, through a series of studies aiming at probing and measuring the structure and properties of materials. In design, a holistic approach to materials is adopted which requires the characterization of materials for their experiential qualities, alongside the technical understanding. Despite the increasing attention to the notion of materials experience, design methodology lacks a systematic tool to support the experiential characterization of a material at hand. This paper presents the development of a toolkit to facilitate the *experiential characterization of materials*. The toolkit has been developed based on existing tools and approaches within the materials and design domain, and through two exploratory workshops conducted with design students and design professionals. The workshops provided useful insights to improve the toolkit's final design, which is presented in the paper. While the toolkit needs further adjustments and validation, the discussion highlights how this approach can support design practice in conducting materials characterization studies in diverse situations.

materials experience; characterization; materials; design tools

1 Introduction

Over the last decades, research has devoted increasing efforts to support a dualist understanding of materials, which *emphasizes the role of materials as being simultaneously technical and experiential* (see www.materialsexperiencelab.com; Karana, Pedgley & Rognoli, 2014; Ashby & Johnson, 2002; Miodownik, 2007). Traditionally in science and engineering, materials are characterized *technically*, through a series of studies aiming at probing and measuring the structure and properties of materials (Leng, 2009; Zhang, Li & Kumar, 2008; Ashby & Johnson, 2002). Thus, material characterization concerns *what a material is* and how it behaves under certain conditions (e.g. under compression or in contact with water). When it comes to materials in product design, experiences that materials elicit in user interactions are equally important to achieve a holistic understanding and inform the design process (Ashby & Johnson, 2002; Miodownik, 2007; Karana, Hekkert &

Kandachar, 2008). Such an understanding of materials does not only provide guidance on how people are likely to experience a particular material in future product applications and how to improve materials accordingly for commercial success (Karana, Pedgley & Rognoli, 2015), but it also inspires designers and material developers to come up with innovative material and product ideas (Karana et al., 2015; Wilkes et al., 2016). In other words, understanding material experiences can enrich designers' vocabulary and open up the design space for unique functions and expressions (Karana et al., 2015; Barati, Karana & Foole, 2017).

Karana et al. (2015) define this activity as the ***experiential characterization of materials***, which concerns investigating how a material is received, what it makes people think, feel and do. They emphasize that when the experiential qualities of a material are probed and mapped alongside the material's technical properties and performances, a thorough understanding of the material is achieved to guide the design process. Accordingly, the experiential characterization of materials should provide designers with an understanding of *what* people experience when they encounter a material (e.g. they find it 'surprising', or 'cozy'), *to what extent they agree with each other* (e.g. how many of them are 'fascinated' by the material), and *why* they experience a material in the way they do (e.g. what sensorial qualities of the material elicit 'surprise').

This understanding is particularly essential when materials are taken as departure points of the creative process, and are explored for their potential to evoke unique and meaningful product experience (Karana et al., 2015; Wilkes et al., 2016; Miodownik, 2007; Karana, Pedgley & Rognoli, 2014; Chen et al., 2009; Gransber et al., 2015; Light.Touch.Matters EU project, http://www.ltm.io.tudelft.nl/). However, design professionals often have limited time and skills to invest in user studies, which might usually take considerable time within a project timespan (Sanders, 2005). There is no single tool to date to support experiential understanding of a material in a systematic, holistic, yet *agile* way, thus facilitating the uptake of this practice. In this paper, we present our initial attempt toward the development of a tool to support design professionals and material developers in conducting a set of user studies to characterize materials experientially. In the next sections, we first present the notion of materials experience as a foundation for our tool. Then, we will elaborate on the existing tools developed over the last two decades to support designers in their experiential understanding of materials. We will then present the development of the tool through two iterations: first, the development and testing of a draft version, used in two workshops with design students and design professionals. Secondly, we describe the refinement of the tool towards its final version. In the discussion, we address possible uses and applications of the tool and identify future steps for the tool validation.

2 Understanding Materials Experience

Materials of products are acknowledged as one of the most effective sources to affect the experiences people have with and through products (Karana, 2009). While the experience of metal changes whether we encounter it in a sleek water bottle or in a gun, the opposite also stands true – a gun made of foam will be hardly as scary as a metal one. The term '*materials experience*' was first introduced by Karana et al. (2008) and elaborated in a recent framework by Giaccardi and Karana (2015), emphasizing the active role of materials in shaping the ways people interact and experience products at four experiential levels: (1) **sensorial level** (e.g. we think the material is heavy or rough), **(2) interpretive level** (e.g. we think it is modern or high-quality), (3) **affective level** (e.g. we feel fascinated or surprised by the material), (4) **performative level** (e.g. the material makes us tweak it or caress it). These levels articulate an *operational understanding of materials experience*, categorizing different experiential qualities that can be elicited by materials. Nevertheless, these levels of materials experience are highly intertwined and experienced as a whole, influenced by each other and by other factors such as time and context of use (Karana, Pedgley & Rognoli, 2014; Giaccardi & Karana, 2015). Hence, materials experiences can be quite challenging to study and research. It requires a delicate balance between studies that provide both a holistic perspective on the overall experience and detailed, specific information that allows designers to understand how materials can be manipulated to fulfil a design intention. In the next section, we will overview the tools that have been developed to date to provide such an understanding of materials.

3 Tools for Understanding Materials Experience

In recent years, research has made increasing efforts to foster the inclusion of materials experience considerations in product design (Pedgley, 2014; Ashby & Johnson, 2002; Wilkes et al. 2016). These efforts led to the development of few tools that can help designers to explore, assess and manipulate the experiential qualities of materials. For example, Rognoli's Expressive-Sensorial Atlas (2010) was developed as a tool to deepen designers' knowledge about materials' experiential qualities. It consists of a collection of maps related to one or more properties (e.g. tactile experience map), which designers can use to rank and compare different materials. In this way, the tool invites designers to reflect upon the sensorial and expressive properties of materials. Van Kesteren (2008) devised four tools (the Question tool, the Picture tool, the Sample tool and the Relation tool) that consisted of checklists, visuals and vocabularies to stimulate designers in the consideration of materials' sensorial properties during the early phases of design. Zuo (2003) developed instead the Material-Aesthetics Database, describing materials textures based on four dimensions: geometrical (e.g. irregular- repetitive, plain- bumpy, etc.), physical-chemical (e.g. warm- cold, mist- dry, etc.), emotional (e.g. cheerful- dull, comfortable- uncomfortable, etc.), and associative dimension (feather-like, silky, etc.). The tool is meant as a database of research outcomes, generated through user studies, that designers can browse during materials selection, exploring the interrelationships between the experiential qualities on a matrix (Zuo, Jones & Hope, 2004). Similarly, Karana's (2009) Meanings of Materials Tool encourages designers to select materials based on their 'meaning evoking patterns', based on a dataset generated by empirical studies across different user groups. The tool has been tested in several case studies and projects (Karana, 2009; Karana, 2012).

Bang (2007) adapted the Repertory Grid technique to investigate users' emotional concerns to textiles. The approach combines the comparison of material triads by rating them on selected properties (e.g. hard vs soft); and qualitative methods to achieve deeper insights about user-material relationships (Petersen & Bang, 2016). Recently, Hasling (2016) developed a canvas to organize and distinguish different material qualities (e.g. associative and emotional) particularly to be used in design education.

The majority of these tools were developed to serve different purposes, e.g. for educational purposes (Rognoli, 2010; Hasling, 2016); or materials selection (Zuo, 2003; Karana, 2009), rather than to specifically support *active research* for the experiential characterization of materials. Their underlying logic can be used to structure materials experience studies, as demonstrated in a number of projects (see e.g. Karana, 2012; Lilley et al., 2016; Sauerwein, Karana & Rognoli, 2017; Howes et al., 2014; Salvia, Rognoli & Levi, 2013; Overvliet, Karana, & Soto-Faraco, 2016; Asbjørn Sörensen, Jagtap & Warell, 2017). However, the tools listed often focus on one level only (e.g. the sensorial, Sensotact® by Renault, Allione et al., 2012); and they ground on an earlier definition of materials experience (Karana, Pedgley & Rognoli, 2014), thus they do not cover the characterization of materials' performative qualities. Nevertheless, all these attempts share the following concerns to facilitate an experiential understanding of materials for design professionals: (1) it is important to provide information both on the material's experiential qualities, and on their interrelationships; (2) tools should provide the results of the study in an engaging and inspirational manner to support the creative process.

The way these tools have been applied demonstrate the variety of situations that materials experience studies entail. Sometimes, designers might want to compare the same material in different variants (e.g. more or less fibred; or different colors, see for example Karana, 2012); or to explore one specific material in comparison with other known materials (Bakker et al., 2015). In some other cases, designers might be interested in only specific aspects of materials experience, for example the relationship between sensorial qualities and triggered actions (see for example Barati et al., 2017). Lastly, materials experience studies can be conducted in controlled environments such as a lab setting or a design studio; yet often times, designers engage with users' responses to materials during exhibitions or events (Camere & Karana, in press). Our goal is thus to facilitate the experiential characterization of materials in this variety of situations, and in relation to the four experiential levels (Giaccardi & Karana, 2015).

4 Designing a tool for designers

Design methods and tools are meant to assist designers in handling wicked problems (Buchanan, 1992) and uncertainty characterizing design problems and practice (Dorst, 2011), as effectively and efficiently as possible (Daalhuizen, 2014; Cross, 2006). Design tools aimed at supporting design practice should stimulate *reflection-in-action* (Schön, 1983; Stolterman et al., 2008), *externalization* of design ideas and *perception* of new facets of the design situation (Dalsgaard, 2017). They should be designed so that they are immediate to learn, precise and simple, and allowing a quick engagement with the design situation (Stolterman, 2008), without being prescriptive of design outcomes (Daalhuizen, 2014). Aspects such as how *flexible* the tool is, how much *freedom* it provides and how *easy* it is to use should be considered in the tool development to achieve its easy uptake (Stolterman & Pierce, 2012; Daalhuizen, 2014).

Moreover, design professionals often have limited time and skills to invest in user studies (e.g. performing statistical analysis from empirical data). For this reason, they tend to prefer qualitative and self-developed toolkits over structured and quantitative studies (Koskinen et al., 2011; Sanders, Brandt & Binder, 2010). To that end, the most important features of a tool to explore user experience is the stimulation of empathy (McDonagh & Denton, 1999; Mattelmäki, 2005) through the engagement with rich experience information that can provide inspiration for idea generation (Sleeswijk-Visser, 2009; Sanders, 2005). Accordingly, designers have shown preference toward visual and little text-based representations of such rich information (e.g. diagrams, graphics) over long, textual reports in both product and materials experience studies (Karana, Hekkert & Kandachar, 2010; van Kesteren, 2008). These requirements, together with the considerations on how materials experience can be investigated, outline the ingredients of a tool to support design professionals in the experiential characterization of materials.

5 [Ma2E4]: a tool for experiential characterization of materials

Based on this analysis, we conclude the subsequent objectives:

- The tool should provide both **specific (i.e. individual levels) and holistic (i.e. interrelationships between four levels)** information about materials experience, balancing rich, qualitative descriptions and targeted, comparable data.
- The tool should provide **structure** and **vocabulary** to collect, analyze and present data, without being prescriptive of design outcomes and solutions.
- The tool should be **agile**, **easy-to-learn** and **flexible,** to be adopted in different situations to support materials experience studies.
- The ultimate purpose of experiential characterization studies is to reveal new insights and facets of how materials can be manipulated to elicit novel and positive user experiences. The tool should support organizing and communicating results in a way that it will **inspire** designers toward such user experiences.

Accordingly, we set out to design a tool to meet the listed objectives. The tool is structured around the four levels of materials experience, i.e. sensorial, interpretive, affective and performative (Giaccardi & Karana, 2015). To balance holistic and specific information, the tool should provide information on the experiential qualities elicited by the material (e.g. 'rough' or 'smooth'), the specific ***mode*** in which the quality is experienced (e.g. if a material is perceived as 'very rough' or 'mildly rough'), and the ***interrelationships*** why this experience is triggered (e.g. why do they think a material is 'natural' or 'surprising'). Table 1 shows what these three layers entail with regard to a material's experiential understanding.

Table 1. three layers in experiential characterization of materials.

	sensorial	interpretive	affective	performative
quality	rough	elegant	surprised	caressing
mode	very rough	elegant like a luxury palace	negatively surprised	gentle/repetitive caressing
relationships	the material is very surprising because it looks rough but feels very smooth.			

We name the tool as **Ma2E4**, acronym for *Materials-to-Experiences at four levels*. As it consists of a collection of tools, one for each experiential level, it will be referred as a *toolkit*.

For the ***sensorial*** level, the Ma2E4 toolkit includes the sensorial scale developed as part of Karana's (2009) Meanings of Materials tool, and later adapted in Sauerwein, Karana and Rognoli (2017). The list provides frequently used sensorial qualities (both by designers and end users to describe materials), which were empirically validated across different materials experience studies (Karana, 2009). Similarly, for the ***interpretive*** level, we adopt the list of 22 meanings commonly associated with materials (Karana, 2009). These meanings offer very broad interpretation and several distinct sub-meanings (e.g. a material can be handcrafted in the sense of exquisite refinement or in the sense of imperfection). In order to detail the specific understanding of the different sub-meanings, we rely on the use of pictures, which can help articulating the mode in which the meaning is experienced because of the unequivocalness of visual information (Govers, 2004).

As there is no specific vocabulary available in relation to the ***affective*** level of materials experience, we adopted the taxonomies from product experience for both positive (Desmet, 2012) and negative (Fokkinga, 2015) emotions elicited by products. These vocabularies provide comprehensive sets of descriptors (n=25 facets of positive experiences; n=22 negative emotions). To obtain a manageable list, and relate it more to materials affective experiences, we cross-matched the vocabularies with the set of descriptors found by Karana in an earlier study (Karana, Hekkert & Kandachar, 2008). In this way, we could select 20 emotions that were validated through systematic research (Desmet, 2012; Fokkinga, 2015) and that are also used in describing materials at the affective level (Karana, 2009). The list includes an equal number of emotions that are generally considered positive or negative; however, the real valence (i.e. the pleasantness of emotions) can largely depend on user's subjectivity (Russell, 2003). To detail the specific mode in which the material is experienced, we adopt Russell's model (2003), which explains emotions as characterized by the two main dimensions of arousal (i.e. intensity) and valence (pleasant vs. unpleasant). The four-axis diagram shown in Figure 1b will be used to rate whether the emotion is actually experienced as pleasant or unpleasant, and the intensity to which this state is perceived.

As we mentioned, no specific tool is available to characterize the ***performative qualities*** of materials. While we acknowledge the need of further studies on the topic, to give an initial idea we decided to include the performative materials exploration pictures provided by Karana et al. (2016), which describe different types of actions elicited by material-user interactions (Figure 2).

6 Toolkit development

The toolkit was developed through two iterations. In the first stage, a draft version (Version 1) was tested in two workshops, both with design students (workshop 1) and design professionals (workshop 2). These two workshops were aimed at testing the overall approach of the toolkit, its specific components (i.e. the tools included) and exploring the benefits and limitations with prospect users of the toolkit (i.e. design professionals, material developers and design students). We observed participants' usage of the toolkit through the workshops and discussed their experience with the toolkit at the end of the workshops. The sessions were also audio-recorded. Participants' comments were transcribed after each session and analyzed through content analysis (Krippendorff, 2004).

Figure 1. From left: a) The draft version of the Ma2E4 toolkit; b) card and maps included for the affective level.

6.1 Toolkit Version 1

The first draft of the Ma2E4 toolkit was designed as a box containing several envelopes, each addressing one activity for the experiential characterization of materials (Figure 1a). The envelopes provided *cards* with the instructions for the facilitator and *maps* to record how people act upon and describe a presented material (Figure 1b). Beside the four levels, the tool also included two more activities, one at the start and one at the end of the experiential test. The first activity was called *'free exploration'*, during which participants were given a material sample and asked to interact with it freely, while explaining their first impressions. The activity was meant to explore people's initial reactions without the influence of the provided vocabulary of the toolkit. After this, the facilitator could proceed with the 'study' focusing on the four sub-activities related to the four experiential levels. Lastly, the '*reflective close-up'* suggested showing participants a prototype demonstrating the material in a shape (Figure 1a). This phase was particularly meant for researchers to understand whether (or not) people's reactions change when they see the same material embodied in products. We suggest that designers who already have some product application ideas for a material at hand might include these ideas (as physical prototypes) in the study.

The toolkit provides facilitators with instructions to go through the four levels of materials experience one by one, as separate activities, and in the subsequent order: performative – sensorial – affective – interpretive. The ***sensorial tool*** consisted of the sensorial scale, printed on transparent paper, so it could be overlapped during the analysis of results and provide an immediate grasp of the differences between participants' answers. The sensorial level also involved asking three specific questions to users: 1) what is the most *pleasant* sensorial quality? 2) what is the most *disturbing* sensorial quality? 3) what is the most *unique* sensorial quality?

The ***affective tool*** included the affective vocabulary, printed as stickers, and the map to record participants' answers based on Russell's (2003) model of emotions. In this activity, facilitators should ask users to describe the emotional state elicited by the material and choose three representative words from the set. Then, they should place the stickers on the map rating how intense / mild, pleasant / unpleasant the selected emotions felt.

The ***interpretive tool*** consisted of the interpretive vocabulary, also on stickers, and a set of 21 pictures associated to each meaning. The pictures were not validated, yet they were included to investigate the value of visuals for detailing meanings of materials. Facilitators should ask participants to choose three meanings out of the set provided, and then associate two pictures to each chosen meaning.

For the ***performative level***, facilitators should ask participants to interact with the material for 1-2 minutes. Then, users should choose few pictures from the set provided (Figure 2), to represent the actions that the material inspired them. Facilitators and users should also name the actions and note them down on the map.

Figure 2. example maps, stickers and cards provided to support the performative level.

6.2 Workshop 1

The first workshop was conducted as part of an elective design course "Materials for design" at Delft University of Technology (Figure 3). It involved 16 design students (male: n=9; female: n=7), all attending the MSc level. Students were familiar with the notion of experience-driven design, but have limited expertise in conducting structured user studies. The workshop lasted 3 hours, including 30 minutes of introduction and 45 minutes of discussion at the end of the activity. They were asked to simulate a user study using the first version of the Ma2E4 toolkit, alternating in the role of facilitators and users. They were divided in eight couples of user-facilitator. As facilitators, they were given the draft version of the toolkit containing the instructions to lead the user study. As users, they were presented with a material sample and they were asked to describe their own experiences with it, following the instructions of the facilitator. For this workshop, we chose relatively new and unfamiliar materials: mycelium-based composites, which are materials fabricated from the growth of fungi on substrates of organic waste materials, e.g. rapeseed straws (Camere & Karana, 2017). At the end of the user test simulation, the maps through which facilitators collected the users' response were hung on a whiteboard, grouped by experiential level (Figure 4). In the subsequent discussion, we demonstrated to the participants how results could be analyzed and what kind of interrelationships could be identified in the data.

Figure 3. pictures from the two workshops supporting the development of the Ma2E4 toolkit (left: workshop 1; right: workshop 2).

Figure 4. the maps collected and grouped by experiential level during the end discussion of workshop 1.

6.3 Workshop 2

The second workshop took place within a masterclass for design professionals on the topic of "Materials-driven design" at Delft University of Technology. A total of 8 design professionals (male: n=6; female: n=2) joined the workshop. All participants had significant expertise in materials and design research. As in the first workshop, the participants were given a brief introduction to the topic of materials experience (around 30 minutes), after which they were divided in couples to simulate a user test session. The workshop followed the same procedure of the first one.

7 Results

Both workshops provided relevant insights and demonstrated the potential of the toolkit, nurturing its development. Results from both observations and collective interviews were grouped in three categories: 1) related to the approach; 2) related to the specific components of the the toolkit; 3) related to the way the toolkit is designed (i.e. overall design). We discuss these findings in detail hereafter, supported by quotes from the participants.

7.1 The Toolkit Approach

Participants from both workshops were generally satisfied by the toolkit. The toolkit was found easy-to-use. Both workshops ran smoothly and participants had no difficulties in understanding the activities suggested. Professionals from Workshop 2 appreciated the richness of data provided by Ma2E4 toolkit, in contrast to the approaches that they were used to (*"I've done more empirical studies, structured studies (…) but I often feel that something is missing."* – professional 1). Also, participants felt engaged in the exploration of each experiential level: "*I like how the different tools support the exploration in different moments… I like the emotional map because I had an idea of doing it* [i.e. exploring affective materials experience] *but I only had the Self-Assessment Mannequin* [i.e. the SAM, Bradley & Lang, 1994]. *But that has less to do with a material, it's more for a product. I like the interpretive also, because it's not rating…"* (professional 4). At the same time, they agreed that the tool *"is very interesting because you can really catch the influence of the different qualities of materials on the overall experience..."* – (student 3) and that it is also inspiring: "*in terms of inspiration I think it's really useful"* - (professional 2).

Furthermore, professionals from Workshop 2 have praised their significance to support the conversation with users *("I like how the vocabulary made it easier to express and talk about experiences… it really supported the conversation because normally it's so difficult to name emotions"* - professional 5). Indeed, design professionals appreciated the potential of the toolkit more than design students. This was because professionals acknowledge the investment of time and efforts that structured user studies normally require, and they valued the agile and easy-to-learn approach of the Ma2E4 toolkit.

7.2 The Toolkit components

Although the toolkit proved to be an agile and easy to use research tool, few limitations were found in the characterization of interpretive and performative qualities. Concerning the performative level, it was difficult for facilitators to simultaneously look at users' actions and choose the right pictures to represent them. Moreover, it was very challenging to identify a specific naming for the actions (i.e. fiddling instead of touching). Lastly, the pictorials provided were confusing because they showed different types of materials and shapes ("*I found it difficult because the pictures were from very different materials... if we could have pictures with the same materials, or same color... otherwise it's too different"* - student 2).

The interpretive level also entailed some confusion and difficulties. First of all, the set of interpretive pictures was found too limited by participants: "*the interpretive pictures, they were too few. They are not really meaningful to express the meanings..."* (student 7). Secondly, participants were not really sure on how to interpret the choice of the pictures, because these were not explicitly linked to each meaning (*"how can you evaluate the pictures, as data?"* – student 6). This is also related to another issue raised by participants: the difficulty in understanding how they could analyze the data collected through the Ma2E4 toolkit. "*In my experience, it's all about how you analyze. Because we had this discussion about the [interpretive] pictures, I asked the participant to specify what s/he wanted to add…and those comments are also very valuable, but how do I fit them in the data?"* (professional 3). One participant reported that showing the results of the sensorial scale as overlapped (n.d. being printed on transparent paper) was very engaging for him, because it provided a sort of immediate visualization of how participants' answers were differing (professional 2). This suggests that in order to support the analysis and interpretation of data effectively, the Ma2E4 toolkit should also tackle the representation of data so that it will help organizing findings in an informative as well as inspirational way.

Furthermore, the analysis session of the workshop made it clear that the three questions asked during the sensorial level were not necessarily related to sensorial qualities, but also to other experiential characteristics. For example, to the question *"what is the most unique sensorial quality of the material?"*, few participants answered *"its contrasting features"* (e.g. looking heavy but feeling light). The participants recommended keeping these questions rather open, in relation to all four experiential levels and their interrelationships.

7.3 The Toolkit overall design

Participants emphasized that they experienced the activities at each level as very distinct. This was mainly because the levels were presented one by one, through different envelopes. This complicated the exploration of the interrelationships between the experiential levels. As a results, the overall design of the toolkit should be improved to facilitate a more holistic understanding of materials experience.

8 Toolkit Version 2

Based on the insights obtained from the workshops, we concluded the following points of attention which guided the further development of the Ma2E4 toolkit:

- the toolkit should provide a holistic overview to support designers in revealing the interrelationships between the experiential levels; hence, the overall design should integrate better the activities related to each experiential level;
- the toolkit should support not only data collection, but also data analysis and visualization;
- the performative level should include a vocabulary of performative qualities; the related images should be improved and possibly include similar materials in all pictures
- interpretive pictures set should be expanded and better linked to the suggested meanings.

Figure 5. the Ma2E4 toolkit, redesigned based on the insights gathered in Step 1

Accordingly, we redesigned the Ma2E4 toolkit (Figure 5) as consisting of:

1. a ***manual of instructions***, which provides a brief introduction on materials experience and tips on the toolkit usage;
2. the ***facilitator's guide***, which includes the questions and activities designers should ask and perform during the study;
3. the ***experiential characterization map***, to record participants' answers.

Next to these, the toolkit includes two sets of words (i.e. the ***affective*** and the ***interpretive vocabulary***) and a collection of images (i.e. ***the interpretive picture sets***) to be used for refining the interpretive descriptions.

The experiential characterization map is designed as a folded A3 (Figure 6), so that each experiential level can be explored separately. At the end of the test, designers/facilitators can unfold the map and have a holistic overview of participants' answers. Going through answers, they can identify interrelationships and ask more detailed questions on the motivations behind user's answers. Being formatted as ISO:A3, the map is easy to reproduce and print. The folding instructions are provided in the Ma2E4 manual of instructions and shown in Appendix I.

Few specific changes were also made at each experiential level. For the performative qualities, we developed a list of actions describing the pictorials (Figure 7). The vocabulary and the pictures were organized according to the framework presented by Angelini et al. (2015), which suggests three main categories of gestural interactions with material artefacts. The three categories are: 1) ways of ***touching*** the material (e.g. pressing it, punching it, fiddling it); 2) ways of ***moving*** the material (e.g. folding it, flexing it, weighing it); 3) ways of ***holding*** the material (e.g. pinching it, holding it gently, etc.).

Figure 6. unfolding the experiential characterization map and revealing each experiential level separately.

The ***sensorial level*** remains unchanged, except for the exclusion of three questions concerning the pleasant, disturbing and unique qualities of materials, as these questions provided answers on a more general level and not directly related to sensorial.

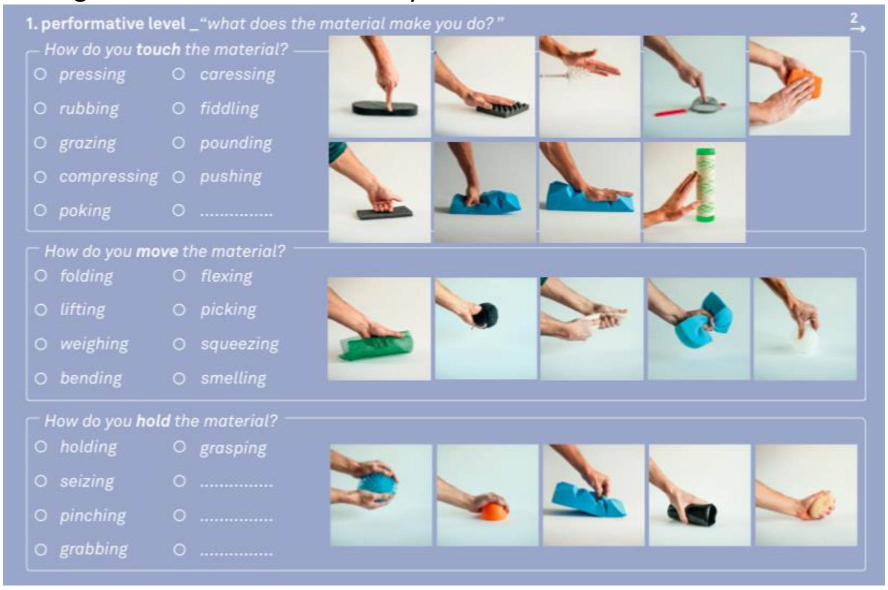

Figure 7. the performative vocabulary and the pictures included in the Ma2E4 toolkit.

For the ***affective level***, the vocabulary is provided on a card instead of stickers, which would have not been practical for design professionals to reproduce (Figure 8). The graph based on Russell's (2003) model is now organized on three axes instead of four (i.e. pleasant/unpleasant and level of intensity), based on the workshop insights. Indeed, the rating of intensity was found difficult to rate as 'negative', because users were asked to select the three most important (i.e. 'intensely perceived') words to describe their emotional experience. In this version, the purpose of the third axis is to detail which of the chosen emotional descriptors is more relevant to describe the user's emotional state, assuming that all three are intensely perceived.

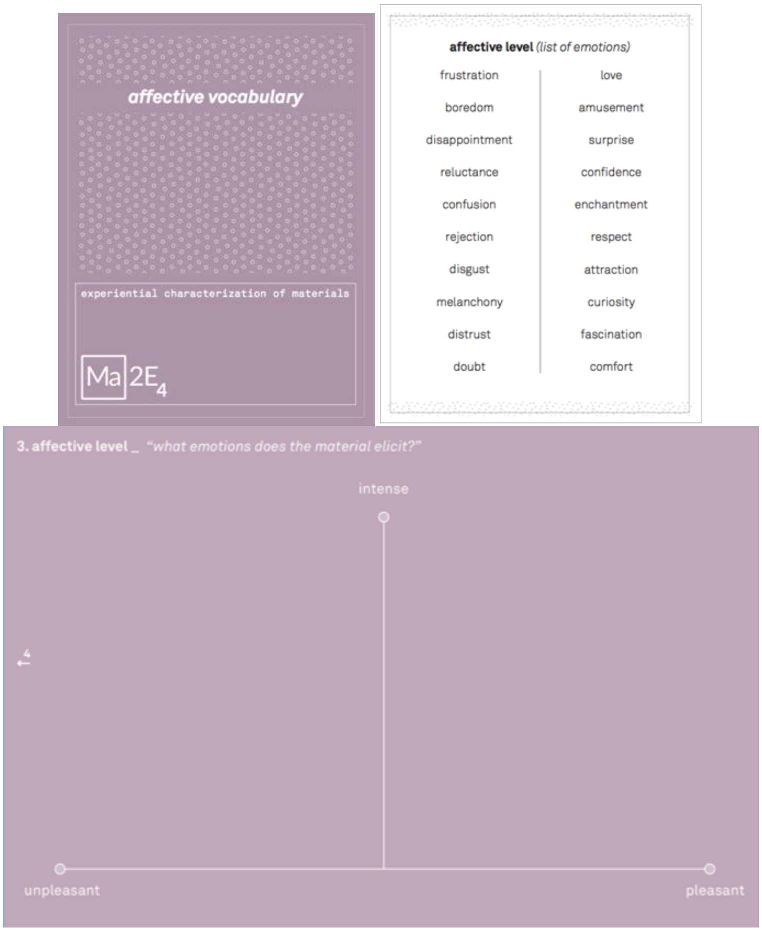

Figure 8. The affective vocabulary and the map to record participants' answers at the affective level.

Similarly, the ***interpretive*** vocabulary was also provided as a card instead of stickers (Figure 9). The set of interpretive pictures is now expanded, including 3 pictures for each meaning provided (Figure 10). As it is known that designers develop their own collections of pictures (Keller et al., 2009), which they often use as visual references, we also suggest that designers could develop their own set of visuals filling in the provided template, or expand on the provided one. To allow easy reproduction, the set of interpretive pictures is formatted as A3 sheets (Figure 10). Designers should ask users to select one picture (out of three provided for each meaning) to specify their interpretation of the selected meaning. We suggest that the pictures are cut and pasted on the map by the facilitator.

As suggested in the workshops, designers / facilitators may feel the need to deepen the conversation with users and ask the motivations behind their answers. The last step of the tool (***final reflection***) provides the opportunity to do this, unfolding the map completely and asking the three questions previously included at the sensorial level (i.e. "what is the most **pleasant** quality of the material?", "what is the most **disturbing** quality of the material?" and "what is the most **unique** quality of the material?"). Then, designer / facilitator can ask users to reflect on their previous answers, trying to catch the relations between the different experiential levels. For example, they can ask: "why do you think the material is aggressive? What are the sensorial qualities that make the material 'aggressive' according to you? And, how is this connected to the emotions you selected?", etc.

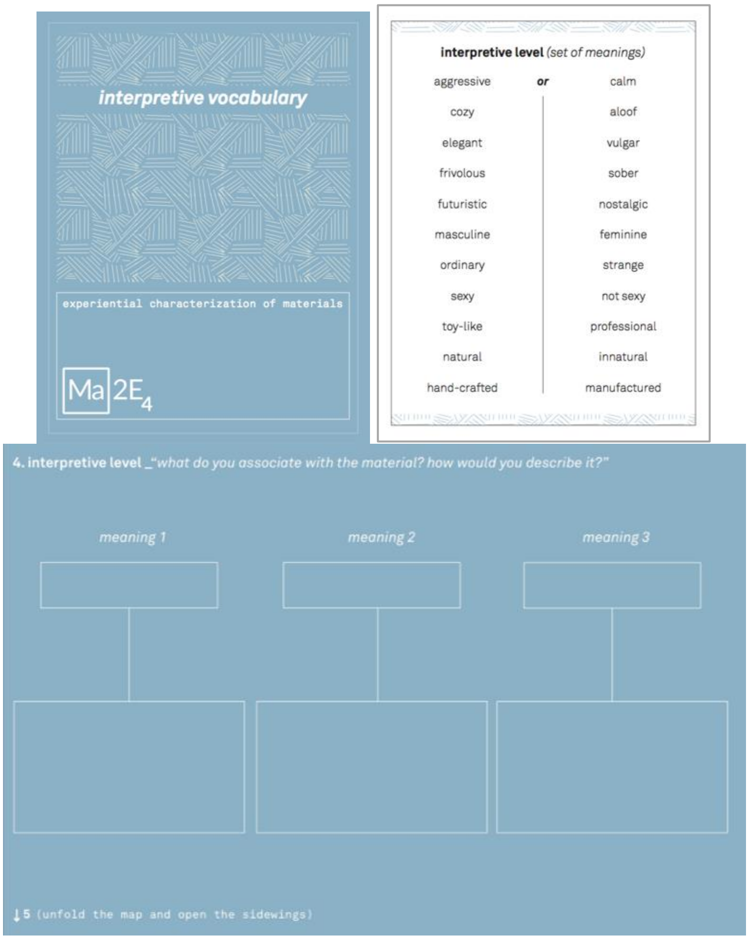

Figure 9. The interpretive vocabulary and the map to record participants' answers at the interpretive level.

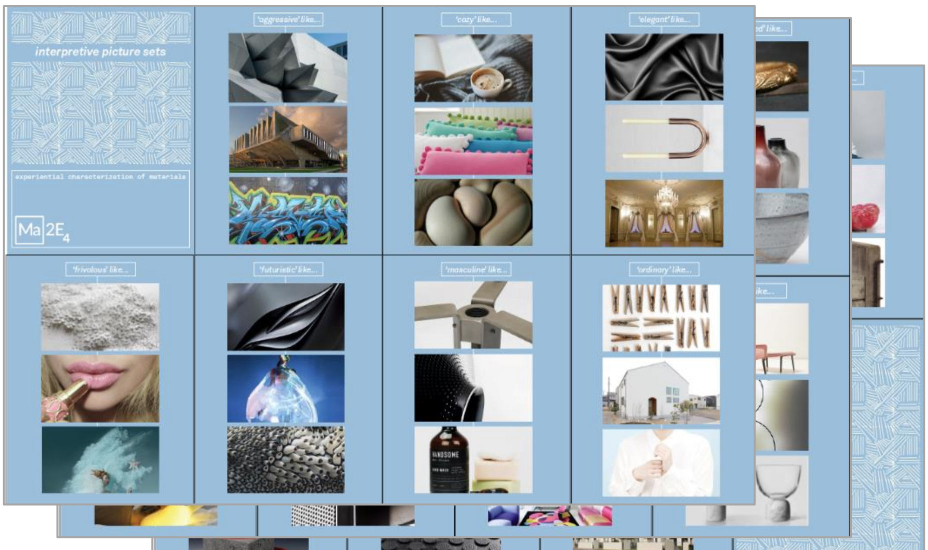

Figure 10. The new picture sets related to each interpretive quality.

9 Discussion

The new Ma2E4 toolkit was designed as flexible and agile as possible, to better support design professionals and materials developers in conducting user studies to understand how people experience a specific material. This activity, defined as the experiential characterization of materials, is particularly important in Material-driven design (Karana et al., 2015), which is increasingly chosen as an approach to envision unique product applications or to stimulate the further development of new materials. Whether it is used to characterize novel and unknown materials, or to reveal new insights about a known material, the Ma2E4 toolkit can facilitate such experiential understanding of the material at hand. The toolkit is designed to allow different uses, depending on the specific needs of the design situation. Herein, we will discuss possible situations in which the Ma2E4 toolkit could support the research activities.

The Ma2E4 toolkit allows to conduct research on one specific material or to compare the material at hand with other known ones, which is a common practice in understanding materials in design (Ashby & Johnson, 2002). Moreover, it can be used to test multiple variants of the same material. In projects where designers act as developers of new material proposals (i.e. *DIY materials*, Rognoli et al., 2015), designers can link the material variables (e.g. 'material ingredients', Rognoli et al., 2015) to the experiential qualities. Doing so, they can purposefully manipulate material properties to achieve the envisioned experiences. Moreover, while we emphasize the importance of all four experiential levels, the Ma2E4 toolkit could also be adopted to investigate one specific level in more details (e.g. affective level). As explained earlier, the tools developed for each level ground on rigorous studies conducted by scholars within the materials and design domain. They can provide reliable results for detailed understanding of a specific level. Yet, designers might also decide to adapt additional tools for a specific level, while maintaining the overarching framework. These *appropriations* are common in design methods and tools (Stolterman, 2008) and we seek to encourage professionals to approach the Ma2E4 toolkit in this way.

To analyze the data gathered in Ma2E4 studies, designers can choose between an exploratory approach or a more structured one, depending on their specific needs. Designers might use Ma2E4 toolkit to explore users' perspective and reveal new facets of a design situation (Dalsgaard, 2017). At the end of the tests, they might already identify *materials experience patterns* (Giaccardi & Karana, 2015; Karana et al., 2015) that inspire new ideas. In this case, they can decide to skip any type of structured analysis, but simply to map out the most relevant insights obtained from the study.

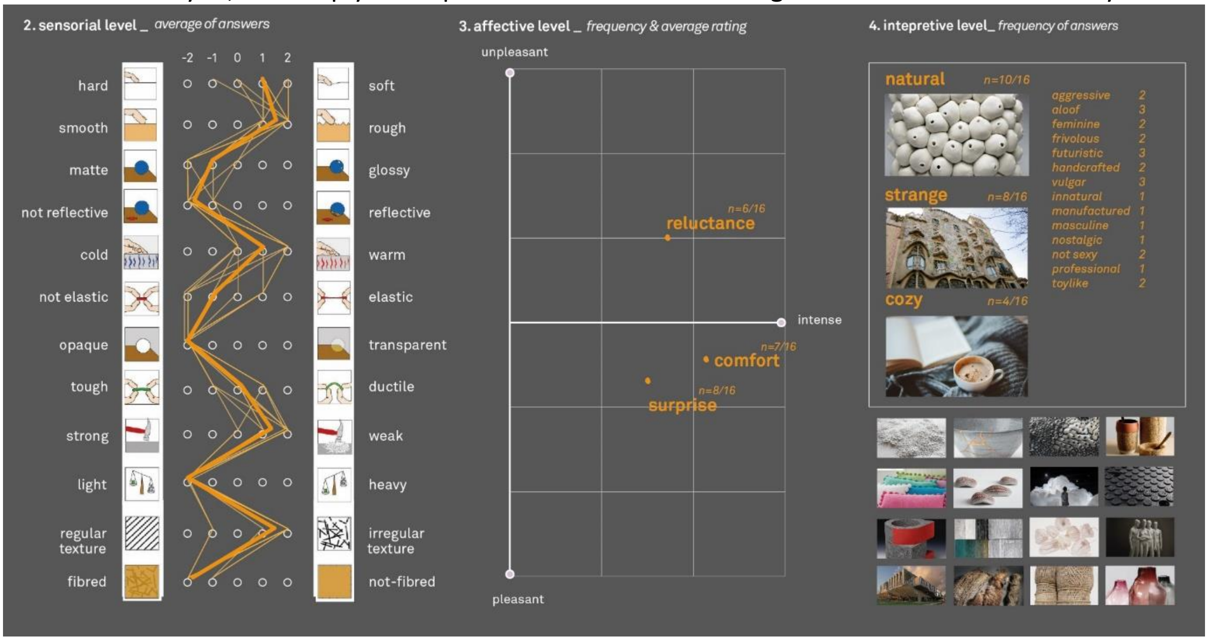

Figure 11. examples of how Ma2E4 data (for one material) can be analyzed and represented through systematic methods.

Yet, when designers or materials developers engage in larger projects, either research- or business-oriented, they might need to analyze data with a more structured approach. Despite its flexibility, the underlying structure of the toolkit allows the collection of comparable results, which can be analyzed through statistical tests, such as ANOVA (for the sensorial level, as seen in Karana, 2014; Sauerwein & Karana, 2017), frequency of choices (e.g. for the affective and interpretive qualities) and factor analysis (to identify correlations between the answers, Karana, 2009) (Figure 11).

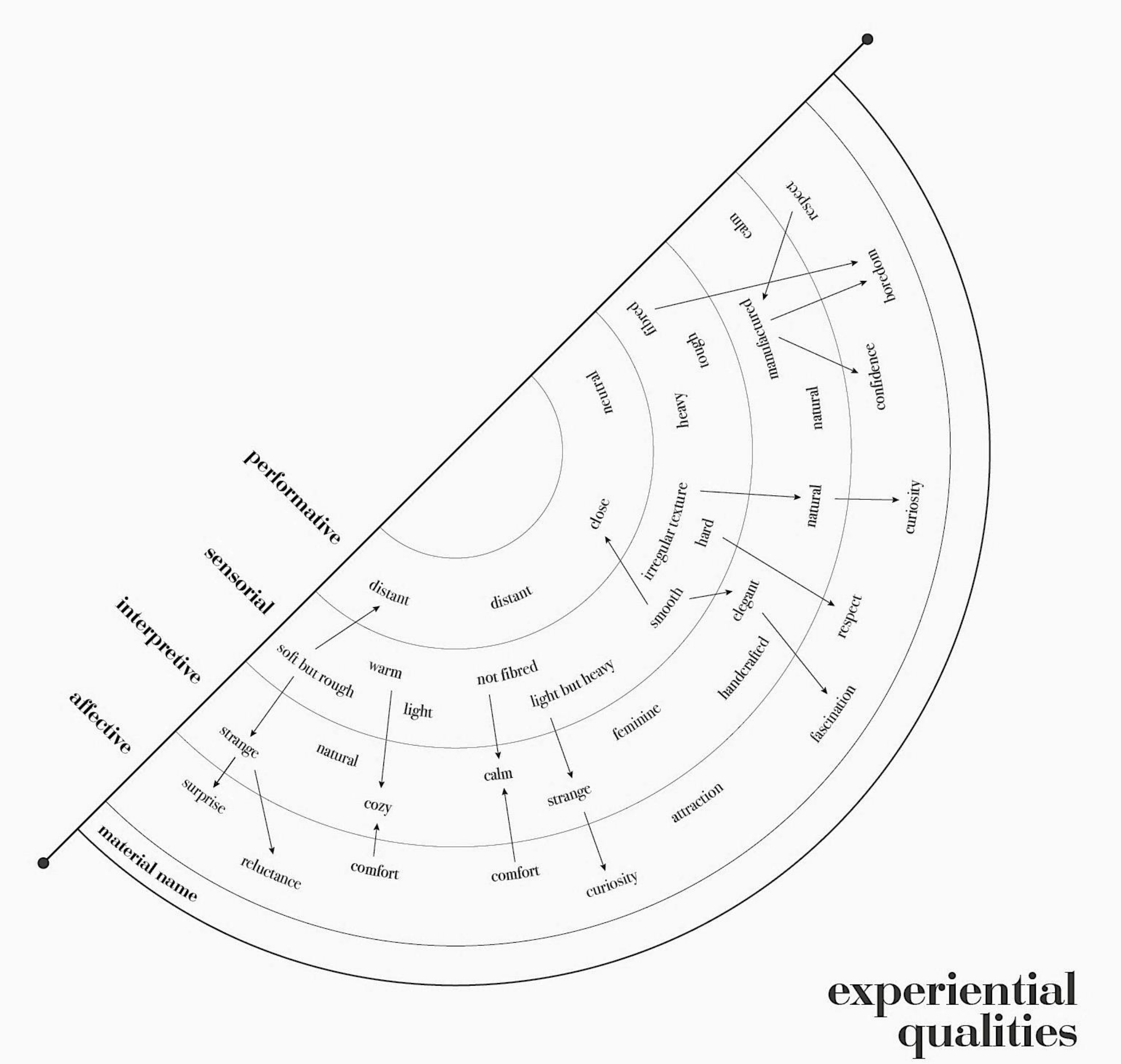

Figure 12. The canvas designed to map the materials' experiential qualities at the four levels of materials experience and their interrelationships.

The way data is visualized and communicated is also very important to stimulate reflections over users' reactions and inspire design (Sleeswijk-Visser, 2009). Keeping this in mind, we developed the experiential characterization map with a high visual component, so that once completed, opening and confronting the maps would already provide a visualization of the results. Nevertheless, it is important to further support designers in this step with a targeted tool, especially in the case of larger projects when results need to be presented in a more systematic way. We suggest as a possible solution to this the canvas illustrated in Figure 12. The canvas consists of four rings, which can help mapping the insights gathered in relation to each experiential level. It can be used to summarize the most *relevant* user insights, either based on the designers' / facilitators' own interpretation of the findings or on the structured analysis of the user responses.

We also suggest that the canvas can be used to present the interrelationships between the technical properties and the experiential qualities of materials (Figure 13), emphasizing the dualist perspective needed to understand materials. An example of how this approach can inform the further development of emerging materials is demonstrated in a nationally-funded project “Mycelium based materials for product design”. The canvas was used recently in the exhibition “Fungal curiosities”, to present the project’s preliminary results during Dutch Design Week 2017 (Montalti, 2017).

Figure 13. Exhibition ‘Fungal curiosities’ at Dutch Design Week, displaying the technical properties and experiential qualities of mycelium based composites (Montalti, 2017).

The Ma2E4 toolkit was developed based on the insights gained in two exploratory workshops. While we acknowledge that the approach and the toolkit needs further validation (e.g. on whether our design suffices to support the analysis and visualization of data), we can foresee its possible contribution to materials and product development. Further applications of the Ma2E4 toolkit, e.g. in graduation projects or in projects from design practice, will bring new insights on how the experiential characterization of materials can be conducted to inspire materials and product development. Moreover, as we speculated at the start of our journey, further work will be needed to support the performative level. This is due to the relatively recent introduction of the notion (Giaccardi & Karana, 2015) and thus to a lack of vocabulary on materials’ performative qualities. The research into the construction of a vocabulary for performative qualities of materials would inevitably support the further development of the Ma2E4 toolkit. At the present moment, the toolkit relies on existing tools and research conducted over the years in the domains of materials and product experience. Yet, its originality and relevance lies in connecting different strands of research to foster a holistic understanding of materials experience and an agile approach to this type of studies. In this way, we hope to facilitate the practice of characterizing materials experientially, to achieve a dualist understanding of materials, and further stimulating design with a specific material at hand.

10 Conclusions

The paper presents the development of the Ma2E4 toolkit, aimed at facilitating the experiential characterization of materials. Our goal is to foster the uptake of this practice by providing an agile, reliable and inspiring tool. The toolkit has been developed grounding on existing literature and through two exploratory workshops, involving design professionals and design students. The workshops provided useful insights on the toolkit's final design, which is presented in its current version in the paper. While the toolkit needs further adjustments and validation, it has proved to support design practice in conducting user studies to understand how a material is experienced.

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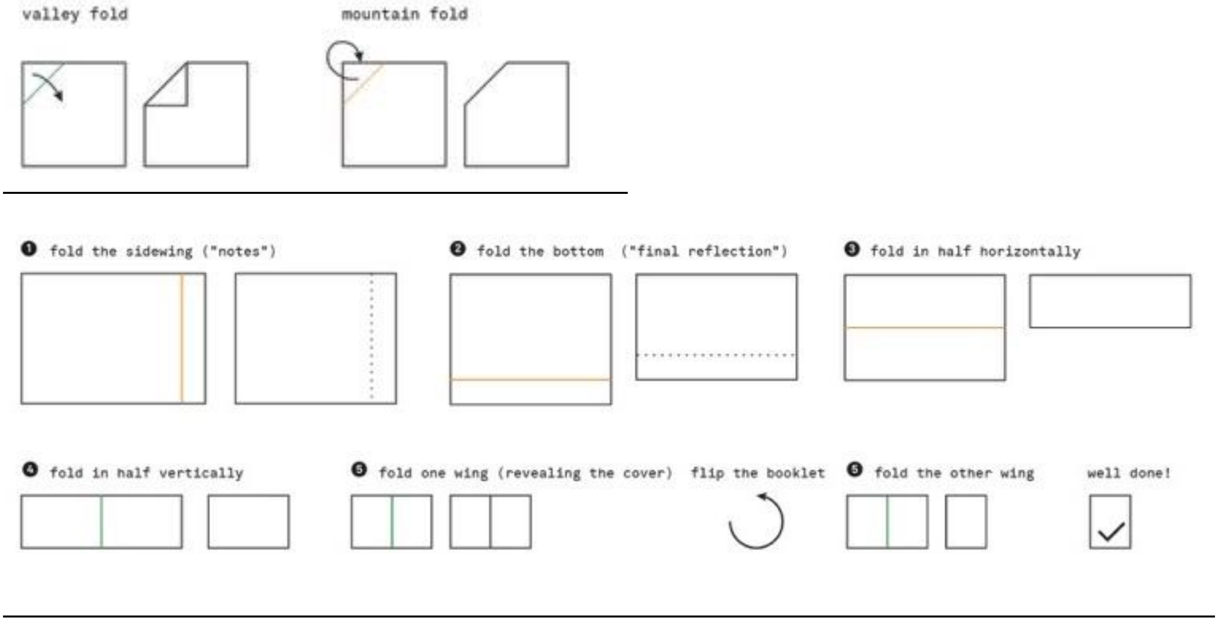
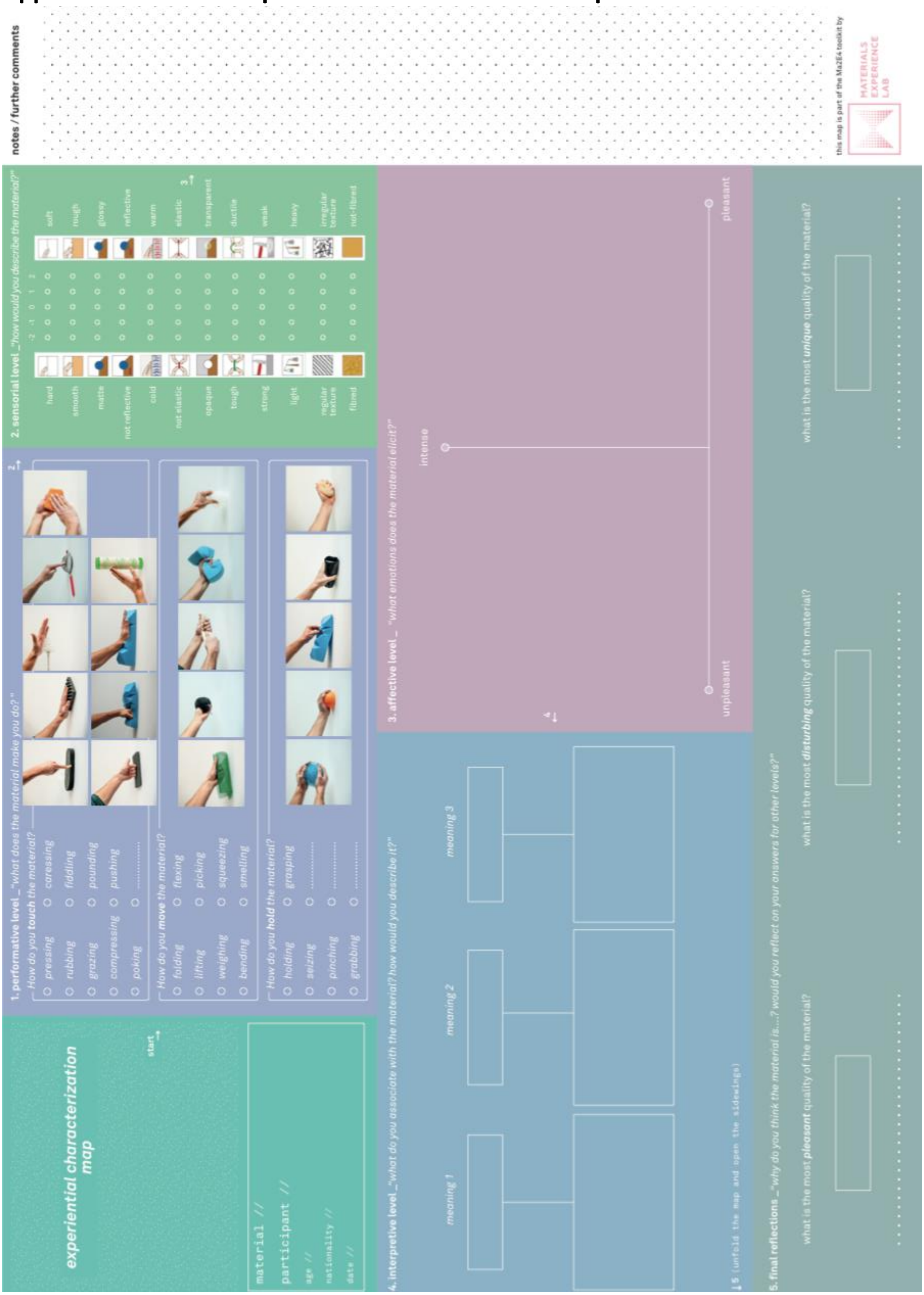
Appendix I

Folding instructions, as included in the Ma2E4 manual of instructions.



Appendix II – Ma2E4 experiential characterization map



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Natural Materials – Nature of Materials

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The material world is recently and very rapidly changing; altering the relationships between materials – the substance of everyday life – and designers – the professionals who are responsible for transforming materials into daily life objects. This vibrant context prompts us to explore and attempt to conceptualise these fluid relationships and review conceptual tools that will help to open up the scope of materials-based research in design. To address the multiple and multi-faceted relationships designers are situated in, we borrow concepts from social sciences that explore materiality within its multiple environments. We draw on conceptualisations of materials as active and as having capacities to bring about change and proliferate relations, and responding to new developments of biotic materials. By considering historic materials, particularly milk-based plastics, we propose a new category of autonomous materials. We discuss the emerging designer-material relationships with the hope of directing future enquiry into materials and discuss the implications of a new class of materials – the 'autonomoids' – for design research.

materials, milk plastics, biotic materials, materials-based research

1 The Emerging Material World and Conceptual Dilemmas

This paper aims to elaborate on the emerging and changing designer-material relationships within the current developments in materials science and product design fields. The material world is "vibrant" and "active" (Bennett, 2010), literally in the sense that atomic particles are always on the move, but also in the sense that the material circumstances of our daily lives, its materiality, is constantly changing. But materials are also "active" in the sense of the word found in science and technology studies (STS), because they *cause* change, and *affect* other human and non-human actors, as well as affecting professional and daily life practices.

In recent years, we are talking about a materiality where materials are "smart", where materials "grow" themselves, where they are natural, or synthetic, or biotic… These materials *act*; a glove using a soft, flexible non-Newtonian material, becomes hard and strong when hit by a hammer. These materials are *alive*; fungus put in a chair-shaped mould, grows to become a chair. It is as if these materials can *take on human responsibilities* regarding our duties to protect nature. Even plastics, which have a reputation as the most 'anti-nature' materials, can be nature-friendly or nature-derived, depending on what is inscribed in their molecular structure. New production machinery can *develop* new materialities, with rapid prototyping methods generating shapes quickly and apparently without effort. And material things can *communicate* with each other, through the "internet of things".

For designers, the professionals, who are assigned the task of adopting materials in forms that both suit the daily life needs of humans and protect nature, and who thereby alter and modify both humans and 'nature', these developments are crucial as well as confusing. Because there are various disciplines interested and involved in design and production processes, design's pragmatic relationship to materials is varied and operates with quite inconsistent conceptualisations of them - materials are both substances that are shaped in the hands of designers to find their place in our everyday lives, and they are also described as if they have independent human-like characters – the 'warmth' of wood, the 'spookiness' of fungi. Dominating this pragmatic relationship to materials are culturally defined conceptions of nature, which are in themselves complex, increasingly characterised through what seems to be a limiting nature-culture or nature-design distinction, expressed as a material-designer/human-nature divide.[1] The relationship of humans, in general, to nature is complex and contradictory – we act "against" nature when we use the earth's finite resources, but if we think about human organs or tissues, we know they are natural, biologic, even as we try to use bio-medical science, and new materials, to imitate, repair or replace them.

Thinking through these material developments in terms of this range of perspectives, generates a number of questions, all variously related to design. Some are to do with their implications for designers' professional identity, such as whether materials science and product design need to form a new collaboration, and if so, how much of an engineer is the designer and how much a materials scientist. Some are more fundamental, such as asking where materials end and where the product starts, even to the extent of asking what it is valid to call *a material*, how to address active-liveness of materials for pragmatic purposes of design and designing. This raises the question of at what point does the *design* start between the level of material development and of use? The perplexing extent of material formulations, and the degree to which materials can be modified means these are boundaries that are shifting and blurred and moved us to explore the "nature of materials" within these new material developments.

To explore these multi-faceted relationships, and ontologies of materials we bring in approaches from social sciences, mainly material culture and science and technology studies, and attempt at a working conceptualisation of materials. This perspective provides us with a new way of addressing these emergent and fluid relationships. We nuance their active-ness by introducing the concept of "autonomy," and discuss the implications of bringing in a sociological approach, i.e., pointing to the relations making up material reality – and arriving at this new conceptualisation of "autonomoids." Some of the current developments in materials, such as changing qualities of plastics from "synthetic" and "harmful" to "bio-" (as in bioplastics) or self-growing materials as in the case of biotic materials, provide good examples of changing relationships between materials and humans, and especially from a designerly perspective for materials based researches in design, in terms of the relationships between materials and makers/designers. We focus on milk plastics, such as Casein, that are "derivatives" of milk. These materials allow us to elaborate on nature/design relationships with reference to a wide range of industries over time, because milk-derived plastics have been used in various sectors and have a history almost as long as that of synthetic plastics. They also raise rich

[1] The recent Design History Society conference DHS 2017: Making and Unmaking the Environment engaged with this nature-design divide saying designers are "either blamed for causing environmental problems, or hailed as possessing some of the competences that could help solving those problems." (conference call accessed on 11th Mar 2018 from https://www.designhistorysociety.org/conferences/view/dhs2017-making-and-unmaking-the-environment)

conceptual matters related to a range of concerns about bacteria, hygiene, nature, and sustainability.

In what follows we first introduce the theoretical framing that informs our exploration of the relations folded into milk plastics, then present our analysis of milk plastic's making. This analysis leads us to our conceptualisation of certain materials as "autonomoids," and in the concluding section we elaborate on design-material relationships, and discuss the ways in which "autonomoids" may contribute to design practice.

2 Conceptualising Materials

"Every material is a becoming" (Ingold 2012: 435)

Various approaches to materiality are relevant to the design discipline. Because design's interests and concerns are varied, approaches from different disciplines have been distinctly useful for, and applied to design research. Due to the social as well as technological nature of the practice, methods and approaches from social sciences as well as engineering disciplines are employed in exploring design's relationship to materiality. For example, dominated by concepts derived from engineering approaches to human-machine relationships, ergonomics obtains data through physical and morphological measurement methods (Dreyfuss, 1967). However, this is not comprehensive enough to explain humans' interactions with materiality as we are cultural and emotional, as well as physical, beings. The Design and Emotion umbrella – including design for behaviour change and some approaches to interaction design – uses theories derived from cognitive psychology and semiotics, gathering data through mainly quantitative methods to understand users' interaction with designed objects (Desmet & Hekkert, 2007). Karana (2009, 2017) in her many works makes a timely inference to the field through her work on materials by stating that material selection tools and approaches derived from engineering disciplines are inadequate in addressing multi-faceted relationships through which users appreciate materials (and materiality), and proposes better suited models for design to study these complex relationships.

Against this background, we want to explore more in depth sociologically oriented approaches from material culture, design anthropology and science and technology studies. These explore the phenomenological relationships of social and technical relationships folded into design objects in general and materials at a more fundamental level. Through objects and daily practices, in which objects are utilised, scholars explore the processes that are implicated in designing and the ways objects come to be (Clarke, 2011; Molotch; 2005; Shove, Watson, Hand, & Ingram, 2007).

The ways in which materials seem almost to act like humans, or are ascribed human-like properties in this process, resonates with Jane Bennett's ideas. In her political philosophical account of materials, she concentrates on material's active liveliness: "a creative materiality with incipient tendencies and propensities, which are variably enacted depending on the other forces, affects, or bodies with which they come into close contact" (2010: 56). She does not distinguish between the agency of materials and humans, which she refers to as "life". She maintains that materials are "life", just as much as human beings. Moreover, as Bennett (2010) argues materials are *active* in shaping the environments in which they are *enacted*.

Recent studies of industrial materials from different sociological traditions point to the, in Shove et al.'s (2007) terms, "mutually constitutive" relationships among human and non-human actors. For example, Misa's (1995) STS account of steel shows us how steel transformed transportation and made a whole civilisation mobile, meanwhile getting defined and patented *as* steel through negotiations among various producers and stakeholders. Schaztberg's (2003) business historical account of aluminium reveals complex interrelations between human practices and material developments, showing that canned foods revolutionised how we buy food and organise food stores. In Klein and Spary's (2009) book that takes a material culture perspective on the materials of early modern Europe, Orland's (2009) chapter elaborates on the making of milk in relation to different disciplinary traditions, their material culture and practices. Bensaude Vincent and Stengers (1996) conceptualise this as "informed materials" to explain that materials are already inscribed with knowledge about the environment into which they are born. Extending their idea, Barry (2005) shows the ways in which pharmaceutical materials are already informed with what is required - existing information technologies, patents and laboratory equipment. Studies on different materials suggest that materials are fundamental but non-fixed. As these scholars emphasise, as much as the different environments of which materials become a part are involved in defining (at least temporarily) their qualities, the materials themselves are also active in making their own qualities.

This brings us to the opening quote of this section, as Ingold (2012: 435) suggests: "every material is a becoming." In his review of recent explorations of the material/ agency nexus, he suggests that materials and humans are "knotted" together and they "co-respond" to each other. His term "correspondence" is a nuanced term explaining the co-constitution of different worlds, human and material, to which he assigns individuality and activeness in mutual co-responses to effects. He honours the entanglement of our "lines of life" with materials in a "meshwork" that is governed by correspondence rather than hylomorphic form-giving (2012, 2007), and notes Karen Barad's call to allow 'matter its due as an active participant in the world's becoming, in its ongoing "intraactivity"' (2003: 803).

However, while we strongly subscribe to the need to engage with materials with this degree of intimacy and ambition, we wish to be less abstract than are Barad and Bennett. And also we want to clarify that this discussion is not limited to only new-age and biotic materials. As Daniel Miller (2007) levels a charge of romanticism against Ingold's approach to materials and materiality, evident in the prevalence of 'traditional' materials, and artisanal rather than design-related examples in his work. Ordinary materials and traditional materials also correspond. However, Miller's (2007) ideas that materials (and objects) are not an end in themselves, but that they are processual actually confirms the Ingold's (2012) ideas materials as a becoming, and as a process; they are constantly in the making, and particularly so in the case of multiple enactments of a material – "Parkesine has multiple coexisting incarnations – as medallion, as comb, as card case or pen" (Shove et al, 2007: 102). However, Miller (2007) is concerned about individual processes. So while we are concerned with 'lines' of material development, as Ingold might have it, it is in a way a literary engagement with those lines – helping to develop 'a conceptual language as well as new forms of material practice' as Jenny Bergstrom puts it (2010: 172). Many of Ingold's principles do of course hold in this approach. As a material is invented and comes to be, comes to mean, it does so because it corresponds in some way(s) with human practices, both everyday life practices and design practices, which at the same time are bringing it about, or more properly in Ingold's terms perhaps, helping it to come forth, sometimes using exploratory hands-on approaches to material development. As such, as well as being attendant to individual stories and histories of different materials, we strive to achieve broader conceptualisations that can be applied to material engagement in general.

Within this perspective design researchers have worked with these fluid meanings and multiple environments. Fisher (2004), who focused on users' relations to materials has shown plastic, the modern marvel material appears "tacky" in certain contexts and "smelly" at times. Tonuk (2016) working on bioplastic materials and products into which they are made, focused on how materials come to be and the resulting material-product relationships. She has shown that qualities of these materials, the meanings and values attached to them, vary depending on the different environments in which bioplastics circulate, and that these qualities are negotiated among different actors. Hence, she has conceptualised materials as "temporally specific phenomena" (Tonuk, 2017).

Even this brief analysis has far reaching consequences for shaping how most effectively to conceptualise materials in design – rather than being stable entities that can simply be "specified", materials appear as a "processual" phenomenon without fixed meanings or interactions. Moreover, this view emphasises the designer's agency, their role in *making* material meanings, as well as being affected by them, over a view of designers as passive receivers of the meanings that users associate with them. Technical approaches down play the point that designers sit in an environment of multiple dynamics. While public opinion likes to think of them as the creative brains, out of which somehow ideas flourish, the design process is bounded by its environment, production technicalities, the availability of materials etc. Designers are but one of the agents with which things interact in their becoming.

This theoretical framing broadens the scope of the environment for design studies of materials, and it acknowledges that this context includes multiple users of materials and products, beyond the end user/consumer (who are themselves multiple). This broadening of the scope of materials design research to that of multiple environments of the designer has implications of its own, particularly so when considered in terms of the deeply embedded cultural categories that coalesce round ideas of nature. So rather than categorising the ways in which materials with different origins affect our relationship to nature, we see a nature-design unity as, using Manzini's (2016) terms "design culture". And the history of milk plastics is a good illustration of this, as it suggests that when it comes to materials, there is less contrast between the two terms in "nature-design" than at first appears.

3 Material antecedents – milk, bacteria, mould

Tracking a material to its origin to identify its real character is a method that Seetal Solanki proposes on her online platform "ma-tt-er". Clearly such an enquiry resonates with current interest into where things come from, a reflection of our awareness that origins matter because of their social and ecological effects. And of course, it reflects our sociological interest as the authors of this article, in how things come to be and how they circulate through multiple contexts, within Manzini's "design culture".

The story of Casein plastics – from surplus liquid to useful material to anachronism – mirrors the trajectory of plastics from trash (side-effect of petroleum distillation), to product, to trash. In it we can see its values for the communities involved with it and the values and qualities of different materialisations of milk and plastics. Closely connected to the life and livelihood of many humans and animals, milk is sometimes, palpably sour and smelly, sometimes it is understood as healthy, clean and sanitary, sometimes sustainable, sometimes inferior. A useful way to conceptualise these dynamic and multiple meanings is offered by Callon, Méadel, and Rabeharisoa (2002) who propose that goods are differently "qualified" in and through different actors with which they interact. Hence, to understand materials, we must look at them in their multiple environments and meanings. Consequently, in this story we will track how relations unfold around the various actors relevant to milk and plastics and attempt to conceptualise the resultant matter among changing conceptions of milk, bodily fluids, mould, bacteria, hygiene, daily life, nature, and sustainability – portraying a wide array of materialities and relationships.

Among these categories, are both positive and negative themes – they are a contradictory mix. A material made from milk (or mould) may be considered authentic, and therefore valuable, but also *dirty* – it is the origin of pathogens. The discovery of the relationship between bacteria and disease in the nineteenth century by Pasteur and others (Worboys 2000), led by the end of that century to a strong association between dust and disease. This "bacteriophobia" is an element in a more complex relationship to nature – a disenchanted one, according to Jens Jørgensen (2015). The properties of plastics have been figured as an antidote to this modern, antipathy for the dirtiness of nature – their seamless surfaces valued for this reason (Forty 1986). Plastics emerged as part of a material culture that was increasingly aware of the risk to health of pathogens carried in dust, and they allowed a "clean" modern style. And they were actually clean because they could be cleaned, disinfected. The twentieth century synthetic plastics gave us hope of control because of their sheer 'wipe-clean' surfaces. In their war-time book on plastics Yarsley and Couzens' image of the life of 'plastic man' emphasised that plastic goods have "no crevices to harbour dirt or germs" (1941), nowhere to harbour unruly nature. In the modern world nature can be controlled, but also is always beyond human control, bacteria are both homely, they are in us and of us, and they are frightening, they are against us.

Before thinking more specifically these 'biotic' materials, new and old, unformed and vilified, it is useful to track their origins in milk, and their antecedents, which we find in glue and varnish. Milk was known as a source of sticky stuff when Cennino Cennini wrote these instructions for making glue out of cheese:

> *There is a glue used by workers in wood; this is made of cheese. After putting it to soak in water, work it over with a little quicklime, using a little board with both hands. Put it between the boards; it joins them and fastens them together well.' (Cennini, 1954 (ca1400): 68)*

In a long arc of time, the novel approaches to producing materials using the action of fungi and other organisms in the 21st Century can be connected to this glue made from mouldy milk, though the industrial process that developed in the late nineteenth century sought to 'de-nature' the material – to use the chemical constituents of milk rather than its propensity to grow mould. It was the casein protein in the milk that formed Cennini's glue, though processed by mould rather than by chemists. By the end of the nineteenth century chemists had analysed the properties of the casein molecule to produce a useable plastic material, perfected from 1897 when two Germans, Spitteler and Krische made a durable and waterproof material by treating casein with formaldehyde. The material was patented in 1899 as Galalith – literally translated from Greek and Latin as "milk stone" (Plastiquarian, n.d.).

4 Progressive modern plastics

The plastics industry was sufficiently well established by 1929 to support a trade paper, *British Plastics and Moulded Products Trader.* Its first volume included articles about casein plastics in each issue that cover potential applications for the materials and technical issues, and they outline the origin of the materials. These suggest its characterisation had a complex relationship between ideas of "nature" and "modernity", based on the clues in these articles to the names the material was being given.

A search has revealed around 100 casein-derived plastics names, of which sixty have a connotation of nature, associating them with stone with the suffix "-lith" (or "-lit", "-lite", "-it"), as in Galalith. Twelve refer directly to casein's origin in milk, using the prefix "lac-" or "cas". Ten use the suffix "-oid". "-oid" literally indicates likeness – from the Greek *oiedēs* meaning "likeness" or "form of", which itself derives from *eidos*, meaning *form* (Collins, n.d). Several of the names for casein plastics use the "-oid" suffix as in Cassoid or Lactoloid, implying the plastic is *like* milk, which it is not, really, being a material not a foodstuff.

The suffix "-oid" brought a progressive connotation to casein plastic, by connecting it to what was by the early 20th Century a successful new material, Celluloid, already common as a replacement for items such as starched collars and tortoiseshell brush and mirror backs by the late nineteenth century (Friedel, 1983: 119). The rhetoric of the Italian Futurists used this overtly progressive connotation of new materials. Emily Braun (1995) arguing for the influence of the Futurists on the development of Italian fashion, cites the 1920 *Manifesto of Futurist Women's Fashion*. Here, with an echo of the rhetoric surrounding contemporary "growing design", its author "Volt" (Vincenzo Fani) encourages fashion designers to "fling open the doors of the fashion ateliers to paper, cardboard, glass, tinfoil, aluminium, ceramic, rubber, fish skin, burlap, oakum, hemp, gas, growing plants and living animals".

It is only a small step from these provocative quasi-materials to fashion made of milk, and it was a step that Mussolini's government took, by supporting the development of Lanital, a casein based wool substitute. Lanital was developed in the face of trade sanctions after Mussolini's invasion of Ethiopia in 1935, and used for service uniforms. It had some of the properties of wool, as well as one extra, and unpopular, one. It smelt like sour milk when it got wet. This smell, part of the material's "lively materiality" (Bennett, 2010) inadvertently connected casein to its natural origin – an aromatic and slightly unpleasant connection that perhaps contradicted the futuristic connotation that Marinetti and Mussolini would have preferred. Just as milk resisted categorisation, or quickly got sour or crème-like in the chemistry laboratory as Orland tells (2009), the milky origin of Lanital – its "soul" – exerted itself in its associations and valuation.

Despite this unwelcome return of the material's repressed nature, some contemporary accounts emphasised casein's natural origins, in terms of both its source, with its connotations of a natural lifestyle, and its production, which required traditional crafts methods. A 1929 article in *British Plastics* described the British Erinoid company, emphasizing the rural beauty of the factory's location in an old converted woollen mill. Erinoid was set up in 1914, in Stroud, Gloucestershire to make "Erinoid", a casein plastic. This was timely as the outbreak of war cut off supplies of Galalith to the UK – by then essential for making the buttons for service uniforms. The article describes a semi-mechanised process with significant craft elements that included the hand-work that was necessary to compensate for the irregularities of the product. The surface of the material was initially rough and had to be polished. Rods came out at different diameters. Sheets were buckled after the "seasoning" in formaldehyde that was needed to turn a hard, brittle material into a tough and usable one.

The first attempts to make a casein plastic, 'Syrolit', at Stroud were in 1909, and several papers at the time referred to "the making of buttons from milk" (Hull Daily Mail, 6th April 1909). The *British Plastics* article calls Erinoid a 'progressive' company, however, the company itself promoted its material in *British Plastics* as 'artificial horn' – a backward looking association that aligned with the by then firmly embedded characterisation of plastics as substitute materials. The imitative use of celluloid and its consequent characterisation as a cheap, low quality substitute – ersatz – which promoted social dissembling, reached a point by the nineteen sixties where the word 'plastic' could be applied to any thing, or person not considered to be genuine. (Meikle 1995: 290). The outline of casein's development in *British Plastics* from 1930 used similar terms, noting that Krische and Spitteler patented it as 'Plastic Compositions: ivory artificial, horn artificial, amber artificial, wood treating'. However, it ends by associating the material with innovation: 'The future holds great promise for this comparatively new product. Its beauty and charm as a decorative material have not yet been full appreciated by the public' (Dodd 1930: 478).

The way this narrative emphasises both Erinoid's modernity, and its sylvan origin, indicates that there is no necessary connection between a natural source and what is taken to be authentic and innately valuable, in fact if the reporting on Erinoid had been for a general rather than a trade readership, its association with the countryside might be taken as evidence of a desire to counter the association with fakery that plastic had already accrued by the 1930s.

5 Plastics and nature, new and old

So, we have materials from natural sources, past and present, industrial and pre-industrial. Casein simply comes from milk – cows produce the protein that is then chemically manipulated into the plastic. In contrast contemporary developments promise biotic materials that generate artefacts by "growing design". This is not simply using nature as a source of material that is then manipulated, they come about from letting nature 'do its own thing' in a more or less managed way, preserving some of the **autonomy** of the organisms that are directly producing the material. Carole Collet (2013) describes an approach to new materials, among other four categories, a fifth category that relies on "**hacking"** nature's components, not to use the bits as components of polymers like with casein, or cellulose, but to re-program organisms in a way that preserves their autonomy, but has them “do a different thing”. In a way this “hacking” is not essentially new in the context of human modifications to the environment. In relation to materials, heating up horn and bending it into desired shapes can also be regarded as hacking, in that it changes the material to conform to a human intention.

Nature is clearly the significant cultural category in the characterization of these new materials. Nature is implied by casein’s milky source and by the more autonomous biotic examples. In one a ‘natural’ material – cows milk – is clearly a resource, perhaps therefore having some characteristics in common with material we find in the ground, or growing on it. In the other we are perhaps harnessing the power of nature to create material, instead of finding materials in the stuff nature provides.

However, to understand how these materials come to be, the task is not so much to categorise our relationship to nature, or nature’s relationship to new materials, but rather to look at the “nature” of this relationship, by taking up the challenge to think all materials as active agents. For when we act on materials they act on us, when nature changes materials, materials change nature as well. Bensaude Vincent and Newman (2007:1), give the examples of “a glowing jellyfish injected with a phosphoric material, or a genetically modified corn” and argue that these are still natural beings, yet our categorisations related to nature has changed and so has the materials. And their existence puts into question what can be termed natural and what cannot. We need to think about what we mean by nature in each case, but this is not simple because of the tangled circulation of ideas that coalesce round this ‘most complex’ concept (Williams 1976). However, it is clearly this concept that that gives both synthetic and biotic materials their *meanings* (McCracken 1986).

Raymond Williams outlines three senses of “nature”: first, nature as something’s essential quality, as in “my true nature”; second, as the “inherent force that directs either the world or human beings, or both”; third as the material world itself, either containing or not containing humans. He notes that the root of the word is in the Latin “nasci”, to be born – from which we get the sense of nature as origin, the place things come from, and the words native, nation, innate etc.

This last sense links both casein plastics and contemporary ‘growing design’ to nature by simply indicating that they *have* an origin, with the gloss that both are ‘biotic’; they have animal/vegetable rather than mineral origins. However, while the fact that they are not from fossil sources associates them with the **autonomy** of animals and plants that live and reproduce, this fact alone says little about what the materials are taken to be – their qualities – or the implications of that natural origin for our valuation of them.

Williams’ third sense of “nature” may help with this, acknowledging that humans sometimes include themselves in the category ‘nature’, and sometimes not, and it may be easier to do this in relation to the ‘nature’ of materials that originate in the farmyard, or the greenhouse, than for materials from the laboratory and the refinery. We can perhaps imagine living in a farmyard or greenhouse, but not in a refinery and so it may be easier to identify with ‘biotic’ materials – they seem *more* natural and therefore more human. This connection, with a common-sense idea of nature as that which is not human but is “humane”, might assuage concerns about their novelty, their strangeness. We may more easily find Ingold’s “correspondance” in such materials.

Recent work in STS stimulated by concerns about the permanence of the twentieth century synthetic materials and their appearance ‘out of place’ (Douglas 1966) in the oceans offers us another way to think about these paradoxical relationships between materials and nature. In a recent ethnography of Pacific oceanographers who quantify the plastic in the ocean Kim De Wolff (2017) sailed with Algalita Marine Research and Education, founded by Charles Moore, who named the Pacific ‘garbage patch’. This work is about the effect of ‘old-new’ materials – the ubiquitous synthetics of the twentieth century, which in the early twenty first century seem poisonous, too permanent and too costly to an abstract sense of ‘nature’ in Williams’ second sense.

Williams points out that ideas about nature are always ideological. The idea of nature: “played critical roles in arguments about, first, an obsolete or corrupt society, needing redemption and renewal, and, second, an 'artificial' or 'mechanical' society, which learning from Nature must cure." He equates these two positions with Romantic and Enlightenment thought, noting the role of "newly scientific generalisation: 'Nature teaches . . .' 'Nature shows us that . . .'" emphasising that what was shown or taught could range "from inherent and inevitable bitter competition to inherent mutuality or co-operation." (1976: 223-4)

So there is a political dimension to this discussion, given the current variety in political engagement with the consequences of human actions for environmental sustainability. 'Biotic' materials are informed by the subtle and complex insights into the nature/ culture relationship that derive from STS, which should re-calibrate our ideas about that relationship. In the process of doing the science of oceanography, studying the interface between plastic and non-plastic – "live" – matter in the ocean it is impossible to properly distinguish the two, practically, when categorising the matter under the microscope, and in terms of ethical decisions about what to do about some of the plastic artefacts that float about supporting colonies of marine life. Kim De Wolff describes the impossibility of distinguishing "plastic" from "real" in the samples that the Algalita crew collect – if bits of jellyfish have plastic particles inside them are they "real" (natural) or not?

6 Conclusion

DeWolff's work in the "plastisphere" – the indeterminate zone round plastics in the ocean that is not clearly either nature or culture, suggests an indeterminate, troubled relationship to nature that plays out in her suggestion that "plastics are named as potential species" because of our entanglement with them, past and future (2017: 5). In these terms, it is not clear how to assess contemporary design interventions into the world of new materials. They might be proposed as a solution to a problem – that's how designers often think – the problem being one of too persistent materials that disturb our relationship with nature. But framing the problem that way preserves the nature/culture split that STS suggests is not tenable, or useful, any longer. They are perhaps not a solution then, and the "bio-design fiction" examples certainly are not, since they exist only in the imagination. Taken as a whole, this design work has an attractive coating of concern for human-nature relationships, appealing to Williams' second sense of a nature that includes humans and generating materials that are to some extent autonomous, part of a 'natural rhythm' that can die as well as live. However, this palliative "autonomy" may mask the strong sense of a categorical human-nature split – a nature that does not contain humans, but over which humans have dominion that is evident in the "augmented biology" dimension of new materials work. Here, as Camere and Karana (2017) suggest, nature is hacked through digital fabrication, with "nature" carrying the sense of "not containing humans", a material world that is available to us to manipulate through bio-hacking. So these materials seem to reproduce the equivocal and entangled relationship between humans and nature, rather than being a solution to any problem (as yet to be defined precisely). As such, rather than a solution, this entanglement might point to a pattern, in which nature and culture feed back into each other, as the new unit of analysis, through which new materialities are enacted with the co-working, or as Ingold (2017) puts is with the "co-respondance" of material and social "knots."

However, they are a novelty, and in their relationship to our continuing adaptation to material purposes of the substances people find in the world they are clearly in the same tradition as the work that produced casein plastics. There are some symmetries between the two. The milky smell from Lanital betrayed its biological origin and another *British Plastics* article observed that casein in preparation is an excellent medium in which to grow microorganisms, which connects it both to Cennini's cheese-based adhesive and to new materials made from fungi (Poultney, 1929: 28). There was a trajectory from stuff to decay because the waste from casein plastics couldn't be recycled in the manufacture of new material, making 'artificial manure' was the only productive solution ("Technician", 1930). Casein went from material to muck. Material produced from fungus goes from muck to material (then to muck). The new biotic materials add to this passive decay an element of autonomy, and for this reason, they could perhaps be characterised as a new class of materials, the "autonomoids".

However, these principles apply to any material, in that every material has its own incipient physical tendencies, enacted in their various contexts. Their qualities occur 'naturally', i.e. spontaneously, in different ways whether they have been put there by chemistry or chance. As such, materials in design cannot be seen as categorisations of nature, or simple manipulations of nature; materials change nature and nature changes them. As humans' relations to nature's use and value changes, so do our relationships to materiality. Casting materials into the world as autonomoids troubles our categorisations of humans' relationship to nature, and rejects placing ourselves against nature in the sense of manipulating or disturbing it. Nature as a human concept evolves with our materiality, however it also has its active liveness. From this point of view, designers cannot 'hack' nature or materials. They can work with them, and cannot force them to come up with desired outcomes or interactions. Designers perhaps will do best if they get to know their autonomoid colleagues, and work with their tendencies and put their creativity into work in thinking about their possible enactments, which might be material as well as social.

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Materials Liaisons: facilitating communication in Design-Driven Material Innovation (DDMI) projects

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In an increasingly complex 'problem' landscape, interdisciplinary collaboration is becoming an important part of design practice. This paper presents research from an EU H2020 funded project which is trialling a new Design-Driven Material Innovation (DDMI) methodology. The collaborative process, involving designers, scientists and manufacturers, presents a number of language barriers. For the project to move forward, at the very least, designers need to understand the material's potential and scientists need to understand what designers want the material to 'be like'. The study focusses on one approach – appointing 'materials liaison officers' – to facilitate the interdisciplinary exchange of materials information. Drawing on interviews and workshop material the author discusses the benefits and limitations of using a 'bilingual' liaison to translate material understanding from one discipline to another. The findings highlight several aspects that affect interdisciplinary communication: familiarity with the material type being developed, the number of processes involved in production of the material, the approach of the designer, and the role of materials samples as boundary objects to anchor the dialogue.

design-driven material innovation; materials communication; interdisciplinary collaboration; facilitation

1 Introduction

Design is increasingly being recognised as an important catalyst at various stages of the product development process, rather than the conventional 'product design' stage. Design-driven materials innovation (DDMI) for example, involves bringing designers into the process at the beginning of the material's development to help guide the scientific enquiry towards an innovation which is desired by design and therefore considered more marketable.

The research presented in this paper is part of a DDMI project where the aim is to develop a 'circular' fibre for textiles, composites and plastics; one which is both made from waste materials and can also be made into new material after the use phase.

The current project involves 18 partner organisations from 10 countries, comprising textile and industrial designers, design researchers, a materials consultancy, materials scientists, social scientists, manufacturers and life cycle scientists. The main collaborative effort takes place during twelve two-day workshops, over 3½ years.

DDMI projects present a particular communication challenge. People with very different disciplinary/national/cultural languages need to understand one another, when their worldviews, working practices and vocabulary are likely to be very different. The project glossary, compiled by the author with input from project participants, demonstrates the very basic level at which misunderstandings were frequently occurring during the first few workshops. Technical terms such as 'fibre', 'filament', and 'spinning'; scientific terms such as 'hydrophobic' and 'titer', and terms where meaning varied between disciplines, such as 'scenario' and 'prototype', reveal a complex combination of communication barriers. Introducing a glossary was one simple way of deciphering and clarifying these nuances in language. Anecdotally, this intervention appeared to draw attention to misunderstandings and participants became more conscious of their language, more often explaining the terminology they were using.

Moreover, it became apparent that for DDMI projects, it isn't sufficient for designers to understand the material's potential and scientists to understand what designers want the material to 'be like'. For the collaboration to work communication must also build trust in what is being asked or said.

The study presented here looks at one method used in the project to address these communication barriers. It focusses on the activities of 'materials liaison officers' (MLOs) – four individuals who were appointed as intermediaries at a specific point in the project – the development of the first prototype – where effective materials communication was crucial. Their activities and the different approaches and methods they used are analysed to understand the potential and the limitations of appointing liaisons to facilitate communication about materials characteristics in projects of this type. The implications beyond the current project will then be considered.

2 Context

One of the main outcomes of the EU project will be a DDMI methodology 'model' to build theory in this emerging area. However, the main focus of this study is not the Design-Driven methodology but the methods used within the project to support the interdisciplinary communication about materials and therefore this will be the focus of the contextual review.

2.1 Materials communication resources

Rapid developments in the material sciences in recent years has resulted in the introduction of numerous new materials, broadening the selection available to designers. Yet, as has been acknowledged by others (Hornbuckle 2010; Ashby & Johnson 2002; Manzini 1986), designers often do not have the specific technical knowledge needed to understand how these new materials can meet the needs of their designs.

Resources to enable designers to understand the potential of new or unfamiliar materials have been developed. These include materials databases, sample collections, materials information and comparison software, yet several studies of designers' materials sourcing behaviour found that these are rarely used (Hornbuckle 2010; van Kesteren 2008; Pedgley 1999; Karana 2004). Without exception these authors concur that for designers to understand materials characteristics they need to touch physical samples or at the very least see images of the materials as opposed to property data.

Wilkes et al (2015) propose 'isometric sample sets' in their paper "Design tools for interdisciplinary translation of material experiences", which is presented as a tool for use in DDMI. The authors suggest that providing collaborators with various different materials of the same shape and size provides a common reference point for discussions about materials characteristics. For example, a designer could say 'I need the material to be shinier than this sample' and the scientist can then better determine the desired characteristics to aim for in their development work. Likewise, a scientist could explain the concept of 'tenacity' by showing the designer two opposing samples. This is seen as a way of facilitating a dialogue about the senseoaesthetic characteristics of materials with varying physical (quantifiable) properties between people with very different cultural/disciplinary languages. This approach was then applied by the authors to the Light Touch Matters online course (Institute of Making 2017), which demonstrates how a discussion between a designers and a scientist with a materials focus could prepare them for developing materials together in a DDMI context.

2.2 Understanding materials through dialogue with 'an expert'

The approach of Wilkes et al, focussing on methods that support dialogue about materials, echoes the findings of the author's previous study that designers prefer to talk to 'someone who knows' about materials when trying to find an alternative solution (Hornbuckle 2010). This person must be able to understand the material's potential and translate this into benefits for design. Described as 'materials translators', these individuals were found to be frequently associated with a materials sample collection and have design training (Hornbuckle 2013).

This dialogue can then be supported by 'boundary objects' such as images and materials samples, as advocated by Wilkes et al (2016) after Star & Griesemer (1989). However, the focus is on the people involved in the translation rather than the samples or tools themselves which serve a supporting role. In turn, this places particular importance on 'human factors' such as the compatibility of skills and knowledge of the people involved, their background, ability and approach to collaboration – as Rieple et al (2005) acknowledge much of the skill in boundary-spanning is based on relationship building, trust and rapport as much as ability to speak different languages.

In light of this previous research, the current EU project represented an opportunity for the author to study materials communication in practice within a live interdisciplinary DDMI project. The stance was to observe how people communicated about materials with the particular aim of identifying individuals who were acting as 'materials translators' as well as building further knowledge around the role of boundary objects such as material samples. In actuality, this occurred in a more explicit way than had been anticipated, as the project methodology team decided to appoint people to this role when the need arose. 'Materials liaison officers' (MLOs) were identified to oversee communication at a particular point in the project which presented a unique opportunity to study this phenomenon in more depth.

3 Method

The study focusses on a specific period of the project, where the first materials prototypes were developed in response to design requirements. This is seen as a pivotal moment in the 'design-led' material development, where materials information exchange was of particular importance and therefore strategies to support the communication were devised and put into practice. Five individuals were assigned the role of MLO by the project methodology team. Their role was to communicate materials requirements from the designers to the material developers, who would then produce prototypes.

The research sought to reveal the context and function of the ML process by interviewing the MLOs on aspects considered relevant to understanding the role, its successes and limitations. Each interviewee has been given a codename identified in figure 1. The questions related to three main areas of interest:

- Previous experience
- ML process: from workshop 05 to workshop 06
- Effectiveness of tools and methods used

The project is facilitated through a series of twelve two-day workshops held every two to three months. This paper focusses on what happened during, and in between, workshop 05 and workshop 06 where designers were, for the first time, developing early-stage design concepts and needed to provide information to material developers about the characteristics of the first material prototypes to be produced in the project.

The data collected and analysed comprises transcripts from interviews conducted shortly after workshop 06 with four of the MLOs, as well as common discussions recorded during workshops 05 and 06 about material prototyping, and field notes. As the study focused on only a small section of the materials development process, the intention is to gather more data towards the end of the project to understand how this specific phase related to the project as a whole. The interviews were transcribed and coded by predetermined themes derived from the literature, existing research, field notes and the author's previous research.

The investigation had a dual purpose. First to understand whether the materials communication had been successful between workshops 05 and 06 and to highlight areas that could be improved in the convention of action research. Second, to understand the roles and actions being observed and relate these to the wider context of materials communication discussed earlier, to contribute to the growing body of knowledge about materials communication beyond the immediate project.

It is important to acknowledge that although the author/researcher did not instigate the ML process, they were part of the project methodology team. The data was collected as far as possible by stepping aside from the process. However, the dual role of the research as both action and investigative (and consequently the dual role of the author/researcher) must be acknowledged and taken into account.

3.1.1 Materials Liaison Officer role

DDMI is not well established or understood, particularly in a large consortium project. Therefore, the project plan was experimental in nature, with opportunities to adapt and react to the challenges faced at each stage. These adjustments were considered and implemented by the project methodology team. At the point at which materials developers needed direction from the designers in order to meet deadlines for producing material prototypes (between workshop 05 and 06) the methodology team appointed materials liaison officers (MLOs) to facilitate this exchange in materials information. The lead facilitator for the communication amongst collaborators (also an MLO) explained in the interview how the need for a named liaison was identified:

> *I realised that there was no one who could convey the design request to the prototypist, So I said, okay, it's necessary that there are representatives from the design field […] and maybe it's necessary to propose the creation of this representative that is the liaison officer, and also from the other side, the feasibility side or the technological side. [Des-B]*

There were two levels of MLOs; two representing design, and two representing technical materials developers. Figure 1 shows the communication links between the MLOs, the designers and the technical materials R&D for the two materials being developed in the project.

MLOs were appointed based on their position within the project and their perceived ability to perform the task. They were given a general briefing on the role and full autonomy on how they chose to work. This provides an interesting basis for comparison of methods as there was very little opportunity for cross-fertilisation of ideas and experiences between liaison officers. To the author's knowledge the liaison role had not been discussed at all prior to the interviews taking place, apart from at the initial briefing.

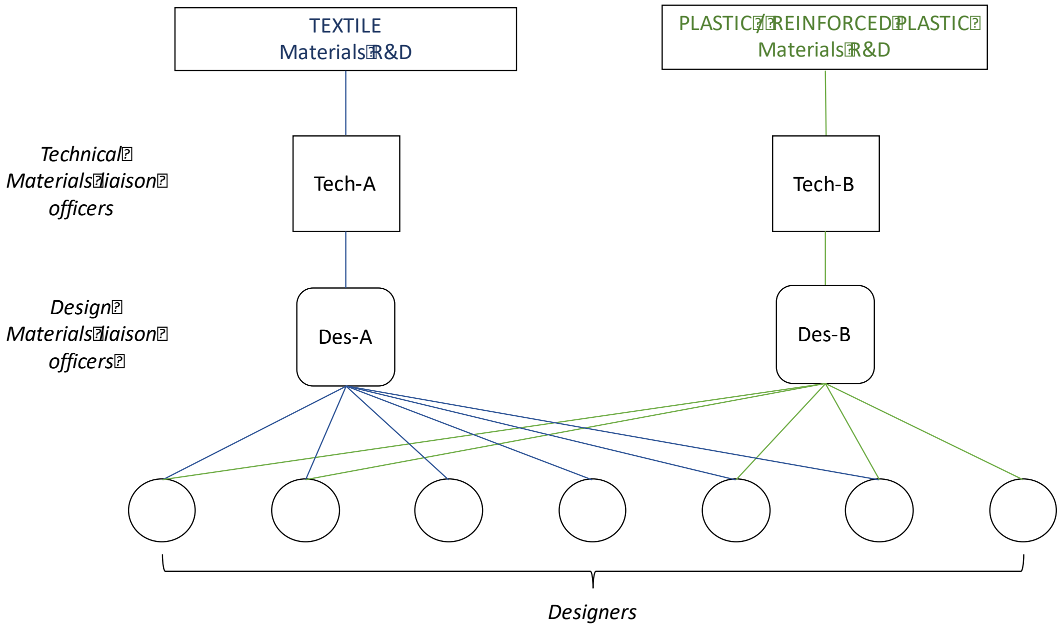

Figure 1 Setting up the dialogue for design-driven materials prototyping via technical and design materials liaison officers

4 Results

The results are presented in three sections relating to the key themes. The discussion will then reflect on the implications for materials communication research and practice in relation to DDMI and more generally.

4.1 Previous experience

Appointing MLOs was not a matter of recruiting someone based on an 'ideal' set of skills or experience, but a pragmatic selection of the most appropriate people within the pool of expertise available in the project; best placed in terms of connections, materials knowledge, affiliations and resources (such as project hours and on the right task).

Table 1 presents the background of each MLO in their own words. First, it is striking that all but one person has past experience of translating materials information between different disciplines. Furthermore, all four identify their role as a liaison between the disciplines within the project context and understand the kinds of materials information designers need such as using senseoaesthetic descriptors, 'showing' actual materials (physical or imagery) rather than using technical and quantitative data. This suggests that within industry the role of liaison in materials communication already exists, even if it is not always identified in those terms.

The person with the least experience of communicating with designers [Tech-B] soon recognised the need to communicate 'the advantages' of the materials and 'how they are physically' which is clearly a different type of dialogue than they would normally have with other technical specialists. It would appear that this individual made a transition during the project from being located purely within the technical realm into a position more akin to 'boundary-spanner' (Rieple, Haberberg & Gander 2005).

Table 1: The four MLOs' backgrounds as described in the interviews

Materials Liaison Officer	Disciplinary background	Has communicated about materials with…	Communication role in current project	Understanding of interdisciplinary materials communication
Tech-A	Aerospace engineer, material science, specifically lightweight materials 5-6 years in fibre-based textiles	Designers Manufacturers Other scientists and engineers	"A sort of linking between what is the design and what is the manufacture on big volume"	"You need to describe the materials in terms of how soft they need to be, how flexible they need to be, in comparison with other material. They don't want to have data in megapascal or something like this"
Tech-B	Engineer in chemistry	Other chemists and engineers	"To help to communicate between different work packages, to translate information from [design] work package to [prototyping] work package"	"I realised that designers didn't know what reinforced plastics are, so during the following workshops I tried to understand them what they are, the advantages, how they are physically"
Des-A	Doctor of Science in Materials but especially fibre textile and clothing science	Manufacturers Designers Marketing Other textile scientists	"The intermediator between the design and science, or design and engineers, because I feel that I'm standing somewhere in between […] and I think that I can speak for both languages, or in both languages, design and also science	"The designer cannot specify what they need in a quantitative way, so they can say, yes, a little bit softer and more matt or something, and that is the thing that then I need to understand what this is, like, enough matt"
Des-B	Industrial design / strategy design consulting related to materials, use of material or development of new material	Scientists, Material engineers Companies Other designers	"facilitator between the competences involved in the project […] the dialogue among the competences"	"If you don't show me materials as a designer I have some difficulty to understand about what technique you are talking about" "the images were really important because they gave the idea of what [the designer] have in mind"

4.2 Materials Liaison (ML) process: from workshop 05 to workshop 06

As illustrated in Figure 2, the ML process took place over a period of nine weeks between two project workshops. This involved three general steps:

1. During workshop 05 materials developers (scientists and manufacturers) presented materials samples to designers.
2. In between the workshops designers developed initial product concepts and provided information to MLOs about the material characteristics they required; MLOs communicated with materials developers who then responded by creating prototypes.
3. During workshop 06 materials developers presented the new material prototype samples to designers.

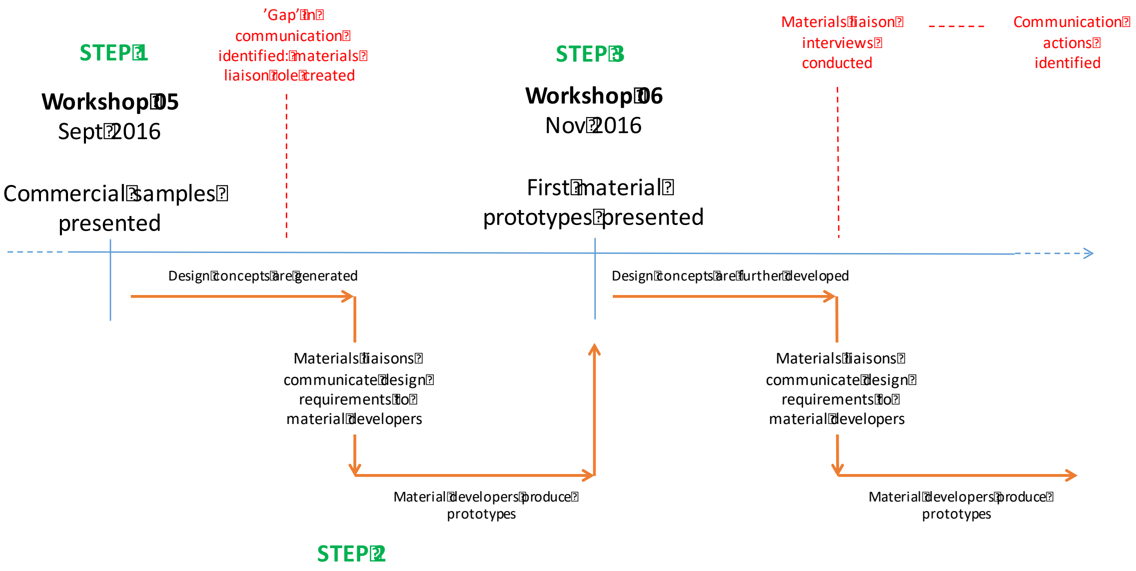

Figure 2 The focus of the study – the ML process – took place over nine weeks between workshop 05 and workshop 06

4.2.1 STEP 1: During workshop 05

The materials presented at workshop 05 were frequently referred to as 'commercial' by the interviewees, to distinguish them from materials that have been produced in the project. The purpose of showing these samples to designers appeared to be both for inspiration as well as to show them the potential of the materials:

> *"We tried to bring something that have another type of interpretation of material, for example, we brought some sort of foam made of polyester, because it's interesting also to see how it's possible to have this typology of material." [Tech-A]*

> *"the idea was to show to the designers mainly, what we can produce in terms of rigidity, flexibility, and so on" [Tech-B]*

> *"[designers] could get, like, better understanding what kind of possibilities we have in the project" [Des-A]*

> *"what they showed me first of all was the potential, the quality, that could be achieved with that kind of technology that the partner makes available, […] and also open the*

> *mind to, okay, what happens if you include these or we change these - was very inspiring." [Des-B]*

4.2.2 STEP 2: In between the workshops

The process of communication *from designers to design MLOs to technical MLOs and then to materials R&D* (refer to figure 1) took place in between the workshops and appeared to offer a good solution to enabling design to drive the materials prototyping:

> *"Based on this design concept, this table that [Des-B] sent to us, first we tried to understand the concept and then we manufactured some samples […] We manufactured these samples to discuss with the designers if it's what they were looking for or, yes, to communicate. To understand, to define better the concept." [Tech-A]*

> *"the liaison officers were, like, a nice step to get, let's say, construction or some relevant order to that whole system, how we can go further, […] that was the one thing which is important, that there are some people who are responsible for something, that those people are named" [Des-A]*

However, there was also some difference in opinion about how much influence the liaisons should have over the materials characteristics that are communicated to R&D with some preferring a completely unbiased approach while one MLO in particular was more involved in deciding and determining the direction of materials R&D:

> *"try to put on the paper some description, simply … not technical, some description about what is the idea of the material you would like to have. After, try to, with the help of a manufacturer, to transform this description in more technical data on which it's possible to work, on which is possible to work to realise the prototypes. Otherwise, these prototypes are simply the choice of singular people" [Tech-A]*

The interviews also revealed some issues relating to the diffuse nature of large consortium projects where it is more difficult to be *"very linked up, all the day together. In a way that these people already have a language by which it's very easy to shape all the attributes that you want" [Tech-A];* where a lack of close proximity to one another makes materials communication and the ability to understand the potential of the material more difficult.

4.2.3 STEP 3: During workshop 06

At the workshop scientists and manufacturers (materials R&D) presented the materials they had produced as a result of the ML process. The MLOs were asked about how these materials differed from those presented at workshop 05. Interviewees described these samples as 'prototypes' to distinguish them as materials produced in the project rather than 'commercial' materials.

The prototypes of the two material typologies (textiles and reinforced plastics) revealed a significant difference in the way that the materials developers were able to respond to the process; a tangible sample of reinforced plastic was produced, whereas only the fibre and finishes (demonstrated on a commercial textile) was produced for textiles:

> *"the [textile] prototype [in workshop 06] was not considered in terms of fabric from stable fibres, there was totally a gap, you know. There was the Prototype 1 that was stable fibre, and then there was the finishing technology." [Des-B]*

This could be because there are a larger number of steps in the production of a textile (and consequently more companies involved), compared to only one or two involved in the production of reinforced plastic. Interviewees noticed that this led to reinforced plastic prototypes that responded more directly to the design concepts within the given timeframe:

> *"There was really a clear tentative to respond to the designer request, expectation" [Des-B]*

> *"I was really surprised that these composites can be so, like, flexible and even like garment-like, […] Because that is like a totally different material, what garment industry doesn't use usually, so it's like something new way to make the garment material." [Des-A]*

There is a further suggestion in this comment that the collaboration had led to a 'surprising' discovery; perhaps the first demonstration of the potential for design to guide the material development in a different direction. This was echoed by the technical MLO responsible for that material prototype:

> *"Some of [the prototypes] are totally different – Mainly the [design] concepts based on flexible reinforced plastics. The rigid reinforced plastic, well, they are very similar to other samples that we produce in other projects, but the flexible samples, for us it's the first time that we prepare something like this." [Tech-A]*

4.3 Tools and methods

The MLOs took different approaches to facilitate the materials communication between the two workshops. As most of the collaborators are based in different European countries, there was no opportunity for face-to-face contact in between the workshops, so communication was conducted via teleconferencing (skype) and by email. Interviewees all felt that these methods were satisfactory in this context. One MLO used the existing design worksheets, which had images and text-based information about the product concept to communicate the design request to materials R&D. While another created a detailed spreadsheet for designers to fill out with the type of information materials R&D required.

> *"the first need that was really clear was to systematise the design concept in clear request, and also understand what kind of requests the technological side needs to realise the prototypes […] or at least, try to understand what the designer had in mind." [Des-B]*

However, when interviewed the MLOs all stated that the most useful type of information provided were images of the product concept and a short description. It is perhaps not surprising that this type of information would be suited to designers but the technical MLOs also said that this helped them to *"identify the general idea" [Tech-B].* In the absence of property data, the visual information was a good enough substitute for technical MLOs to interpret what the material needed to be like in terms of senseoaesthetic characteristics for this first iteration of prototyping:

> *"I noticed that, for example, that [designer] didn't choose specific images and [technical liaison] was not clear … so the images were really important because they gave the idea of what [the designer] have in mind" [Des-B]*

The interviews also highlighted two further issues relating to this phase of the project: how different types of designers responded to the process and the level of design information available at this early stage of DDMI.

Two of the MLO's noted that some designers were more able to engage with the process than others. This appeared related to the designers' familiarity with the material type being developed. For example, MLOs reported difficulties with a textile designer providing information for a reinforced plastic *[Des-B]* and an industrial designer for a textile:

> *"they don't have expertise in textiles or garments or fashion business or supply chain or design or material science, which, let's say, [garment retailer] people have. But on the other hand it's good that sometimes that you are coming like out of scope, let's say, so then you have fresh ideas" [Des-A]*

However, these were also the exchanges that resulted in more 'surprising' prototypes, discussed earlier. This implies that even though it is more challenging to accommodate designers with less

experience of that material typology, it could be the most important and fruitful exchange for materials innovation, and therefore a dialogue that is worth facilitating.
The early stages of DDMI also appears to be the most challenging time for interdisciplinary communication. During the first iteration of prototyping, design concepts are not fully developed and therefore information about materials characteristics is limited, and there are only existing 'commercial' materials to use as a reference point for communication:

> *"it is always when you are making first prototype you need to just, like, imagine and hope and decide something." [Des-A]*

> *"also related to the concreteness of the step in which we are, because we saw some prototypes, we have fibres, we can produce some things, so all stuff are more easy [after the first prototype is produced] The beginning is the very issue in this kind of project" [Des-B]*

This highlights the important role of physical materials samples. The interviewees all suggested that as long as people were able to touch samples within the workshops then images of those samples would be sufficient reference in between workshops. However, the availability of prototypes even in the workshops was clearly an issue: *"A big problem was that it's not possible to have the prototypes that we would like to show" [Tech-A].* Whether it was simply a problem with coordinating the large number of companies involved (as was the case with textiles) or the inability of companies at the start of the supply chain to produce the right amount or type of material for the next part of the process, or a technical issue to do with capability or availability of equipment. The importance of the prototype for providing something 'real' to feed the next iteration of design work was expressed by the interviewees:

> *"if you want to have a [DDMI] methodology you need to have materials … first months you need to start to work with materials." [Tech-A]*

> *"It would be good to have these real [prototype] samples that everyone had those, but maybe it's not possible if we don't have, let's say, enough material, but it should be aimed that we can, with all partners, at least designers to have the samples, material samples we have made, all the time, of course, and with the technical specifications." [Des-A]*

One MLO suggested that a solution, if properly organised and facilitated, would be to use commercial materials samples to create an 'internal reference'

> *"the material I think is the best tools to communicate what you have in mind, attributes, properties, […] I think that talking all the time about these samples, the selected one, the changed one, we can easily refer to them, and if we were able to go ahead, attaching information, let's say, to the photos of these samples […] create internal references, internal materials, and these references of concrete material that you can touch every time that we meet" [Des-B]*

Materials samples are well understood in the literature to be the best way for materials developers to communicate material characteristics to designers. However, the ML process suggests that materials samples could also be very useful to communicate in the other direction, for designers to show materials developers what they would like to achieve, as a comparison:

> *"Yes, so I asked [the designer] if she could obtain a sample because for us it's very important. It helps us a lot to have something similar to understand better [Tech-B]."*

5 Discussion

5.1 The role of liaisons in interdisciplinary materials communication

Each Materials Liaison Officer (MLO) had a different level of familiarity with the material they were responsible for communicating and coordinating. In one case the MLO had worked for many years specifying the material they were responsible for while another had only a general knowledge of the material.

Not surprisingly, prior knowledge helped the MLOs to communicate the desired materials characteristics more easily. When prior knowledge was limited the liaison used tools and methods to communicate between the two disciplines. Both design and technical MLOs identified images of the design concepts as the most useful medium for understanding what design wanted the materials to do; it enabled them to imagine what the material should be like. Whereas specific information about material thickness and rigidity was more difficult for designers to provide at this early stage in the design process.

This difference exposed the effect that prior knowledge and familiarity can have on the ability to innovate. For example; where prior knowledge was greater this allowed for very easy communication but the request to materials R&D was almost pre-determined allowing for very little opportunity to challenge conventional specifications. Indeed, the main 'surprise' in terms of materials prototyping both for the design and technical MLOs occurred when design concepts from one industry (textile-garments) informed prototype development in another (reinforced plastics – aerospace). Hence less prior knowledge of the material type appeared to be leading towards to a more radical material innovation than greater prior knowledge. Greater familiarity with the material would also appear to put the MLO in a position of influence over the direction of materials R&D and this could compromise their impartiality when communicating the designers' requests.

Therefore, there appears to be a balance to be reached in terms of the prior knowledge of the material typology being communicated; knowledge needs to be enough for the liaison to have the language to communicate the potential of the material to designers and also translate the design request into useful information for materials R&D, but not so much prior knowledge that it influences their ability to challenge conventional processes or remain impartial.

The interviewees' previous experience and understanding of the role of a 'materials liaison' indicates that this skillset already exists within industry, yet this role is not explicitly named and no support exists for training or placing people with the right skillset within materials innovation contexts. It may be valuable to recognize the MLO role and its potential for enabling interdisciplinary materials communication. This study suggests that with the right experiences and training, people located either in design or materials R&D could transition into this role so that they are able to bridge disciplinary and communication barriers.

5.2 The role of 'commercial' material samples and prototypes

Within the current project three different typologies of material are under development, although only two were being prototyped during the timeframe of the study: textiles and reinforced plastics. During the ML process these two materials presented very different challenges; namely the number of processes involved; the consequential number of people to liaise / collaborate with (gatekeepers to knowledge); the number of variables that may affect materials characteristics; and, the speed with which prototypes can be produced. Reinforced plastics for example, which in this project were mainly being created for aesthetic purposes rather than for mechanical performance, require only one or two processes. The production of textiles, by comparison, consists of around five different processes (fibre generation, yarn spinning, textile structure, aesthetic finishing, functional finishing) each being performed by a different company. A change to any of these processes can result a change in the characteristics of the finished material. This means that the liaison needs a general knowledge of the processes involved and what can be achieved at each stage as well as the ability to communicate with a number of different material developers. The pace of prototype production is also therefore slower and less responsive for textiles than producing a one-step moulded part, and

aligning all of those different processes so that one feeds the other is complex and adds another challenge.
Nevertheless, the study suggests that having materials samples within the project from the outset – both commercial and project prototypes – is important, particularly for designers to see the potential of materials R&D and for materials developers to get an idea of 'what designers have in mind'. Given the challenge of producing material prototypes and therefore their limited availability, the study suggests that being able to touch the physical materials in the workshop then having images of the prototypes in between workshops as a reference and to aid communication, could be a satisfactory solution. This could also be supplemented with an internal reference collection of commercial materials samples around which an ongoing dialogue can be anchored. Essential to this strategy however, is to 'systematise' the materials so that they are part of an evolving framework relating to the materials R&D, design ideas, interdisciplinary dialogue and decisions. More work needs to be done to create, test and establish such a system.

5.3 Creating the conditions for material innovation through cross-fertilisation

The study has suggested that while it is the more challenging route, enabling designers and materials developers to work across industries could be one way of enabling radical material innovation.
One of the challenges to achieving this is that different types of designers interact with materials in different ways. It is not appropriate to consider 'designer' as one category in the context of DDMI. For example, some designers are 'materials-led' (Karana et al 2015) and develop approaches to materials through hands-on experimentation; it is this experiential understanding of materials that leads the designer to develop new and innovative ways of working with materials. Other designers who are more 'product or function-led' such as industrial designers, are used to 'specifying' materials that are appropriate for their designs with a more distant relationship with materials. The latter are likely to have a general knowledge of materials and rely more on the expertise of intermediaries to help guide them towards the most effective materials selection (Hornbuckle 2013; 2010). With this in mind, the ML approach which is set up to address a gap between designers and materials developers is perhaps best suited to product and function-led designers who are naturally more distant form the material. However, what this then exposes is the limitations of this type of project for designers who innovate through hands-on materials experimentation. It raises the question of whether this 'gap' between design and technical knowledge could be 'closed' in some other way to improve the chances of material innovation and make the most of the opportunity that design intervention early on in the materials R&D process presents. A closer collaboration between materials-led designers and technical materials developers might achieve more interesting results, as has been the case with many other smaller interdisciplinary design materials R&D projects (see for example Ellams 2015). In the context of materials-led design, the ML process may be an ineffective substitute for closer collaboration.

6 Conclusions

The Materials Liaison process as described in this study, demonstrates one approach to enabling designers and technical specialists to reach a shared understanding of desired characteristics when prototyping materials for the first time. The approach is one which relies on the ability of intermediaries to 'translate' design ideas, the potential of the material and characteristics between disciplines in a boundary-spanning role. The study revealed that these roles and skillsets already exist within industry but more could be done to support people in the transition from their own discipline into the position of a 'materials liaison', for example through training or interdisciplinary experiences. Placing more people with this skillset, and the right framework for 'acting' out their role, within materials innovation projects would help to support effective collaboration.
However, this approach also has limitations; it requires someone who is sufficiently familiar with the material typology and production process to communicate effectively, but not so involved that they influence the translation process with predetermined ideas. It is suggested that this process would be most effective when an ongoing dialogue is supported by a system of commercial materials

samples and material prototypes, and importantly when the aim is to facilitate cross-industry collaboration which appears more likely to result in radical materials innovation.

The study also found that the ML process may not be an effective substitute for closer collaboration between materials-led designers and materials R&D. Indeed, other factors in enabling interdisciplinary materials communication have been highlighted in closer, smaller scale collaborations. During a one-day seminar exploring design-science collaborations – *Dynamic Duos* – organised by the Centre for Circular Design, several interesting ideas emerged about how to maximise the impact of designers and scientists developing materials together, for example:

> *"Some of the highlights were the ability of designers to 'ask the right questions', to challenge the scientists, and the need to work together in close proximity – do we need new spaces for design-science work? Creating an atmosphere for the freedom to explore, and reach serendipitous outcomes which may be more 'innovative' than conventional enquiry, how can we do this more in design and science? What can be achieved in science within one month and what can be achieved in design are very different, what can we expect from each discipline given the different timeframes?"*
>
> *(Hornbuckle 2017:3)*

Some of these ideas could be explored within larger consortium projects as well as in industry, but this will require enlightened partners who are willing to take a riskier, more experimental approach to materials development than the conventional science-first model.

Interdisciplinary materials communication, while challenging, will be increasingly important as a greater diversity of disciplines are needed to develop innovative, marketable and sustainable new materials. Moreover, this approach has implications beyond materials development. Faced with an increasingly complex problem landscape, designers will need to work with other disciplines. Having a named person to facilitate the interdisciplinary dialogue could be a way of enabling collaboration, especially when working for the first time with limited face-to-face contact. More research needs to be carried out to define these roles and develop the necessary tools and methods to support them. Within the current project, the research is ongoing; designers, scientists and manufacturers will be interviewed in 2018, which will be an opportunity to review the whole process through to its completion.

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Designers by Any Other Name: exploring the sociomaterial practices of vernacular garment menders

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Studies around the cultures of design indicate a mutually constitutive relationship designers share with materials when in practice. However, professional designers are not the only ones experiencing proximate relations with materials. With the recent emergence of community-based repair workshops, non-professional designer practices of fixing things like garments reveal sites of active material tinkering possibly aiding transitions in current clothing disposal patterns. Using qualitative research methods and a sociomaterial theoretical lens, this paper takes the mending activities of non-professional menders in communal repair workshops in the city of Helsinki, Finland, as its point of departure. The study identifies these menders as vernacular menders and explores their dynamic practices to reveal the situated, embodied, routinized yet creative process of mending. The created outputs by the vernacular menders result in what is termed informal design and point towards extending mainstream conceptualizations of design and creativity. Taking such a view could help to sketch out new roles for fashion designers in pursuing endeavours to better support mending whilst bringing in positive environmental change.

sociomaterial; vernacular menders; informal design; creativity

1 Introduction

The work of designers is often described as a practice involved in giving ‘form’ to materials (Alexander, 1971), solving problems in unique ways (Cross, 2006) or more recently creating new materials (Myers, 2012). Designers’ ways of doing and knowing have been studied at length and theorized in various ways. One stream of current studies has been around the cultures of design that take into account the embodied, situated and material aspects of the work of designers (Geertz, 1973; Hendersen, 1999 in Kimbell, 2011). Work coming out of this field acknowledges that designers are not detached from the world they work in or on (Kimbell, 2011) and points to a close, mutually constitutive relationship designers share with materials when in practice (Shove, Watson & Ingram, 2007). However, professional designers are not alone in experiencing proximate relations with materials. In fact, designed artefacts are often not even used in ways anticipated by designers; they rather get constantly reconstituted when in use (Shove et al., 2007). One site where such re-configurations take shape, lies in the world of everyday repairing of numerous daily artefacts (Graham & Thrift, 2007; Maestri & Wakkary, 2011). Attending to these breakdowns not only results in an on-going recreation of relations between people and things, but the activities are also hotbeds for unleashing everyday "creativity, invention, imagination, and artfulness", as well as design (Jackson, 2014:226, Maestri et al., 2011: 81). Moreover, with the recent emergence of community-based repair workshops, non-professional designer practices of fixing things, such as garments, are being recognized as possible platforms for aiding transitions in current clothing disposal patterns (Twigger, 2013; Chapman, 2013; McLaren & McLauchlan, 2015).

This study will take a closer look at what goes on when non-professional designers come together to mend their garments in these workshops. Furthermore, by way of a generative analysis, the embodied, situated and sociomaterial dependant aspects of mending will be explored. Creative and collective ways through which these dynamic menders extend garment life will reveal sites of informal design outcomes resultant from their mending practices. Thus, through an exploration of the doings (body), sayings (discourse) and materiality (artefacts) of mending practices, this article aims to do the following:

- emphasize the importance of understanding the inseparability of the social from the material, and vice versa, when exploring practices that may assist in driving positive socio-environmental change (Drazin & Küchler, 2015);
- point towards the blurring of designer-non-designer dualities that emerge in and from active material tinkering of non-professional mending practices; and
- articulate implications for endeavours aimed at encouraging garment longevity practices.

The paper will begin by identifying *who* these everyday menders are, illustrate *how* they mend and discuss what happens when they *do* mend.

2 Theoretical framing

Let us begin the discussion first by gaining an understanding of sociomaterial practices. Rooted in relational onto-epistemology, a sociomaterial theoretical framing works towards overcoming dualisms between mind-matter/body, social-material, nature-culture, human-nonhuman in developing an understanding of the making of the world (see Haraway, 1991; Barad, 2003, 2007). Put simply, a sociomaterial practice theoretical lens takes an egalitarian view on the agency of humans and non-humans when considering enactments of practices. What this means is that ways of doing and knowing are not to be separated from the material or the social elements in the enactments of any practice (Gherardi, 2017). Rather, body, material and discourses are all "expressions of the same sociomaterial world" (Gherardi, 2017: 42). Knowing bodies and the things of knowledge do not exist as *a priori* entities merely coming into contact to mediate practice. Instead they are co-constituted through an enactment of practices entangled in the social and the material simultaneously. Therefore, when denoting this mutual constitution of the social with the material in the carrying out of practices, 'intraction' replaces interaction and becomes the preferred term of use (Barad, 2007: 37). Giving importance to this materiality aspect within practices also exists in the literature coming out of the "practice turn" or the return to practices (Schatzki, 2001; Reckwitz, 2002). A unified definition of practice does not exist, but for this paper I will take Reckwitz's definition to further our understanding of sociomaterial practices.

According to Reckwitz (2002) a practice is a "routinized type of behaviour which consists of several elements, interconnected to one another: forms of bodily and/or mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (p. 249). Conceptualizing any practice in such a way points to a number of key aspects. Firstly, neat distinctions between thinking and doing are avoided and ways of knowing are taken as a hybrid of the mental with physical/bodily activities (Shove, Pantzar & Watson, 2012), being carried out in a world not separated but 'entangled' in the social and material (Scott & Orlikoswski, 2008). Knowledge is seen, not as being sourced from the mind alone, but as embodied, experienced and distributed among humans and non-humans or nature and culture, social and material (Gherardi, 2017). As Schatzki argues, "knowledge is no longer even the property of individuals, but instead a feature of groups, together with their material setups" (2001: 12). In other words, knowledge is situated and taken as an on-going accomplishment manifested in the "performance" of a practice (see Reckwitz, 2002 for a detailed understanding of practice-as-performance and practice-as-entity). Secondly, through the situated intractions of things together with humans, understandings on ways of knowing, doing and saying are co-constituted, enacted in current performances and become enablers of future practice (Gherardi, 2017). This leads to the third key aspect whereby the unit of analysis moves from individuals and onto the enacted processes in a routinized, embodied and situated manner (Reckwitz, 2002).

We therefore understand everyday practices as not separate from the materiality of artefacts nor exclusive resultants of social structures (Kimbell, 2012). Rather agency between humans/non-humans is distributed and seen as entangled within a sociomaterial world when in the process of enacting everyday practices. The paper will now provide empirics to further anchor our understanding of mending as a reflective site.

3 Research design

This paper is based on empirical data collected over a seven-month period (November 2016-June 2017) of field work in 8 communal mending workshops in the city of Helsinki, Finland. The data consists of 16 semi-structured interviews with individual participants, one group discussion with 4 participants and 3 expert interviews with mending workshop organizers. The data forms part of the author's larger on-going doctoral research on mending practices. A three-level approach was implemented for the purpose of gathering data (Table 1).

Table 1. Three-level data collection method

Levels	Objective	Data Collection Method	Data Recording Tools
One	Identify mending workshops Attend mending workshops	Web search, Snowball Field observation	Field notes
Two	Make contact and interview organizers	In-depth semi-structured interviews	Transcription of audio recording
Three	Interview participants Participate in mending workshops	Short surveys In-depth semi-structured interviews Group discussion Participant observation	Transcription of audio recording Field notes

Level one included identifying organizers of the mending workshops in Helsinki. Three organizers were selected, two (REMAKE and Korjaussarja) using online research and one (Repair-a-thon) through snowballing (Flick, 2014), whereby one of the organizers introduced me to the third organizer. I then decided to take part in the mending events with the aim of gaining access and permission to conduct my study at their respective workshops. By giving verbal consent, the organizers acted as the gatekeepers, giving access to not only partake in their own workshops but also to make contact with other organizers in the community of menders. The location of each workshop varied depending on who was organizing and where the organizers could gain access for conducting the workshop. All the mending workshops were free of charge and provided participants fee-free access to machines and other haberdashery needed to mend. The initial research, at this level, was limited to observing the activities in the workshops without making direct contact with the participants. These observations from an 'outsider's' perspective documented the structure of conducting the workshops (Nicolini, 2009). Initial observations formed part of the field notes used in later analysis.

Following from this, in-depth semi-structured interviews were conducted with the organizers to identify motivations behind their activities. Each of the three interviews lasted from 1 hour to 1 hour 40 minutes. The full interview transcripts were analyzed, highlighting the perceptions of the organizers of their own practice and that of the participants as a group. This served as the grounds for level three of the data collection, where the motive was to zoom in and get an 'insider' view by tapping into the participants' views on mending practices, motivations for joining the workshops, experiences while mending and observing the doings of the participants (Nicolini, 2009). This was done through short pre-workshop surveys, in-depth semi-structured interviews and one group discussion during the workshop with the participants. The interviews and discussion each lasted from 30 minutes to 1 hour. All interviews were done only after attaining consent from the participants to be audio-recorded and used as data for the purposes of the current study. Additionally, observing the participants as they mended and self-reflexive activities by mending my own garments at the workshops also formed part of the field notes. A triangulation method was then used to analyse the data which included transcriptions of interviews, group discussion, short surveys and field notes (Flick, 2014).

Figure 1 Vernacular menders seen mending at a mending workshop held at an atelier (left) and at a café (right) in Helsinki. Source: author.

The consolidated data was coded using open coding. Open coding was directed towards forming descriptive categories and sub-categories when addressing the questions "who are the menders?", "how do they mend?" and "what happens when they mend?". The data revealed two major groups of menders: the organizers and the participants. As all three organizers held professional degrees in the field of fashion and/or textile design, they were grouped together as the "Professional Menders". Within this category, sub-categories were created based on the varying motivations of each organizer as summarized in Table 2. The second group was categorized "Vernacular Menders" and consisted of the non-professional menders participating in the workshops. The focus of this paper is on the knowing, doings and saying of the mending practices of vernacular menders.

Table 2 Types of Professional Menders and their motivations.

Professional Menders (Organizers)	Motivation (Professional Menders)
The Activist	Waste minimization
The Entrepreneur	Social enterprise
The Craft Teacher	Skill sharing

The term 'vernacular' is used to refer to the everyday, mundane, ordinary mending as sites of creativity and to reveal its importance for research within design (Hawkins, 2017). Using a sociomaterial theoretical lens to study mending practices of vernacular menders revealed the different types of menders. These sub-categories emerged because of the variations observed in the ways of knowing, saying and doing mending. The vernacular menders were then categorized as the restorer, the re-doer, the recruit and the reluctant.

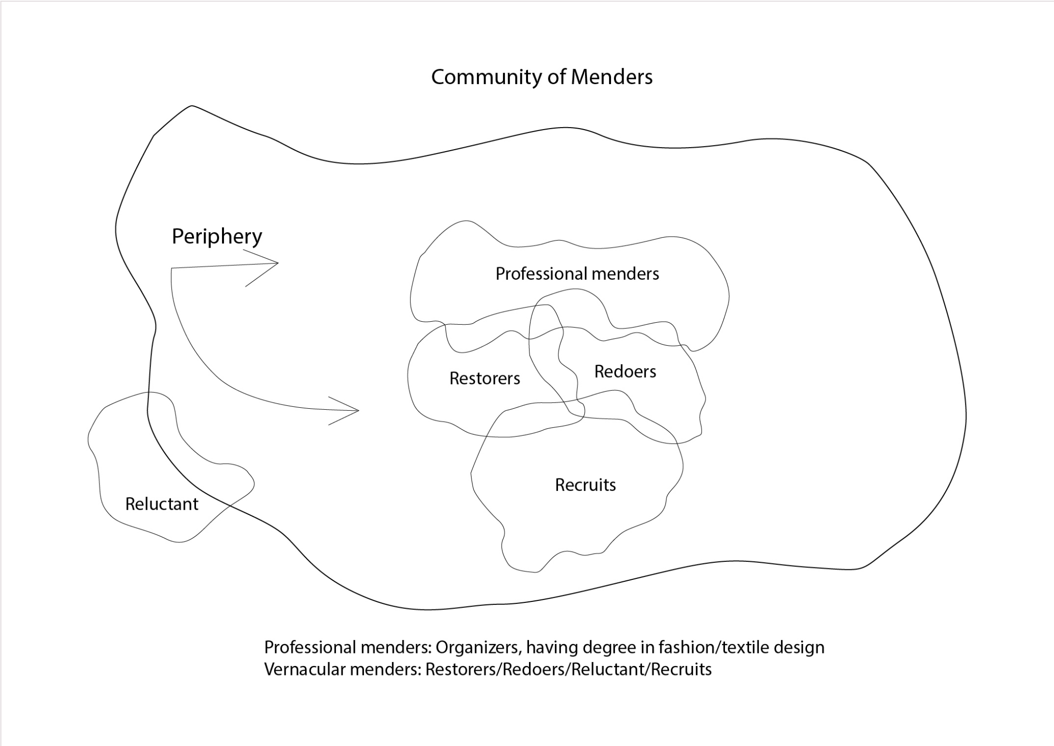

Figure 2 Community of menders: Professional and Vernacular menders' positions in participation. Source: author, adapted from Lave and Wenger's (1998) "Relations of participation and non-participation" diagram (p.167).

These categories are dynamic and not taken to be static, as vernacular menders did move in between them. What is important, however, is to highlight the distributive nature of mending as seen being performed by different bodies all engaged in routinized yet dynamic ways of doing mending (Reckwitz, 2002). This is a point to which I return in later sections ('Results', 'Emergent informal design' and 'Everyday creativities'). Additionally, the social nature of practices is revealed and points to what Lave and Wenger (1998) term as 'community of practices', whereby different bodies with varying knowledge all form part of the community by engaging in the same practice spread across space and time. Moreover, working consistently, whilst entangled with the materials, practitioners learn their way into a practice and move from 'peripheral' corners into becoming fully participating practitioners (Lave & Wenger, 1998). Therefore, as the following section will reveal, these sub-categories hold great relevance for the present study.

4 Results

4.1 Distributive mending

The varying profiles of menders described here illustrate the distributive nature of mending. This section describes the variations within the performances of mending as acted out by different bodies in the context of communal mending workshops. The four accounts illustrate the situated, yet at times overlapping, ways in which mending is carried out and knowledge is distributed (see Figure 2). The discussion will then turn to the embodied nature of the practice and explore ways of knowing as embodied entanglements within the sociomaterial setting when enacting practices of mending.

4.1.1 The restorer

> *I don't want to mend things if they don't look professional, {…} I think I would like it (the garment) to look like it was meant to look originally.*
>
> *I'm very precise, so I know when something is homemade and I prefer the type of mending that looks factory-made and quite exact.*
>
> *I want to have it (pair of pants) fixed in a way that doesn't show the damage. Mostly, I like to use the sewing machine to fix garments, I will put patches of the same colour and fabric of that particular garment {…}. Once I repaired clothes and it became very dramatic and then I didn't use it anymore. So the thing is to make it invisible.*

Professional, original, precise, factory-made, invisible, all point to the restorative qualities of mending. Turning back the clock on garments to erase any or all signs of breakdown is perhaps the most obvious light in which mending is perceived and expected to be performed (Spelman, 2002). Restoring garments to be neat, not grungy, and as they should be, is woven well into this practice.

Figure 3 Restorer digging through scrap denim (left) to find the exact colour so as to add patches inside (middle) the fraying crotch area to strengthen the jeans without showing the mend (right). Source: author.

However, restorers working within these peripheries are well versed in the language of materials and are anything but ordinary. They may not possess professional degrees in the field of garment mending or design, but their knowledge is on par with that of professionals and forms a vital part in the community of menders. Their reason for coming to the workshops is mainly to get a little advice on their mends while sharing their expertise with others. Restorers seek comfort in the company of other menders and avoid isolated moments of mending. In the process of pristinely mending garments, restorers often end up invisibly adding features into the garment. In this manner, restorers might overlap with the works of re-doers. The next section will this explain further.

4.1.2 The re-doer

There is a little hole (on the jacket). I will cover it up, and there is a saying, if you want to cover it, [you] should make it to be bigger and show so it looks part of it. I will use embroidery mending. It's very easy, you don't have to be the best embroiderer. I like the idea of doing something new, I have done this kind of work on t-shirts and if it doesn't succeed I do more embroidery over it{…}. I am more interested in experiments, and I do this a little bit {…}. I think for me I am always looking forward to the result, I think it's fun.

Figure 4 Re-doer using a visible embroidery mend to cover holes on the sleeve of the jacket. Source: author.

The re-doer is an experimenter and a risk taker. Re-doers bring new features onto the garments and re-configure the original design of the garment. However, such mends do not always have to be visible for, as seen, restorers too can re-do invisibly. This reveals an overlap and the fluid nature of the said categories. Additionally, the re-doer well recognizes the variety and differences in the demands of each mending job (Spelman, 2002) and is motivated by a strong desire to learn and improve their technique. Therefore, the range of knowledge oscillates from basic to advanced in this group. Moreover, re-doers normally do not have all the needed equipment at home and participate in the workshop to gain access to materials. Many times, they will be seen making-do with what is available and improvise with those limited materials as they go along with their mends. This can be seen in the following excerpt:

I repaired it (pullover) using a very visible repair and many of the repairs were even on it when I bought it {…}. I find that it gives something special and something more to the garment, I like to do visible mending {…}. I have made some very funny things with visible mending. I also have these woollen trousers and then there were a lot of holes {…} and I didn't have the right colour for these trousers because they were deep blue and I used pink to repair it.

Where a restorer might spend hours searching for the perfect coloured thread, a re-doer is more spontaneous and not afraid to work with the odds. Similarly, while a restorer might hide the additions made to the garment the re-doer makes it a point to show and highlight them. Both, however, when in the process of mending the garments, learn from the original design of the garment and enhance it. This is an aspect to which I will return (see 'Everyday creativities' and 'Emergent informal design').

4.1.3 The recruit

> *I brought my trousers that I stopped wearing because they were ripped here (pointing to the crotch area) so I want to fix them and I don't know how to operate the sewing machine, and I thought the machine will be the best for this because it is what you call a double stitch. And I learned how to operate with a needle in primary school but I wasn't very good so I thought I will come here and learn how to use a machine.*

The recruit is a first-timer and has little to no experience with repairing, possessing very basic knowledge. The recruits want to learn how to put their clothing back into use. They are open to trying out various techniques of (invisible and visible) mending and are keen to learn. Some might be shy to use the sewing machine at first and are normally found around the hand stitching tables.

Figure 5 Recruit seen consulting the professional mender as the two work through the mend with the materials. Source: author.

Taking inspiration from their garments, professional menders and other vernacular menders, recruits collaboratively work on their mends as seen in the following narrative:

> *I was nervous about using the machine because I'm not that used to sewing, but we had good tutors and were helping and being positive. And I was hoping I could replace this section of the jeans and Piia (Professional mender, REMAKE) suggested I could take this part straight from the other jeans, and I haven't even thought about that before and then I was like, aha, let's do this, so I am really pleased with the outcome {…}. Now I will use my skills afterwards and also show some other people the same technique, it has been a very useful and productive evening!*

4.1.4 The reluctant

> *My son's jeans got ripped in the crotch and it was a big hole and he brought it to me, but I did not know what to do with them, and they are in a bag in the summer cottage of broken clothes.*
>
> *If it's just socks then I will throw it away but if I like it I ask someone to fix it for me. I have used a machine at school and haven't done it for it ages. I probably should but I ask my friend {... }. I think to start is the hardest part. I would probably throw [it] away if my dress breaks and I don't have any help.*

The above excerpts are two women speaking, one who had brought in a Burberry jacket with a broken button in need of fixing while the other brought trousers owned by her mother with holes in them. The two women, although reluctant to use the sewing machine or their hands to mend, did not hesitate from explaining how they wanted the garment to be fixed. Both wanted the garments to be restored without the work being visible and in this way sharing some of the qualities with the restorers. Reluctant, out of fear of ruining the garment, do not give a go at fixing it. However, they want to consult and tell the professional mender what to do in a very particular manner. They select the materials themselves and know what and how they want it to be. In this way, they find themselves half-way between being outsiders and peripheral members of the community of menders as seen in Figure 2.

Figure 6 Professional mender seen mending the jacket of a reluctant vernacular mender as per his requirement. Source: author.

Additionally, some even show willingness to try mending themselves after seeing how it is done in the workshop. They learn in terms of seeing but do not "do" at this point, yet are inspired to try. This is seen in the following conversation:

> *Reluctant: came with my friend randomly. That's it. And I found out that I could fix something that was broken. Both the zipper and the bottom button of my jacket were broken {..}, today we fixed the zipper, it's a little bit wonky but it works.*
>
> *MD: What do you normally do when garments rip or buttons break?*
>
> *Reluctant: Well, if it would be a button like this I would find someone to do it for me. But now I know how to fix this (button) one and she (professional mender) showed me and if the same problem happens again I will try to fix it myself.*

5 Discussion of findings

This section will now explore three key themes that emerged from the analysis of the vernacular menders' various practices in the communal workshops.

5.1 Embodied knowledge

> *I prefer using my hands to repair. I feel I have some kind of **connection with the garment** and it's somehow more under my control when it is in my hand. (Restorer)*
>
> *It (mending)[is] relaxing and takes **my mind off things** and lets me unwind and **I wasn't thinking about anything**. (Re-doer)*

Every time someone began mending a garment in the workshops, be it a professional mender or a vernacular, it would always begin with touching the fabric and feeling it between the thumb and fingers. The broken area would then be felt and slightly scratched with a fingernail whilst the fabric was turned inside out and back in again. The direction of the fibres would be felt and the fingers were seen grazing in the direction of each yarn looking intently at the garment construction. The hands were in constant use and in motion, feeling, touching and assessing the material properties of the garments prior to repair. Once the issue was diagnosed the use of hands would not stop, for as the menders began mending, a conversation in motion was witnessed between the mender and the matter – without being able to determine who was telling whom what to do next. From using the mouth to soften the thread just enough to accurately thread the needle to keeping the body in particular postures while working through the mend, the body's reliance on and inseparability from the tactile materiality of the work became effortlessly prominent. Not only was the sense of touch visible, but the sense of sight and feel were ever present too.

Figure 7 Using hands whilst encircled in a group of varying vernacular menders collaboratively working with the materials on their mends. Source: author.

One revealing example was when a man brought a woollen coat in need of a button stitch-up to one of the workshop events. As he was not happy with the way the jacket closed when it was first fixed, he returned to the workshop a second time. The troublesome button was placed together in consultation with the professional mender in various spots several times. Fitting and checking in the mirror, the two bodies worked in tandem with the sewing pins pinned in the coat to find the most aesthetically pleasing spot for it. They used their hands to fix and feel the fit of the coat before finalizing on the best spot for it to be sewn on. These observations point to a reliance on a kind of knowledge that can be seen as not purely coming from an intellectually charged cognitive process, rather an embodied one (Strati, 2007). Additionally, it seems to be entangled in the social (consultations with the professional) along with the material qualities of the coat and the senses and sensibility of the body. Strati (2007) terms this type of knowing as 'sensible knowledge', where the interactions of the hands with matter being worked with provide the basis for the enactments of on-going and future practices. The two are entangled and the knowledge derived is both in the action and in the sensing. According to Gherardi (2012) material engagements such as these enable the tactile and visual senses of the body and inform the performance of practices.

In other words, when using a sociomaterial lens to study practices, knowledge and ways of knowing are not constricted to purely the mind. In fact, an egalitarian approach is taken to the study of practices whereby dualities between mind/body, human/non-human, matter/ideas, are blurred. Knowledge is then taken to be embodied and a reliance on sensible knowledge is seen in the enactment of practices, as exemplified in the above examples. With this comes also the distributive nature of knowledge amongst various bodies (Henke, 2000). Ways of knowing are not confined to just one but various bodies and things. Ergo practices are seen as distributive and ways of knowing are performed and enacted in varying degrees. When they are performed, different bodies enact them in different ways.

Figure 8 Vernacular menders uses hands to scratch, sense, feel and converse with the materials when trying to understand the cause of the garment's breakdown. Source: author.

This distributive nature of practices is then seen in the bodies of the restorer, re-doer, recruit and reluctant vernacular menders, along with the professional menders, all of whom form part of the community of menders. Using a sociomaterial lens to understand the process of mending reveals that knowledge of and knowing how to mend is an embodied and distributive phenomenon (Gherardi, 2016). It brings to surface the importance of and reliance on materiality and bodily movements guided through what is called the "intelligence of the hands" in the enactment of these practices (Strati, 2007: 68). This implies that the process of thinking is not sourced purely in isolated cognitive exercises. Rather it comes from the co-constitution of various minds/bodies entangled in sociomaterial surroundings. Taking such a view on everyday practices also helps in recognizing subtle ingenuities that abound in the on-going shaping of artefacts. The next section will reveal how, through the sociomaterially immersed practices of vernacular menders, informal design outcomes are birthed.

5.2 Emergent informal design

> *I've been meaning to fix these jeans since I fell down two weeks ago and tore the knee {…} so it was T-shaped the way it had torn {…}, this is the burros stitching {…}, I drew it (the pattern) on a paper. And then I made the pattern on the jeans. And decided to sort of cut a small piece out and make a square and twist the sides inside. First, I stitched the square so it is stuck to the patch behind, then I made the crosses. Then I made them (the crosses) by hand {…}, then I thought I don't want to make it like a square so I made it a bit uneven from the grid (Re-doer).*

The process of mending as it unfolded whilst the vernacular menders mended, be it a re-doer or a reluctant, always began with the identification of a problem. In this instance, the problem took form in the breakdown of a garment due to for example a broken button or a ripped trouser. Once the problem was defined the next step entailed analysis of the broken material and the self (embodied knowledge), followed by an examination of the available material and if needed the surrounding knowledge (consulting other menders). Analysis of material would occur almost simultaneously in action and conversation among and between all menders and materials. The menders would not always state what the next course of action would be but through the enactments of their practices the next steps emerged and became visible. This normally came in the shape of menders drawing ideas out on pieces of paper, chalking on patterns they wished to embroider on their mend or placing patches of scrap fabric to mask holes in the garments. This was followed by an experimental phase whereby different threads, buttons, patches and other haberdasheries were temporarily used to get a visual before selecting the final ones leading into the visibly or invisibly mended end results.

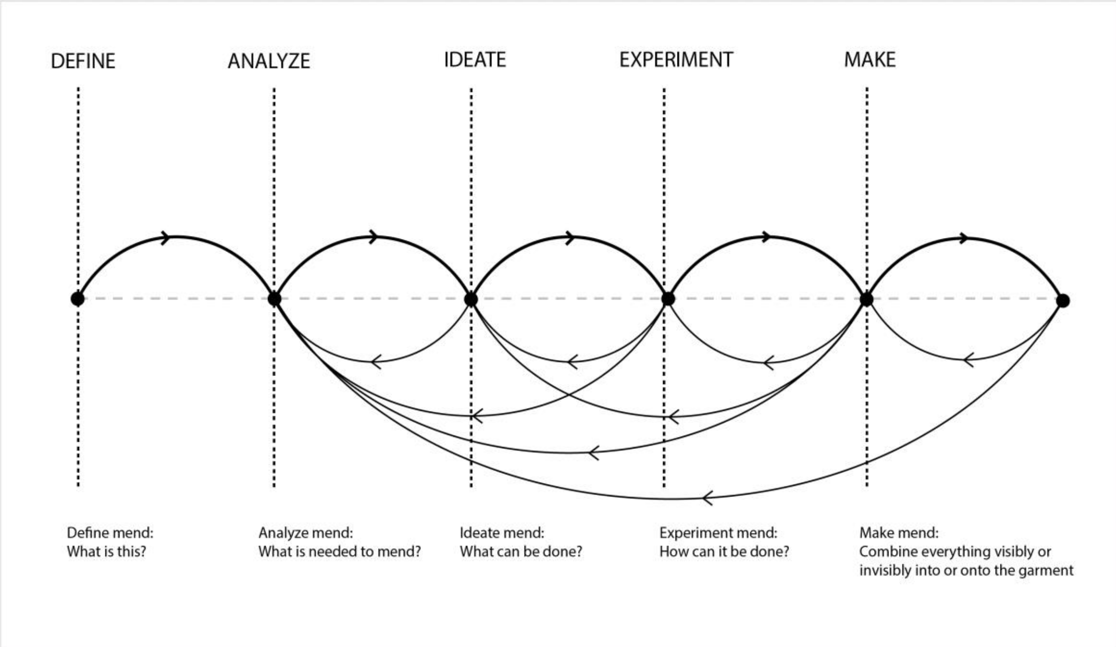

Figure 9 Process of mending. Source: author.

However, this process is not to be taken as a linear one. Quite often, menders would break away from one phase and go back to an earlier stage of the mend if their envisioned experiments failed to reflect through till the making of the mends (see Figure 9). Thus, there is a continuously re-mouldable, dynamic and looped nature of mending, as illustrated in the following quote:

> *At first, I used pink yarn because I thought it will look cool, but as I did it then it was just a ridiculous idea {…} so it was a mixture of making a pattern but also not to make it show too much or make it special in a way. Because these are outdoor pants and I thought it will be a nice detail but also not show from far away, that's why I changed the idea of using the bright coloured yarn. Because I wanted to go wild but then I'm very minimalistic, it's better to go for the classic style even in this (cargo pants). (Re-doer)*

Within these on-going enactments, the vernacular menders collectively used mind/body, social/material, human/non-human elements whilst orchestrating paths towards sound solutions. In their performances moments of improvisational ingenuity were often found. This could take the shape of uniquely visible embroidery mending or invisible mock safety stitches added onto or into the garments, improving garment performativity or aestheticism. To the naked eye perhaps something like an invisible mend might seem to have added nothing new to a garment and instead can be taken as just a mundane part of fixing. However, it was within these routine moments of even invisibly mended hidden solutions one finds reconfigurations to the original design assisting in the garments' transformative continuity. In this way, the reconfigurations are confirming and adding to Wakkaray and Maestri's (2011) concept of 'everyday design', as defined in terms of the ordinary yet unique extensions and modifications to already designed products that result from people's daily usage.

Figure 10 Process of mending: define (upper left)-analyse (upper middle)-ideate (upper right)-experiment (lower left)-mend: visible (lower right). Source: author.

Solutions such as these often lurk at the outskirts of professionally recognized design and are easily overlooked (Finizola et al., 2012). However, when using a sociomaterial practice lens to study mending, one becomes sensitive to these hidden features; design is no longer exclusively found in the creations of those holding academic degrees. Rather an appreciation of the 'spontaneous manifestations' of daily artefacts extending both the life and original design of things when in everyday use is granted (Wakkary and Maestri, 2011; Finizola et al., 2012; Kimbell, 2012). Informal design can then be understood in terms of solutions resulting from a reliance on non-industrialized modes of production carried out by non-professional designers for the purposes of extending the planned life of artefacts (Finizola et al, 2012). Therefore, all the various sketches of patterns, prototype patches pinned on mends to get a visual, placing buttons in various places, experimenting with different threads before the actual mend is stitched (visibly or invisibly) too are given equal importance. They are seen aiding in the renewing of garments, and also form part of this process (Kimbell, 2012). 'Things' or artefacts, like design, are seen as open and constantly in a state of what Ingold and Hallam (2007) call 'becoming' and being re-shaped or re-constituted whilst in use (Shove, 2007).

It is within these collective embodied enactments of mending, distributed across various bodies (not just professional designers), entangled within the sociomaterial that everyday informal design solutions emerge. The solutions reveal how design does not stop with the purchase of new garments. If anything, like designers and/or professional menders, vernacular menders are all carriers or stakeholders involved in the on-going co-constitution of design and designed things (Kimbell, 2012). The next section will take the discussion further by exploring the creative aspects found embedded in the dynamic practices of vernacular mending before concluding.

Figure 11 Dynamic process of mending where the vernacular mender began with a pink yarn (middle) but ended up revising and starting again from the ideation phase and finished with black visible mended (right). Source: author.

5.3 Everyday creativities

> *I have two needles, one is bigger than the other and I use it for everything and it works. (Restorer)*

> *I don't have any sewing machine and I don't have skills {…}. I'm hand sewing this kind of dress (button down) {…}. I really like to use this dress in the summertime, and it's usually nice to use it without a t-shirt or top under it so now I can be relaxed after putting this clasp button I found here that I won't show anything from here (pointing to the chest area). (Re-doer)*

Using a sociomaterial practice lens to study practices allows for a sharper recognition of the subtleties of creativity found within everyday mending. In contrast to waiting for radically ingenious moments, one finds creativity in the continual "making of the world" (Tanggaard, 2012). Here humans share a close relationship with non-humans and things, which are always in the becoming (Ingold and Haram, 2007), whether showing through visible boros stitching or invisibly adding a feature (clasp button) to a dress to make it fit better. These manifestations imply creativity as not an individual trait achievable by only professional menders. Nor is it understood to be an outcome of individual divergent thinking but comes from contact through materials surrounding us. Making do with what is available (re-doer) or sniffing out materials to make garments look exactly (restorers) as they were, creativity is taken as "fundamentally relational" (Tanggaard, 2012: 25). Therefore, restorers like the non-restorers, vernaculars like professionals, all are entangled in a world of materials with histories that communicate "pre-existing ways of doing" and "emerge as part of specific activity and become part of performative action in the future" (Tanggaard, 2012: 25). This can be seen in the following example of a vernacular mender who initially was following the direction of the threads of the other buttons but upon engaging further with the materials realized the following and altered his way:

> *I think you put the thread here and here rather than making a cross, but I think the rope (shaped on the button) is a guide for the thread to go, the button has holes so the thread goes in and when you are moving the thread it is more safer in the ropes, so when you are doing something the thread doesn't get ruined. And it was supposed to be sewn by following the shape of the rope rather than make a crisscross. It's meant for the thread. And maybe somebody else had repaired it in a crisscross before I found the coat. (Restorer)*

While Lapolla and Sanders (2015) might explain everyday creativity sourced in an individual's skill alone, this paper brings the material basis of creativity to the forefront. Like informal design, creativity is seen to be emergent and not taken as a generalized formula to be applied from above onto a practice nor reserved for the 'exceptional' few (Taangaard, 2012). Rather, it is embedded within these small adaptations and improvisations made when enacting practices which on the surface seem standardized. These improvisations are not always exceptional or loud but can also be found in the mundane, the subtle, the hidden and the ordinary. Therefore, unlike Lapolla and Sanders (2015) who place mending on the lower ends of creativity and describe it as lacking in the creation of 'original ideas' (p.185), this study argues that creativity resides in the intractions of the material with social, of the human with the non-human, and in the exceptional as well as the everyday. It becomes a means through which what is known already is recreated (Tanggaard, 2012). Hence, as seen through the aforementioned examples, mending takes current ways of knowing and doing as starting points for building onto. In this on-going, embodied process, vernacular menders constantly rely on the use of their hands and bodies whilst collectively entangled in materials, resulting in dynamic and originally visible or invisible mended design solutions.

6 Concluding thoughts

This paper used a sociomaterial practice theoretical lens to study the dynamic mending practices of non-professional menders as situated in communal repair workshops in the city of Helsinki. In doing so, the study identified them as vernacular menders and revealed the situated, embodied, routinized yet creative process of mending. The created outputs of the vernacular menders resulted in what was termed as informal design and pointed to the need to recognize the fluidity of design and designed objects when in use. The contributions of this study, therefore, reside in the following aims:

- to overcome dichotomies between human/non-human, social/material, designer/user, when studying practices of garment use, and instead highlight the inextricable relations shared between vernacular menders, like that of professional menders/designers, with sociomaterial elements when in the process of mending;
- to acknowledge non-professional designers/vernacular menders/'users' as active tinkerers, extenders of and co-practitioners in design and not passive recipients of designed garments lacking agency;
- to extend current understanding on design authorship to include creatively rich, one-off solutions resulting from non-professional designers' material tinkering.

The relevance of taking such a view assists in bringing forward real-life garment use practices resulting in unique solutions already aiding product longevity. A re-consideration of current mending practices, not as common place drudgeries, but as unique opportunities can also assist in sketching out new roles for professional designers as facilitators in the on-going re-designing of garments. As Twigger (2013) too has claimed, seeing designers in the light of facilitating collaborators (instead of lead/sole practitioners of design and creativity) engaged in sharing expertise with vernacular menders (of varying degrees) could benefit efforts aimed at amplifying garment mending practices whilst bringing in positive environmental change.

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ICS Materials. Towards a Re-Interpretation of Material Qualities Through Interactive, Connected, and Smart Materials.

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The domain of materials for design is changing under the influence of an increased technological advancement. Materials are becoming connected, augmented, computational, interactive, active, responsive, and dynamic. These are ICS Materials, an acronym that stands for Interactive, Connected and Smart. While labs around the world are experimenting with these new materials, there is the need to reflect on their potentials and impact on design. This paper is a first step in this direction: to interpret and describe the qualities of ICS materials, considering their experiential pattern, their expressive-sensorial dimension, and their aesthetic of interaction. Through case studies, we analyse and classify these emerging ICS Materials and identified common characteristics, and challenges, e.g. the ability to change over time or their programmability by the designers and users. On that basis, we argue there is the need to reframe and redesign existing models to describe ICS materials, making their qualities emerge.

ICS materials; expressive-sensorial dimension; aesthetic of interaction; materials experience.

1 Introducing ICS Materials

The materiality of the world where we live is changing under the influence of technological advancement that feeds miniaturization and a continuous democratization process. Fuelled by the diffusion of the Open source and the spreading of fab labs, workshops, and platforms for experimentation and prototyping, the democratization of technological practices is bringing to easier access to data and technologies both owned, through cheap and flexible tools, and shared, also for non-specialized users. As a result, design is becoming computational and interactive, exploring trans-disciplinary approaches, and merging with computer engineering and biology (Antonelli, 2008; Myers, 2012). Through embedded technology, smart object and systems can interact with people and the environment, sensing and reacting to stimuli or transferring data. Based on these experiences, we can imagine a future where industries develop a new generation of interactive materials to fabricate products. These new materials will be dynamic, augmented, and programmable. We refer to these as ICS Materials, as they are Interactive, Connected, and Smart.

In order to lay down a clear definition of these materials, it is necessary to first unpack the lexicon currently used. In the use of the terms connectivity and smartness, "there is a common misunderstanding that interaction design is concerned fundamentally with the digital medium" (Buchanan, 2001). This is supported by the acknowledged declinations of the terms into materials domain. The concepts of 'Interactive material', and 'Smart Textiles' (Stoppa & Chiolero, 2014) underlines the use of electronic and digital technology, while 'Smart Objects' and 'Connected material' are related to the Internet of Things. In contrast, 'Smart materials' work through analogic means (Addington & Schodek, 2005) such as memory-shape alloys and thermo-chromic inks. Instead of a 'Technology-Centered view' we assumed a 'Behaviorist View' of Interaction (Saffer, 2009) which underpins a broad meaning for those terms by including other applications and means of interaction different from digital and computational and adopting an inclusive approach. Thus, the definition of ICS Materials encompasses materials that are: (i) able to establish a two-way exchange of information with human or non-human entities; (ii) linked to another entity or an external source, not only through the internet and digital network; (iii) able to respond contextually and reversibly to external stimuli, by changing their properties and qualities; (iv) programmable, not only through software (Rognoli et al., 2016; Parisi et al., 2018).

Examples such as DuoSkin and BioLogic by MIT Media Lab (Kao, et al., 2016; Yao, et al., 2015), the Recurring Pattern project by the Swedish School of Textiles (Nilsson, et al., 2011) and Transformative Paper by the Institut für Materialdesign Offenbach show that ICS Materials are not limited to computational, electronic, and digital. Indeed, this definition also encompasses interactive materials using chemical, mechanical, and biological means. Therefore, because of their systemic and networked complexity enabling interactivity and smartness (Ferrara, et al., 2018), we can describe them as hybrid material systems that work by establishing interactions among their constituting components, and with people, objects, and environments, through the combined use of electronic, chemical, mechanical, and biological components.

These materials can be fabricated (Coelho, et al., 2009), tinkered, hacked and programmed by designers (Vallgårda, et al., 2016) according to a self-production practice that extends the definition of DIY-Materials (Rognoli, et al., 2015; Ayala Garcia & Rognoli, 2017). Experiments with these emerging class of materials provide a remarkable contribution to design and research, pushing boundaries and opening up to new questions and issues to explore their expressive-sensorial dimension and their aesthetic qualities of interaction.

Although the range of interactive materials increases (Coelho, et al., 2009; Razzaque, Dobson, & Delaney, 2013; Vallgårda & Sokoler, 2010), their peculiar qualities, challenges, and opportunities, as well their possible applications are still to be fully understood. This paper is the first step in this direction and proposes a framework based on the analysis of a selection of existing projects and experiments, focusing on the experiential pattern of these materials, above all considering their expressive-sensorial dimension and their aesthetic of interaction. This proposal builds upon existing frameworks in the literature by different authors, that we put in relations and to expand, according to ICS Materials characteristics.

2 ICS Materials Map

We propose an initial map for ICS Materials (Figure 1) as a tool for understanding and framing materials. It is based on the outcome of a workshop involving the project participants and aiming to classify and organize a collection of best examples of materials, systems, components and products (Parisi, et al., 2018). The model is inclusive and encompasses different classes of materials, according to their degree of interactivity, smartness, and connectivity, and their related technological and systemic complexity. The graphical representation is read from the top to the bottom through the categories of: inactive materials, reactive materials, and proactive materials. The systematic classification of materials is an ongoing effort, thus prone to re-categorizations and extensions, considering other criteria and by furthering the collection of case studies.

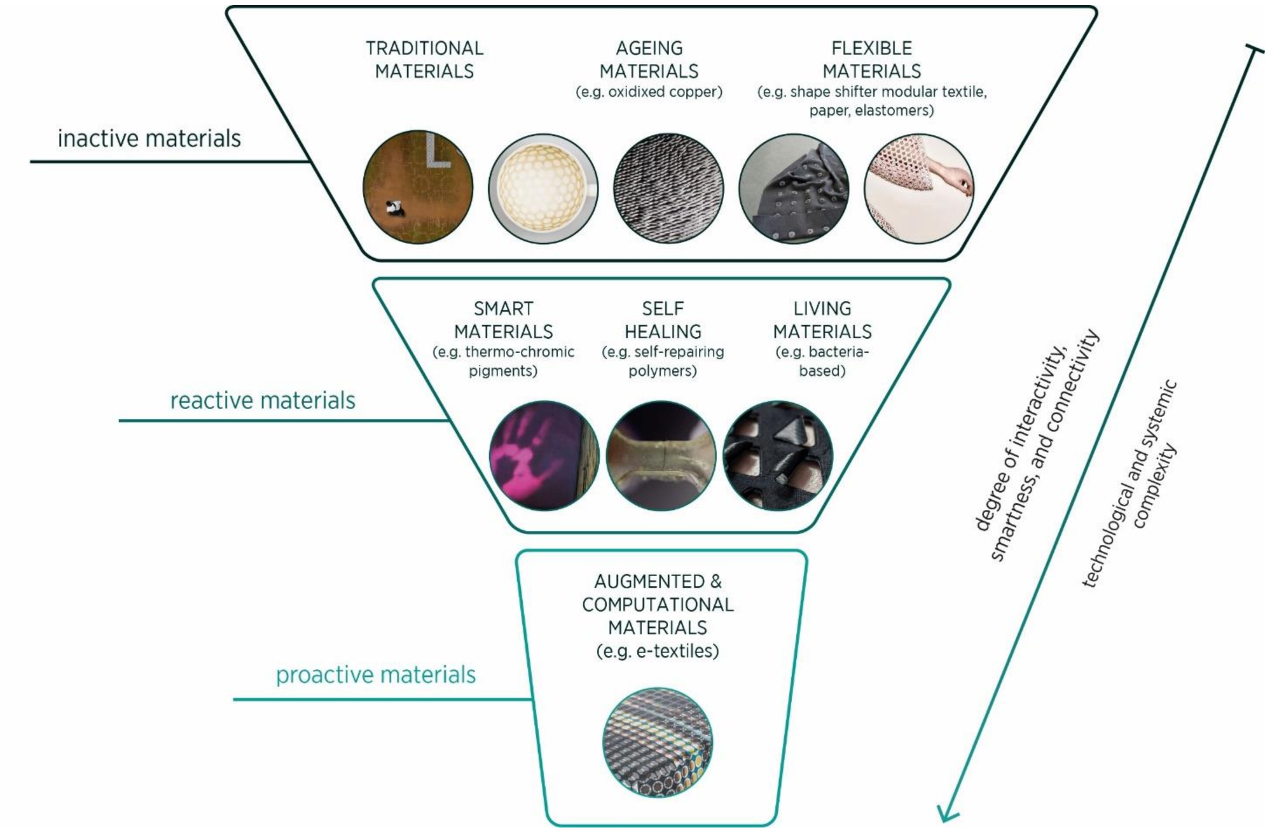

Figure 1. A tentative map of ICS Materials, arranged by their level of systemic and technological complexity, which is related to their degree of interactivity, connectivity, and smartness.

Inactive materials are material with no explicit interaction or allowing interaction at a very low degree and do not show ability to quickly react and connect: in other words, they are mostly behaving in a passive manner. They are mainly traditional materials. Thanks to their chemical or structural characteristics, they are subjected to establish some sorts of interaction with the users and the environment over time. Some materials display such interaction in a more evident or expressive way than other. For example, aging materials, as oxidizing copper, or flexible materials, as paper or elastomers. Their behaviours cannot be designed or programmed, but only exploited in design and can support the following more interactive classes.

Reactive materials include smart materials or combinations of inactive materials with smart materials components, e.g. thermo-chromic inks. They display changeable properties and can reversibly change some features such as colour or shape, in response to an external stimulus, e.g. light, temperature or the application of an electric field. Examples are thermo-chromic and photo-chromic polymers, shape memory alloys and piezo-electric materials. Other examples use living and growing organisms as bio-sensor and bio-activators to sense and react to stimuli, as bacteria. Because they are living organisms, they have a certain degree of intelligence and unpredictability. We might include into this category also self-healing or self-repairing materials, substances with the ability to autonomously repair any damage to themselves without external diagnosis of the damage or human intervention (Bekas, et al., 2016). Reactive materials have a higher degree of interactivity compared with the Inactive materials, but their connectivity is low. They can be seen as *closed materials*, because their performances are designed in the fabrication stage. However, if these materials are combined with other entities in a more complex and intelligent system they can improve their connectivity and smartness. This means that they can be applied "as a critical part of smart systems" (Ferrara & Bengisu, 2013).

Proactive Materials represent complex and intelligent systems of material components based on the combinations of inactive materials or reactive materials with embedded digital, electronic and computational technology in the form of sensors and actuators and connected with external or embedded computers, e.g. many smart textiles. These are also called *augmented materials* (Razzaque, Dobson, & Delaney, 2013) or *computational composites* (Vallgårda & Sokoler, 2010). Proactive materials show a very high degree of interactivity, connective abilities, and smartness. When compared to reactive material, they are more advanced as they can be programmed at every stage of fabrication and use. This acknowledge them as transformable (Ishii, et al. 2012) and open materials, unfolding new scenarios of interaction and a new concept of smartness, as they allow programmers, designers, makers, creatives, and users to operate on them, to obtain results, qualities and expressions. Proactive materials are the ones that best fit the definition of ICS materials. Projects such as Smart Dust (Warneke, et al., 2001) are expected to deliver microelectromechanical systems the size of a cubic millimetre that will take sensing and communication capabilities at the level of the material itself as opposed to the level of the object manufacturing as it is today. Smart materials can then be imagined as becoming an integral part of the future designers' toolbox possibly changing the way design is done.

In the rest of this paper we describe related works, pertaining to the fields of Materials and Design, HCI and Tangible Interaction that deal with the experiential pattern, expressive-sensorial dimension and aesthetic qualities of interaction. We further put forward a proposal to expand the Materials Experience model of a level of interactivity – that we named connective level – and analyse four cases accordingly.

3 Experiential, Expressive-sensorial and Aesthetic Qualities of Materials

In the last 30 years, research in Materials and Design has shifted its focus from technical properties of materials (e.g. flexibility or strength) to their expressive-sensorial qualities that define and affect the materials experience (Manzini, 1986; Cornish, 1987; Ashby and Johnson, 2002; Rognoli, 2010; Karana, Pedgley, & Rognoli, 2014; 2015). Thus, it is now acknowledged that materials need to have qualities that go beyond the fulfilling of practical demands. They must have intangible properties that captivate appreciation and that affect the experience of an artefact beyond its functional value. These properties were firstly named Intangible Characteristic of Materials (ICM) (Karana, Hekkert, and Kandachar, 2010; Karana, Hekkert, Kandachar, 2007), and later intangible sparks of materials (Karana, Pedgley, & Rognoli, 2015); they are qualitative, non-technical, and intangible characteristics related to emotions, personality, and cultural meanings. These qualities of materials have been explored and classified by different scholars. Here we review the literature including authors' contributions on this topic, and we propose a framework for the analysis of ICS Materials in accordance to their peculiar qualities. The framework we propose builds upon a substantial body of work we have developed over a number of years to better understand the principles of materiality. In proposing this framework, we expand our knowledge to include emerging computational characteristics that will become part of future ICS materials.

3.1 Materials Experience

Since materiality contributes to the definition of 'product experience' (Desmet & Hekkert, 2017), the concept of *material experience* arises as "the experience that people have through and with materials" (Karana, Pedgley, & Rognoli, 2014), which is framed into sensorial, affective, interpretive, and performative layers of experience (Giaccardi & Karana, 2015). These levels affect each other in a non-sequential manner:

- the *sensorial experience*, related to how people sense materials. We find materials cold, shiny, etc.

- the *affective experience*, related to emotions elicited by the material, e.g. feeling surprised, bored, etc.
- the *interpretive experience*, related to the meanings evoked by the material and are associated to abstract concepts, e.g. materials are modern, cozy, etc.
- the *performative experience*, acknowledges the active role of materials in shaping ways of doing, physical actions and practices, e.g. to scratch, finger, squeeze, etc.

The material experience is interpreted subjectively; therefore, when defining the qualities, a material should have or using it for an artefact, the role of the designer is key in understanding, envisioning, and creating that specific experience.

In the sub-sections below we are showing other models or concepts of experiential, aesthetics, expressive and sensorial qualities of materials. They are discussed and identified as corresponding or grounding the framework of Materials Experience.

3.2 Expressive-Sensorial Dimension of Materials

We define the sensorial, subjective, qualitative, and unquantifiable, profile of materials as their *expressive-sensorial dimension*. This notion looks at design materials as instruments to characterize a product from the points of view of perception, interpretation and emotion. By means of the expressive-sensorial qualities of materials, designers can embody in the product sensorial emotional references that trigger a particular material experience. The Expressive-Sensorial Atlas (Rognoli, 2010) supports designers in their understanding of the material qualities and unfolds their relations with engineering properties. It is a mapping of the technical, objective and measurable profile of materials, into a sensorial, subjective and qualitative one. Examples of these characteristics are texture (smooth/uneven), touch qualities (warm/cold, soft/hard, flowing/stilted, light/heavy), brilliancy (gloss/matte), transparency (transparent/translucent/opaque). These characteristics may be also used to describe the sensorial level of materials experience.

3.3 Meanings of Materials

These sensorial-expressive qualities are key in determining the meanings evoked by materials that are embodied in a specific product (Karana, Hekkert, & Kandachar. 2007; 2008). A set of meanings conveyed by the materials of a product have been identified by Karana and Hekkert (2008; 2010), such as cozy, aggressive, feminine, high-quality, toy-like, sober, etc. These meanings are used to describe the interpretative level of materials experience. The relationship between material qualities and elicited meanings is grounded on individual-personal, cultural-contextual, and universal reasons. Therefore, the right combination of materials and qualities to obtain a specific meaning are difficult to determine and are related to several variables.

3.4 Performances with Materials

Similarly, a set of performative actions that map ways of doing and practice have been argued as a performative level of materials experience, by Giaccardi and Karana (2015) and further explored in (Karana, et al., 2016). Examples of elements in the performative level are actions such as scratching, fingering, exploring, caressing, squeezing, stroking, etc. These are affected and mediated by the other levels of Materials Experience and inform them in a mutual manner.

As demonstrated by this latter contribution, as experience and interaction have become a matter of concern for material design, so materiality has spilled into in Human-Computer Interaction (HCI). The community around HCI have started to look at interaction and experience with materials as a complement to interaction and digital technology (Petrelli, et al. ,2016), re-valuing the importance of a sensorial engagement of the user with the physical matter and promoting the notion of *material turn* (Robles and Wiberg. 2010), *material move* (Fernaeus and Sundström., 2012) and *material lens* (Wiberg, 2014). This focus on materiality in HCI underpins studies by Vasiliki Tsaknaki and Ylva Fernaeus on the use of raw materials, such as leathers, and the value of imperfection in HCI

(Tsaknaki & Fernaeus, 2016; Tsaknaki, Fernaeus, and Schaub, 2014), and those by Daniela Rosner et al. (Rosner, et al., 2013; Rosner and Taylor; 2012) on the topic of ageing and traces.

Thus, in many respects, materials design and interaction design are converging and offering a new interpretation of what we have defined above as interactive, connected and smart materials (ICS). ICS Materials introduce properties and qualities such as interactivity and temporality that in conventional materials do not exist, are irrelevant, unexpressed or complex to identify. Computational composites, as discussed by Vallgårda and Sokoler (2010), bring in properties such as temporality, reversibility, computed causality, and connectability.

3.5 Aesthetic of Interaction

Other studies move from a tangible interaction standpoint (Hornecker, 2011) and focus on the aesthetic of interaction, e.g. the interrelation between shape, size, material and behaviour in the perception of users (Petrelli, et al., 2016). (Petrelli, et al., 2016) sheds some light on the aesthetics of interaction, providing a useful starting point to analyse the perception of ICS materials along physical (size, shape, material) and behavioural (emitting light, emitting sound, vibrating) characteristics. This study identifies seven aesthetics dimensions of tangible interaction, namely pleasant, interesting, comfortable, playful, relaxing, special, and surprising, that are linked to the *affective level* of Materials Experience, and could be useful to describe the emotions elicited by ICS materials.

3.6 Connective Experience

To fully grasp the experience with ICS materials, an additional level that captures the relationship between the materials and their surroundings is needed. Indeed, ICS Materials are able to establish connections with other non-human entities, i.e. the environment or other materials, artefacts and organisms, to transfer and receive data. However, these interactions beyond the human control, are observed and perceived by people, contributing to the materials experience. We name this level as the *connective level*, as an expansion to the current levels of materials experience (Figure 2). It describes the interactive behaviour of materials and addresses the following questions: *"How do materials interact with the environment and other things around them? How do their constituting components interact between them? In which manner and with which behaviour? How can materials mediate between the human and the environment? What are the results?"*. The qualities in this level map criteria such as the speed of action, the regularity or irregularity of actions; the reversibility or irreversibility of mutation; the predictability or unpredictability of actions, the repetition, the autonomy or automatism of action, the modality of transformation and expression, e.g. stratification, reduction, movement, sound, light, etc. Although all these observations are prominent in interactive materials, they may also be applied to materials with a low degree of interactivity, such as ageing materials. The notion of Becoming Materials (Bergstrom, et al., 2010) highlights this dynamic and open feature.

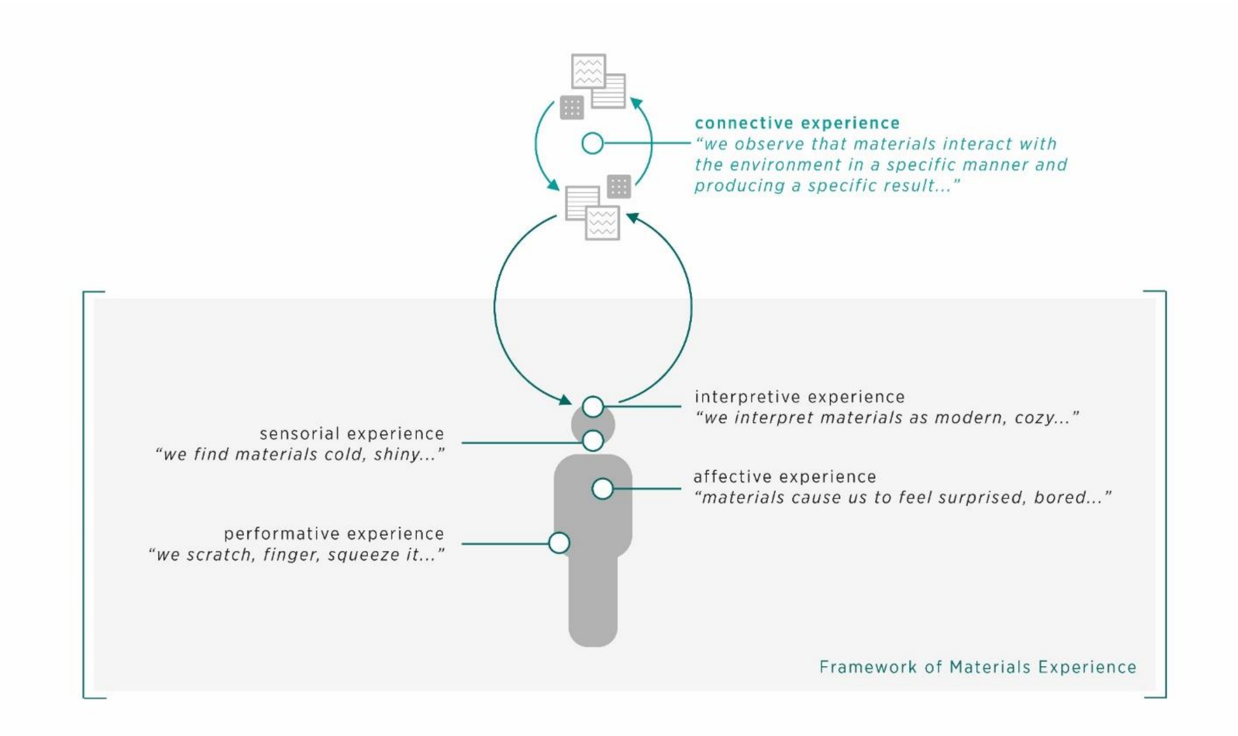

Figure 2. The Materials Experience framework (Karana, et al., 2015; Giaccardi and Karana,2015) enriched with an additional level related to non-human relations, namely the connective level of materials experience.

4 Unfolding qualities of ICS materials

As the proposal of the connective level of materials experience may suggest, with the emergence of ICS Materials, new qualities related to interaction, dynamism, and connectivity are arising and old models to observe and interpret materials become obsolete. Furthermore, the aforementioned diverse models to interpret materials are not mutually exclusive but may overlap. For example, the affective and interpretative levels of materials experience correspond to aesthetic qualities of materials, whilst the sensorial level of materials experience corresponds to expressive-sensorial qualities of materials.

We illustrate the extended framework with four cases of ICS materials going through the levels of materials experience, namely the sensorial level, by referring mainly to the expressive-sensorial characteristics, the affective level, by referring mainly to the aesthetic qualities of interaction, the interpretative level, the performative level, and the connective level here proposed, to address the integration of interactive and smart capabilities of such materials. It is presented as a short description that summarizes the analysis conducted over the selected materials, in form of case study. These four cases of proactive materials have been selected from a collection of 98 examples of interactive materials, gathered in the scope of the research project and analysed to ground the framework. The four selected cases exemplify different ways of materials to be interactive, connected and smart through diverse means, namely electronic, chemical, biological, and mechanical.

Being the Materials Experience mainly based on a subjective interpretation, the analysis reported is based on the personal understanding of the authors that can be considered as an example of self-reflection applied to design. The aim of this analysis is twofold: first, to verify the validity of the framework for this new class of materials; and second, to identify similarities and differences with respect to other classes of materials at diverse levels of the Materials Experience.

Figure 3. DuoSkin by MIT Media Lab and Microsoft Research, 2016. Image used with permission, retrieved by http://duoskin.media.mit.edu.

4.1 DuoSkin

DuoSkin by MIT Media Lab and Microsoft Research is an on-skin interface made of gold metal leaf (Figure 3). It senses touch inputs, displays outputs with the use of thermo-chromic ink, and allows wireless communication (Kao, et al., 2016).

4.1.1 Sensorial level

Made of gold metal leaf, this artefact has a relatively smooth surface with an irregular texture. Because of its nature of thin mono-material surface, it is very lightweight. Its chromatic appearance is based on the natural colours, reflectiveness and glossiness of metals.

4.1.2 Affective level

Being in contact with the wearer's skin in the form of a tattoo, it evokes an intimate and personal feeling. For the same reason, sometimes it might be perceived as intrusive. When it is used as an interface or display, it may be felt as playful and surprising. Being customizable, it elicits a sense of ownership.

4.1.3 Interpretative level

Being similar to a jewellery as an instance of body-decoration, it can evoke a sense of preciousness and luxury, and it is decorative. Due to its digital components, it can be perceived as high-tech. Being customizable by the user, it elicits uniqueness.

4.1.4 Performative level

The user is invited to customize the product by cutting it. As an interface, its sensorial-expressive qualities invite touching, fingering, and interacting.

4.1.5 Connective level

It interacts electronically with a digital device, by providing an immediate input or reproducing a physical output, activating colour changes through the use of a thermo-chromic ink applied to the tattoo surface. In this last case, the interaction is quite fast, but gradual and reversible. It may be also possible to obtain visual patterns for colour changing response, by using different inks and designing circuits.

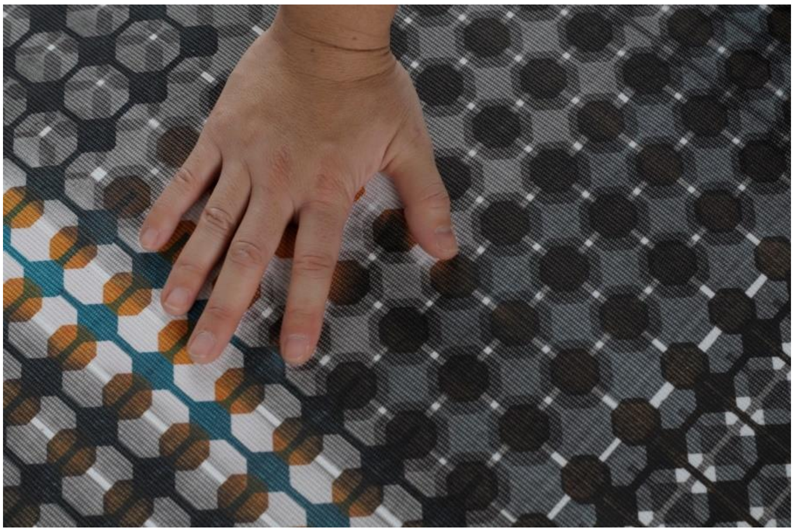

Figure 4. Recurring Patterns Project by Smart Textiles Design Lab at the Swedish School of Textiles, 2011. Image used with permission*, courtesy of Linda Worbin and the Smart Textiles Design Lab at the Swedish School of Textiles.*

4.2 Recurring Patterns project

This project (Figure 4) is a collaboration between the furniture company IRE, Smart Textile Design Lab at the Swedish School of Textile, University of Borås and Smart Textiles prototype factory (Nilsson, et al, 2011). The researchers involved in this project are Linnéa Nilsson, Mika Satomi, Anna Vallgårda, and Linda Worbin. The project explores how to use programmable textile qualities changing in context over time in furniture design. To answer, the prototype of a pouf, a cushioned footstool, was covered with a smart textile that changes expressions in a dynamic interplay with its use. A bright pattern gradually reveals when someone sits on it, and disappears when the user stands up. This is possible thanks to four components of the material: woven cotton with embedded conductive threads; a layered pattern printed with a combination of pigment colour and thermo-chromic ink (with a state of change at 27°C); pressure sensors to detect when someone sits; a computer programmed to control which conductive thread should be activated thus triggering the colouring of the thermo-chromic fabric.

4.2.1 Sensorial level

Made of woven cotton, the surface is warm, soft, and regularly textured. The patter is regular and geometric, and with desaturated and neutral grey colours in its static state. When activated, the conductive threads heat up the surface and let a bright yellow and blue pattern emerges.

4.2.2 Affective level

Thanks to cotton fabric, the material may be felt as relaxing, pleasant and comfortable. Furthermore, woven cotton is a conventional and daily used material, therefore the sofa may elicit a sense of trusting and familiarity. When in action, it may be perceived as surprising, interesting, and even playful.

4.2.3 Interpretative level

Due to the nature of the material, it elicits a sense of ordinary and traditional. Its sensorial qualities may provide a sense of cosiness. At its static state, its neutral colours may evoke sobriety. When the colour changes, it may be interpreted as modern and strange.

4.2.4 Performative level

The shape of the artefact and the sensorial qualities of the material invite to comfortably sit down and caress the surface. When the change of colours occurs, the user may be more focused on observation and visual interaction.

4.2.5 Connective level

In this case, the material interactions and expressions are strictly connected to the user but mediated by a computer. When someone sits down on the pouf, the sensors detect it. A computer then activates the conductive thread that heats up and gradually reveals a bright pattern, thanks to the chemical reactions to heat of the thermo-chromic ink. The pattern gradually disappears when the user stands up. This material can be programmed to obtain other results and qualities of interaction and expression.

Figure 5. BioLogic by MIT Media Lab, 2015. Image owned by MIT Media Lab, retrieved from http://tangible.media.mit.edu/project/biologic/.

4.3 BioLogic fabric

Another example by MIT Media Lab, Tangible Media Group, is BioLogic Fabric (Figure 5), a shape-changing fabric using embedded Bacillus Subtilis Natto bacteria as bio-actuators reacting to moisture. In partnership with New Balance, this material was applied to sportswear, reacting to body sweat, causing heat zones to open, and enabling sweat to evaporate (Yao, et al., 2015).

4.3.1 Sensorial level

Made of synthetic fabric, it is lightweight, flexible and tight. Its surface is textured in a regular way. Its surface is dark, desaturated, and matte. Thermally, its functioning allows to ventilate the skin and to provide a cool sensation.

4.3.2 Affective level

Being in contact with the user's skin in the form of a garment, it evokes an intimate and protective feeling. For the same reason and for the use of bacteria, it might be perceived as intrusive, dangerous and unreliable. When it is shape-changing it may be perceived as surprising or interesting. When it is cooling down the body, the feeling may be pleasant, relaxing, and comfortable.

4.3.3 Interpretative level

Because of its aesthetic and functioning it could be perceived as technical, high-tech, futuristic, and sophisticated.

4.3.4 Performative level

The user wears the material, but it does not have a direct and intentional engagement with its functioning. The performance regards the body heat and the sweat produced by the user in his or her practices, actions and movement.

4.3.5 Connective level

Thanks to the bacteria that are embedded in the fabric, it reacts to humidity causing a shape-changing reaction and allowing a laser-cut texture to open. This action is gradual and proportional to the degree of humidity and heat. It is reversible.

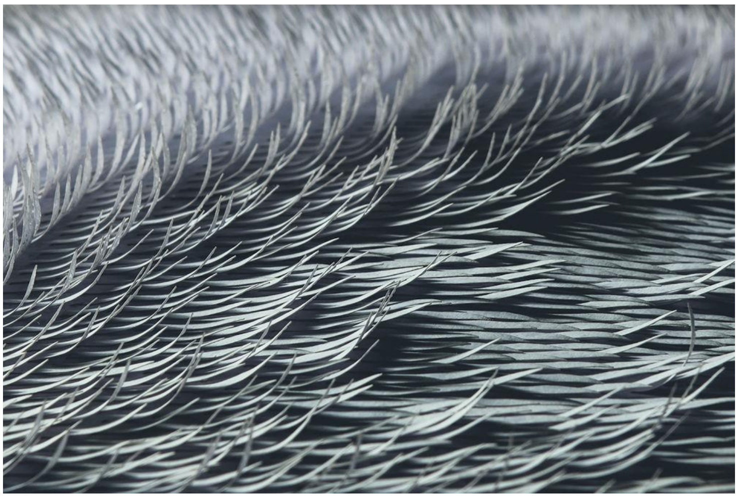

Figure 6. Transformative Paper by Florian Hundt, a result of the cooperation "Intuitive brain" between Prof. Dr.-Ing. Markus Holzbach, Institute for Materialdesign IMD, HfG Offenbach and BMW AG, 2015. Image used with permission, retrieved from http://www.hfg-offenbach.de/en/pages/institute-for-materialdesign-imd#projects.

4.4 Transformative paper

Transformative paper (Figure 6) is a layered structure, which reacts to short-term environmental conditions, morphing into various states. Due to the anisotropic property of moisture expansion of paper, the small segments in which this surface has been designed reacts to humidity by stiffening. Designed by Florian Hundt, this project is a result of the cooperation "Intuitive brain" between Prof. Dr.-Ing. Markus Holzbach, Institute for Materialdesign IMD, HfG Offenbach and BMW AG.

4.4.1 Sensorial level

Made of paper, it is lightweight and porous. The texture in which the surface is segmented could be regular or irregular, providing different shape-changing reactions. The colour is the natural and neutral colour of paper.

4.4.2 Affective level

Being made of a well-known and daily used material, this surface may elicit a sense of trust and familiarity. When in action, it may be perceived as surprising or interesting. Its textured surface may be felt as relaxing, pleasant, and seductive to the eye and touch.

4.4.3 Interpretative level

Due to the nature of the material, it elicits a sense of ordinary, sober, and traditional and nostalgic. When its shape changes, it suggests sophistication and modernity. The qualities of the interaction may evoke a feeling of cosiness.

4.4.4 Performative level

When dry, the surface is very tactile and invites the user to caress and to raise the separate fragments. When the material performs movements the user’s curiosity to observe and touch is stimulated.

4.4.5 Connective level

Exposed to minimal change of moisture, it creates a subtle and almost invisible movement. When it gets wet, it produces a very evident transformation by performing movements. This action is reversible.

5 Discussion and Conclusions

The case studies bring about some preliminary considerations on qualitative patterns that characterize ICS materials. We now outline the peculiarities of this class of materials against traditional ones, according to the five levels of the Materials Experience.

A first reflection regards the three levels of the Materials Experience defined as Sensorial, Affective and Interpretive. What emerges is a substantial similarity between ICS and traditional materials since the novel technological materials analysed are initially perceived as traditional ones (e.g. gold leaf, paper, technical sport-swear…). At a sensorial level the impression is indeed given by the material used as external skin and not modified by its technological augmentation. Similarly, the affective level strongly depends on the previous experience of users with the material constituting the skin of a product, despite the un/expected behaviour could add a sense of surprise. Similar considerations can be drawn for the interpretive level: in static conditions the materials do not differ from traditional ones, but they may trigger different interpretations while acting the programmed behaviour.

It is evident in all the case studies that, compared with traditional materials, the qualities of ICS materials are dynamic, usually reversible, and ever-changing in reaction to different stimuli. In other words, ICS materials are never the same, modifying their qualities over time: they are qualities *to become* (Bergstrom, et al. 2010). The evident difficulty to describe ICS materials qualities in their continuous modification shows the limits of the three aforementioned categories of the Materials Experience. Tools and models to analyse, describe, and characterize these materials, as the Sensorial-Expressive Atlas (Rognoli, 2010), the framework of Materials Experience (Giaccardi and Karana, 2015), and the Meanings of Materials tool (Karana and Hekkert, 2010) seem indeed in need to be reframed and redesigned to fit these dynamic and ever-changing experiences, considering materials and their sensorial, affective, interpretative, performative, and connective relations also by a temporal perspective. Moreover, interactions and responses, that might be programmed in advance by the designer, should be considered in the expressive-sensorial and experiential characterization, as features of the material. Looking at ICS materials through the lens of the performative level, their dynamic behaviour emerges to an even greater degree, since the interaction they trigger in the user is strongly dependent on their actual state. In this sense the connective level, namely what happens out of user's control, acquires a predominant role, influencing the other four levels.

Furthermore, it must be noted that in the analysed cases arises a tension between the sensorial and emotional comfort and solace, and the possible feeling of intrusion and not confidence provoked by the means of interaction, either digital and biological. Sometimes this tension is even stressed by the contrast between a high-tech and futuristic behaviour of materials, and a familiar and traditional feeling due to the use of conventional materials in their natural and more iconic appearance, such as paper and gold leaf. This behaviour usually is unexpected and is a reason of surprise and interest for the user. Because of this behaviour, intentional tactile interaction between the user and the material become limited to make room for the observation of materials activity through non-human relation with the environment and other entities, and with the users' body.

These results show that ICS materials are extremely flexible in providing countless qualities pertaining the Materials Experience at its five levels. In doing so, they could potentially allow designers to modify the properties of the materials according to the functional, aesthetic and sensorial aims they intend to embed in the final product. In other words, designers can become the programmers (Vallgårda, et al., 2016) of the qualities of materials, both in terms of functionality and aesthetic at large, overturning the role of designers in respect to materials. The materials are not chosen anymore for their properties but are programmed, modified, crafted to respond to specific needs or situations. The design contribution acquires therefore a relevant role as it happens for the so-called metamaterials, whose technical characteristics are given by the shape, rather than the material itself. Similar reflections about programmability could be done regarding the final users of products that integrate ICS materials: as a matter of fact, their programmability could be also delegated to the user.

Beyond the foreseen programming capabilities of ICS materials, their characteristics of being Interactive, Connected and Smart offer relevant opportunities in terms of tangible interaction. The materials themselves can become the product interface or components of interface to interact with a computing or information processing systems (Kretzer, Minuto, & Nijholt, 2013; Minuto, et al., 2011) in a vision that opens great opportunities and new paradigms for product and interaction designers, that could act on different levels of the design project at the same time. The product interface, while fulfilling a technical role (e.g. the shell of a household appliance), could also be programmed to have defined aesthetic qualities, acting as switch or feedback system. To these, we could also add a certain level of programmability on the users' side, providing a dynamic and customizable experience.

This extreme flexibility and programmability makes even clearer the complexity connected to the design of/with ICS Materials and the inadequacy of analytical tools such as the Materials Experience framework in supporting designers in the definition of expressive-sensorial, aesthetic and experiential qualities of the materials. Consequently, the primary results seem to suggest the need of a new analytical tool able to frame the complexity of ICS Materials. Nevertheless, to validate these initial results, a more in-depth analysis on other examples of ICS materials gathered in the research is needed.

Which tools and methods can help to analyse, describe, and characterize the qualities of these materials? How can designers program ICS materials and thus to control the final qualities of a product? How can users modify the qualities of a product acting directly on its constituting materials? What opportunities do ICS materials open in terms of design innovation? These are focal questions to be addressed in the prosecution of the research.

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Visual Materiality: crafting a new viscosity

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A re-materialisation of the visual in terms of viscosity is provided by this article. The argument is grounded in practical design processes from on-going research in the integration of archival material into AR/MR environments (Augmented Reality and Mixed Reality). This is an approach to emergent materiality not because new materials are invented but because existing visual, digital and traditional craft materials are re-configured. The archival material we use for this project is visual rather than textual, and it portrays moving bodies. The re-materialisation happens through experimentation with materials, affect and perception. Visual materialities, in this case viscosity, rely on a phenomenological approach to vision whereby design materials cannot be separated from the active perception of the designers, the participants and even the materials themselves. This article outlines the final iteration of the *AffeXity* project where glass was used as a design material to enhance viscous materiality. Viscosity is experienced as depth, layers, stickiness, reflections, motion, and an affective quality of dreaminess or the passage of time.

visual materiality, viscosity, glass, phenomenology, Augmented & Mixed Reality

1 Introduction

This article offers a particular glimpse of research processes centred on the creative integration of archival material into mobile Augmented Reality and Mixed Reality environments (AR/MR).[1] Part of the research program of the Living Archives research project at Malmö University in Sweden, the intent is not simply to present archival material in digital form but to call attention to performative practices of archiving.[2]

[1] The concepts Augmented and Mixed Reality are sometimes used interchangeably. However, in this paper, we follow the understanding of Mixed Reality as the overarching concept in which Augmented Reality technologies are understood in the context of other technologies (Billinghurst, Clark & Lee, 2014). Augmented Reality, most often understood as a way to “enhance reality with digital content in a non-immersive way” (Billinghurst, Clark & Lee, 2014: 79), is used to refer to specific software in this paper.

[2] http://livingarchives.mau.se

The goal is to open up visual archival material for an encounter with images that has a greater ability to afford perceptual depth and affective engagement. The material qualities to arise through our experimentation with AR/MR can be grouped under the term *viscosity*. This counts as an emergent material experience not because a new material is invented but because a careful re-configuration of existing design materials can produce a different qualitative experience. Viscosity has haptic, visual and affective qualities. In terms of touch, the texture can be glutinous; visually it exhibits distortion or a play between opacity and transparency; and affectively (where affect is seen to be a convergence between the emotional, pre-reflective, embodied and perceptual (Stewart 2007, Barthes 2005, Kozel 2012) it can be both enticing and disconcerting. Glass acts as a visual lens but also a catalyst for memory and imagination - this makes it powerful for designing ways to open out archival material.

Viscosity is an evocative term that might seem to be a metaphor, but it is a description of perceptual experience and reflects aesthetic choices that were implemented in the design process. Viscosity has a presence in a range of design disciplines, it can refer to how information, interaction, and communication can flow more smoothly across devices (Olsen 2008); or to the cognitive perception of effort in relation to workflow goals (Poelmans 1999), or in computer graphics, it refers to the simulation of highly viscous fluids (Kawabe & Nishida 2016). These uses of the term are not analogous with ours, however research into viscosity in computer graphics does open a range of characteristics that resonate with our sense of viscosity from a phenomenological perspective. Temporality, density, and pressure (Peer et al, 2015) are felt in the MR experience, particularly given that the archival material we use is film and video footage of dancing or moving bodies, and elasticity has a stretchy quality that is textural, temporal and spatial (Kawabe & Nishida, 2016).

This paper is structured around four sections. In the first section the phenomenology of perception as it is relevant to our consideration of visual materialities is grounded in Maurice Merleau-Ponty's reflections on the perceptual experience of the painter and Tim Ingold's reminder that the material world participates in the sentient process. In the second section an overview of the *AffeXity* project is provided with emphasis on visual strategies for using AR/MR to open archival material (Kozel 2012, Kozel et al, 2014, Engberg et al 2017). The focus of this paper is a recent design iteration of *AffeXity* that experiments with the use of hand crafted glass to provide an added layer of viscosity to the experience. In the third section the design process for creating the glass is described: the *how*, the *what* and the *why* of glass in relation to viscosity. The final section is a technical perspective on vision: how the camera and AR/MR code see, in particular what happened when we introduced 3D glass objects into the visual field.

2 Visual Perception

A phenomenology of perception is key to understanding viscosity as a visual material. For this we will rely on Maurice Merleau-Ponty's philosophical thought on the sensing of lived experience, in particular how vision works in the artistic encounter between the eye and the world. Unlike other applications of Merleau-Ponty in HCI which rely on *The Phenomenology of Perception* from 1942 (Giaccardi & Karana 2015, Svanæs, 2013), we draw on his later work, "Eye and Mind" the last work he published before he died in 1961 and *The Visible and the Invisible* incomplete at his death, where he complexified his own account of visual perception by relying less on on proprioceptive and anatomical examples and more on artistic and poetic ones (Ingold 2011, Kozel 2007). The reversible and "chiasmic" approach to visual and haptic perception from his later work is more appropriate for understanding the play of viscous materiality when designing the visual layers of Mixed Reality experiences, and for explaining how both the visual sensibilities of the human and the digital camera coincide in our process (Merleau-Ponty 1987, pp.130-155).

Merleau-Ponty's existential phenomenological approach acknowledges and even celebrates the opacity of the world, without trying to tidy up, instrumentalise, or regulate it. The body at the centre of the lived experience is not that of "an information machine", it is embedded in the world and implicitly tied to other beings, “the others who haunt me and whom I haunt” (Merleau-Ponty, 1985, pp. 160-161). Writing the essay “Eye and Mind” (with the original French title “L’Œil et l’Esprit”) on art in the early 1960s he was still operating with the model of mid-century humanism, but his deep reflections on vision evoked a sort of animism, a vitality of the natural world, objects, and other beings in it, so that the primacy of the human being gave way to “the primacy of perception,” and the ability to perceive was shared by animate and inanimate substances alike. The mountain looked back at Cézanne as he painted. It writhed and heaved. If there was a fundamental category for perception, it was that of movement.

In terms of crafting an approach to visual materiality, a phenomenological approach means that materiality cannot be considered separately from vision and touch: from the body in the very process of seeing and touching, and of being seen and touched. This implies that as designers we do not consider the visual externally as a property of the object or separate from the processes of seeing. Visual materiality is created by the way we see the material and the way the material and the devices look back at us. Materiality is not separable from the body, and the body is “an intertwining of vision and movement” (Merleau-Ponty, 1985, p. 162). Further, touch is not just the domain of the hand, vision not just performed by eyes. What Merleau-Ponty learns from the painter is that vision is “voracious,” inducing “delirium,” and the body is implicated in the world: in fact, the body is able to see precisely because it moves about in the world. Vision is never total, it is always a play between what is seen and what is not seen, touched and not touched, between the visible and the invisible; and touch is not constrained to the haptic, we touch and are touched through resonance, radiation and vibration (Nancy, 2007). With relevance to the play of layers possible with careful crafting of Mixed Reality, the essence of the visual is to have “a layer” of invisibility (Merleau-Ponty, 1985, p. 187). This partial quality of what and how we see means that we are constantly building a visual sense of the world at the same time as the picture changes and certainty is lost. “Vision is not a certain mode of thought or presence to self; it is the means given me for being absent from myself” (Merleau-Ponty, 1985, p. 186). Full transparency is impossible, just as complete archival documentation of the past is impossible.

More than just saying that perception is uncertain or unstable, a close reading of Merleau-Ponty such as that provided by social anthropologist Tim Ingold emphasises how what we see also has a sort of sentient being. There is a deep entwinement between the world and those beings who inhabit the world. The world looks back at us. When he writes that the world does not just expose “only its rigid, external surfaces to perceptual scrutiny” (Ingold, 2011, p. 12), it is possible to take inspiration for how a re-configuration of materials including AR/MR on mobile devices might escape the dominance of the flat cold surface of the screen. If each body is “irrevocably stitched into the fabric of the world, our perception of the world is no more, and no less, than the world’s perception of itself - in and through us” (Ingold, 2011, p. 12). To be sentient is to open up to a world, “to yield to its embrace” (Ingold, 2011, p.12), and to enhance the viscosity of the perception is to let oneself plunge into the visual field as if it were liquid, or to rebound, stroke it, or move through it. Designing for visual materiality in the phenomenological sense is designing for bodily resonance, not just for the eyes.

The “delirium which is vision” in Merleau-Ponty’s words (Merleau-Ponty, 1985, p. 166) can be seen as the magic of “opening one’s eyes upon a world in formation” and more than that, at seeing the world in formation *because of* and *through* our vision (Ingold, 2011, p. 128). This captures the essence of emergence in visual materiality. A deepened account of Merleau-Ponty opens for the designer for an expanded visual approach in the design process as well as his or her own visual perception in the design process. This deepened understanding of the phenomenology of perception in design will only increase in relevance as the development and proliferation of AR and MR technologies increase in coming years.

3 AffeXity

3.1 *AffeXity: Passages & Tunnels (2013)*

AffeXity is a Mixed Reality project that integrates dance and video experimentation with AR browsers running on mobile devices in urban spaces. The first iteration was shown in 2013 as part of the Re:New Festival in Copenhagen. Called *AffeXity: Passages & Tunnels* the goal was to use AR in conjunction with archival material in such a way as to create a sense of travel through time, or at least to a different space of memory and imagination.[3] The freely available AR application Aurasma was used to create a layered and performative engagement with archival material. The archival material was from dance, film and artist archives: film and video of bodies & objects moving in time and space is a category of archival material that is difficult to display in 2D static forms, and is often accessed through computer screens or in solitary viewing modes. We experimented with opening possible performative modes for encountering the material (Kozel et al 2014).

We modified the usual QR code triggers for launching the AR media by replacing them with still frames from the video footage of various sizes to launch short video loops. These images were attached to the outside of the Nikolai Contemporary Art Gallery in central Copenhagen. We called these images "tags" and some were quite large. They were tucked into the gothic elements of the architecture and helped to promote a thick affective quality for the performances and guided tours – most of which happened at night (figures 1 and 2).

Figure 1 A view of AffeXity: Passages and Tunnels being performed at night. Source: Jeannette Ginslov

[3] The research team for *AffeXity: Passages & Tunnels* (2013) included Susan Kozel (artistic direction & concept), Jeannette Ginslov (visuals & concept), Wubkje Kuindersma (dance), Oliver Starpov (dance), Camilla Ryd (image processing & interaction design), Jacek Smolicki (images & sound), Daniel Spikol (technical direction).

Figure 2 A view of an AffeXity target image placed on the building. Source: Jacek Smolicki

Our visual aesthetic for layering media was to play with the opacity of the video (making it semi-transparent). This feature allowed the video to be suspended in the device at the same time as the camera functioned, without blocking or replacing the camera feed. Through the video the tag image could be seen, and the space in between tag and video was also seen. This activation of the space between tag and device remains a key design component of *AffeXity* (Rouse & Barba, 2017). In the *Passages & Tunnels* iteration it became a performance space and enhanced the architecture and spatial elements, in the next iteration it is the location of glass layers and contributes to the visual materiality of viscosity.

3.2 AffeXity:Glass (2017)

The interest in glass emerged several years after the first showing with the desire to tour *AffeXity: Passages and Tunnels* to different locations. As this work is embedded in a long-term research project on archiving, with an interest in the GLAM (Galleries, Libraries, Archives and Museums) and cultural heritage sectors, we considered transforming the *AffeXity* approach to visual materiality into something that could be useful for galleries or museums for showing their visual archival material. There were two significant material developments for this second iteration: 1) shift of AR platforms from Aurasma to Argon; and 2) the introduction of glass as a material for the tags.[4]

Why glass? The idea of inserting a glass layer or object over the flat visual tag was based on the desire to escape the seeming 'flatness' of the 2D image that was used to trigger the media in the first version of *AffeXity.* For this first performance prototype, we had the advantage of embedding the 'tags' of various sizes into the crevices and nooks of the gothic architecture of the Nikolai building. The old brick walls and small arches made the tags seem less flat, producing an almost holographic effect.[5] However, once the work was removed from this specific site we could not reconcile the aesthetic qualities of the MR experience with producing simply flat tags – like photographs or posters. The quality of time-travel or passages would be lost. Glass seemed like a beautiful and evocative way to introduce a layer of density to the space between the tag and the

[4] The 2017 research iteration of AffeXity called AffeXity:Glass was by Susan Kozel (concept), Jeannette Ginslov (visuals), Maria Engberg (Mixed Reality design), Henrik Svarrer Larsen (glass design) and Colin Freeman (camera vision). See http://livingarchives.mah.se

[5] https://youtu.be/41gB7exGZGo

device that could be reduced in size and more able to tour. It also might be a way for museums or galleries to present material in fairly contained spaces with controlled lighting.

In this second iteration, the re-configuration of design materials was our focus: video, still image, mobile device, AR browser, glass and perception. The glass was intended to be experienced both directly and through the layers of visual media. Once interposed between the image and the device, the glass seemed less hard and more gelatinous, fluid or flexible. It had a sort of viscosity when layered with the opaque moving imagery.

4 Using Glass

4.1 The design process

From the perspective of the glass maker, "hot" hand-formed glass is made through the craft of glassblowing, allowing for an intimate engagement with the material as the molten glass is shaped. Paradoxically, glass in its cold form is still a liquid, a "still" liquid. The spectrum of variance in viscosity of different glass batches is what defines them as a malleable material to a blower. For *AffeXity:Glass* the optical qualities of the glass were the focus, given that the glass was combined with the trigger image for the Argon AR browser and had to work with the visual recognition software (more on this below). We limited our explorations to solid glass in rather generic shapes either clear or white with varying opacity; some with inserted bubbles or sand to give inner and outer texture (figure 3). While the shapes were constrained to basic circles, spheres, triangles and rectangles, the making involved was manifold as hand-forming included shaping solids and indenting castings, incorporating bubbles, sand, coloured patches, as well as some glass cutting (figure 4 and 5).

Figure 3 The glass objects that were made. Source: the authors

Figure 4 Shaping of glass. Source: Mads Hobye

Figure 5 Additional glass shaping to add layered qualities. Source: Mads Hobye

Figure 6 A viscous image: shaped glass with a "swoop" and a tracking image underneath. Sources: dancer: Oliver Starpov, still from video: Jeannette Ginslov, photo: the authors.

Some of the glass shapes were made to enhance visual qualities of the images acting as triggers for AR – in particular the ‘swoop’ in the glass shape that was used with one of Oliver Starpov’s dance solos (figure 5 and 6). Other glass textures more abstractly echoed the visual qualities of the movement in the video: the rounded shape picked up on the curve of the archway while the bubbles embedded in the shape added qualities to the layers of media – a watery quality the evoked time or submersion in memory (figure 7). And finally, some shapes were speculations of what might contribute to a viscous experience, emphasising the phenomenological sense of the objects being sentient, inviting us to plunge into the combination of glass and archival material, to swim in it and have it rebound on us, surprise or captivate us.

Figure 7 A round glass shape with bubbles and a tracking image underneath. Sources: dancer: Wubkje Kuindersma, still from video: Jeannette Ginslov, photo: the authors

In the digital realm, glass and glass coatings have been used in interactive products but so far primarily on flat glass (Transparent Intelligence 2017). Until recently, there have been very few efforts with three-dimensional glass, and these have focused mainly on embedding technology within the glass (Dynamic Transparencies, 2017; Olofsson, 2017; Contemporary Glass Society, 2017). Our work speaks to some of these efforts on interactive glass, yet is distinct by drawing the three-dimensionality of glass into visual digital media. *AffeXity:Glass* incorporates the temporal spectra of the moving media in the AR-application and the functions of perception and memory in the person who experiences the designs. The design interest in the layered material is not the duality of seeing an object (picture and/or glass) on its own and then seeing it on the screen overlaid with videos of dancers, but rather in the interplay between image, glass and media, closely related to small movements of the camera and its holder. These micro hand movements of the person holding the camera can include deliberate adjustments to see better or to choose different viewing angles for the 3D glass objects, but they are equally the involuntary trembles of hands and arms, and the negotiation of physical space shared with other bodies who may be using their device to access the media in close proximity. It is possible to focus on the glass placed on the photographic tags or glass with the image embedded within it as a viscous image (see figure 6), however with the *AffeXity:Glass* design research, viscosity refers to the entire material experience, including devices, people, tags and media.

4.2 *Cultural reflections*

The insertion of glass into our process provoked and inspired our design process, revealing how a material can have both significant cultural and embodied reactions. The obvious initial reactions were sensory and tactile, but also related to our imagination, childhood memories and cultural connections to the glass objects, despite their comparatively neutral shapes. Curiously, our reactions were often negative, in the sense that cultural or personal resonances arose that were not welcome: we did not want them to interfere with our aesthetic and design decisions. Various members of the design team reacted against the glass looking like ubiquitous flat screen displays, Christmas Tree baubles, candle holders, or paperweights. The more we worked with glass, the more glass we saw around us or remembered from past histories.

We wanted to design in such a way as to avoid these associations, then we realised that this was impossible or undesirable. Why design with the desire to be a-cultural, particularly when working in a culture traditionally known for working with glass? The cultural references are unavoidable, a colleague said, so work with them. Another colleague immediately and viscerally said "I hate glass" and did not want to hear anything further about the project. Most people responded to the seductive quality of glass, with imaginative and personal resonances from childhood arising in a favourable light. We found ourselves, while working with the glass prototypes, wanting to touch or stroke them. Our glass maker warned, but too late, that one piece had sharp edges: one of us cut a finger and the dried blood stayed on the piece for some time. This array of unexpected cultural and personal affective resonances around glass almost derailed our process. In particular, *Google Glass* became a counterpoint for us – meaning it is an opposite use of AR, both experientially and in the consumer market – provoking the ironic reference to our work as *AffeXity:Glass*, a working title that somehow stuck.

The push of cultural resonances and the pull of affect impacted the design process. The vocabulary used to describe stages of the process and reactions to what came out reflects a range of phenomenological reactions: yearning, allure, seduction, repulsion, desire to touch, hold, handle, wanting to feel the temperature and how it would fit in one's hand. Almost ephemeral: seeing through it, seeing into, suspension, reflection, refraction, distortion. We followed the lead of our glass designer who advised that it is more a question of being aware of which culturally coded symbols one incorporates, depending on whether these are helpful or not, for the design intentions. Two guiding forces in particular stood out, one phenomenological and one cultural: viscosity and *Google Glass*. Viscosity accounts for the pull toward the dreamlike quality glass added to the mix of images and video, evoking a play between imagination and memory, making it appropriate for dealing with archival material. *Google Glass* was an opposite configuration in terms of embodiment, media display, materials and market segment. Contradistinction became a mode of cultural critique and a force for design decisions.

5 Materiality in AR/MR Mobile Media

Already in *AffeXity: Passages & Tunnels*, Augmented Reality software for mobile phones was used. This particular class of software combines the abilities of AR (to combine real and virtual content, to provide interactive content, and to correctly register that content in a 3D space) with the mobility and ease of access and use that mobile phones provide. Another way to understand the affordances of AR/MR systems is in terms of location and image recognition. The former uses the mobile phone's ability to correctly register the device's coordinates, spatial orientation and movement. The latter uses the mobile phone's camera and computer graphics abilities to display and recognize visual elements. Generally, the goal of an AR/MR system was primarily to "draw the world" on the screen accurately and to add virtual content meant primarily for the user's eye.[6] More recently with the

[6] AR/MR systems have been primarily defined as concerned with visual virtual content, whether 2D or 3D. However, AR/MR technologies are also used to provide audio or haptic experiences (Billinghurst et al 2014).

increasing computing power, network stability and computer graphics capabilities of mobile phones, these AR/MR applications are capable not only of directing that computational gaze outward in order to display visual content on the screen, but they can also perceive and sense the world around the device. An AR/MR system can now approximate the physical properties of its surroundings: what surfaces, edges and dimensions it should take into account as it maps out its immediate context via the camera. These later developments in terms of visual sensing and perception are crucial for the purposes of this work as we view the digital dimensions of the project as involving a camera that *perceives*.

AR/MR exist in different configurations of hardware and software packages, and as described above, our project focused on the mobile phone as the device. We have tested different software packages and applications. Aurasma was used in the 2013 version of the project. The constraints of Aurasma allowed us to work within a framework that provided a set of interaction models and aesthetic possibilities. However, using this free application required loading our content onto the company's servers. In addition, Aurasma was sold to HP during our design discussions leading to the 2017 version. The decision was made to start working with an open source JavaScript framework for web-based AR/MR developed at the Augmented Environments Lab at Georgia Institute of Technology, called argon.js, which in turn functions with the Argon AR-enabled web browser for mobile phones (Speignier et al 2015). The Argon browser allows for computer vision tracking of images and objects, using the Vuforia AR software development kit (SDK) for Android and iOS. Vuforia offers image recognition and sensing, or tracking, capabilities for both flat images as well as more complex objects. In the context of flat images, the SDK detects and tracks features that are naturally found in the image itself by comparing these natural features against a target resource database that is set up by developers. It was at this stage of setting up a target resource database that could contain the 2D images used in 2013 as well as the layered three-dimensional objects that we had in mind for *AffeXity* in 2017.

5.1 Glass and image recognition software

The visual materiality of viscosity arose in the iteration of *AffeXity* in which we introduced glass. Aiming at producing a layered materiality that included the original 2D images and an object that could provide us with a three-dimensional, tactile object that could be displayed in an exhibition context. Glass and its perceptual affordances soon emerged as central: the glass objects, the digital cameras and the specific image capturing and sensing capabilities that they have, and finally, the screens themselves that constitute the visual membrane through which the user would encounter the video material being displayed.

The main aim of the design workshops integrating glass and AR was therefore to apprehend how Vuforia could sense the glass objects, alone or in combination with the previously used Aurasma tag images. In brief, we were attempting to turn glass objects into image recognition targets for augmented reality. We used the Vuforia SDK separately to test the feasibility of using the Argon app. Vuforia's 3D detection is called object targets. These are digital representations of the features and geometry of a physical object. There are a number of ways of constructing a 3D model of an object, ranging from more expensive 3D scanners using laser or other light sensing, to scanning software that use mobile phones' camera to detect the contours of an object. Initially, we used the Android application Vuforia Object Scanner,[7] to scan the objects by moving around them and recording different viewpoints. These attempts were made by placing the glass objects onto various white, black, and grey matte surfaces (primarily using textiles) and attempting to control the light so as not to create shadows and reflections. As part of this work with understanding the combination of

[7] https://library.vuforia.com/articles/Training/Vuforia-Object-Scanner-Users-Guide The Object Scanner uses a set object scanning target image upon which the object is placed. The mobile phone camera app then captures the contours and features of that object. However, and crucially, an object whose surfaces are shiny, give off reflections, or disturb the sensing process will not render a proper scan.

materials that we were working with, we handled the objects, taking regular photos to understand the difference between what we could apprehend with our vision and what the camera saw (see figure 8).

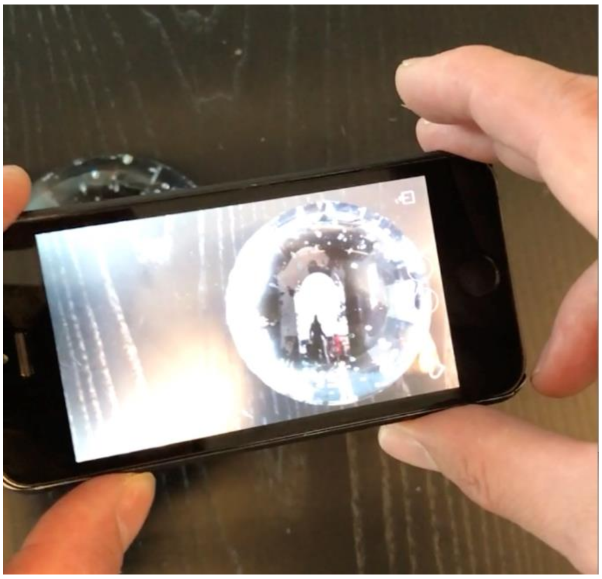

Figure 8 Scanning the shaped glass and the tracking image starts the video content with some of the glass objects. Sources: dancer: Wubkje Kuindersma, still from video: Jeannette Ginslov, and photo: the authors (from a video: https://vimeo.com/242722532)

Our initial attempts to capture our glass objects with the Vuforia Object Scanner app or with a digital camera (images that could then be recombined into a 3D model) did not work. Our assumption was that they did not register as AR tags for on one or more reasons:

- Poor lighting on the objects.
- Transparency and refraction creating false tracking points.
- The handheld scanning caused distortions in the scan.
- A combination of the above problems.

The next step in our process of sensing the glass objects as digital 3D objects was to further seek to control the environment of movement and light on the objects as well as the immediate environment by introducing various elements such as a revolving tray that would allow us to rotate the glass object evenly. This set of attempts to use the Vuforia Object Scanner app was made in a studio space with professional light setups and a lighting tent to limit reflections and refractions. The more controlled setting did allow us to scan some of the objects: particularly the ones with clear features such as opaque bubbles or surface details. These scans worked as recognition objects for Vuforia while still in the studio lighting but failed when we tried to use them in different lighting conditions. From this, we concluded that the transparency and refraction present in the glass objects would not work as a 3D target for Vuforia in a non-controlled setting. To confirm that the process would work for opaque objects we scanned an opaque object and the image recognition with a 3D digital object as the trigger worked in Vuforia under different lighting conditions.

Another phase of the prototype workshops involved placing the existing AffeXity images that were used as tags in Aurasma under the glass to create a layered object (or a viscous image). Although looking at the image and glass together with the naked eye produced aesthetic effects that intrigued us, the digital camera saw something else as the glass distorted the image differently at various angles, thus rendering the image recognition process difficult to control. This illustrates the basic phenomenological point that objects in the world, as sentient beings, also have dynamic perceptual processes.

Already at the outset, we knew from previous experience with 3D capture that glass with its refractions, dispersions and reflections would present a challenge for Vuforia's object recognition code--alone or in combination with the *AffeXity* trigger images already used in the 2013 version. However, the allure of experimenting with the layers of glass and their inherent visual and material qualities was important for the project. The contribution of the research proved at this stage to be a rematerialisation of the visual in the context of AR/MR as a sort of viscosity, supported by the phenomenological perspectives of not just the users but the designers and the devices themselves.

6 Conclusion

In current critical discourse the visual has been abandoned too quickly in a turn towards materiality. All the while computer technologies, particularly mobile phones, rely on and expand what visuality means. Our lives are saturated with visual media, much of which is empowered by computational abilities and circulated through social media. This is not likely to change in the near future. This paper focused on engaging with phenomenological and computational visuality using mobile AR/MR technologies to attain a deeper understanding of how the visual can be designed as part of a complex and re-configurable materiality. The haptic and performative are not excluded from this emergent materiality, rather there is a need to understand and design for what we call a viscous materiality based on a phenomenology of visual experience.

This research challenged the current affordances of AR/MR and the current models of interaction and aesthetic of AR/MR applications. The specific case of using archival material for tags and virtual content shown in the device revealed the need to design for the affective qualities of personal and cultural memory, as well as designing for the cultural heritage locations where this material would be open for public interaction. There is, however, wider relevance to this research. Augmented and Mixed Reality applications are growing in significance to designers and the general public, as many consumer and professional products and services implement layered, networked and mobile apps into their existing business models. The general contribution of this paper points to the need for designers to expand their material and perceptual registers to include the sensory and affective qualities of viscosity, and a deeper understanding of the phenomenology of material experience.

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Textile Waste and Haptic Feedback for Wearable Robotics

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Recent textile innovations have significantly transformed both the material structures of fibers and fabrics as well as their sphere of use and applications. At the same time, new recycling concepts and methods to re-use textile waste are rapidly being developed and many new ways to make use of recycled and reclaimed fibers have already been found. In this paper, we describe how the development of a new textile, making use of recycled fibers, sparked the development of *Textile Reflexes*, a robotic textile that can change shape. This paper elaborates on the development of the new textile material, the multidisciplinary approach we take to advance it towards a robotic textile and our first endeavours to implement it in a health & wellbeing context. *Textile Reflexes* was applied in a vest that supports posture correction and training that was evaluated in a user study. In this way, the paper demonstrates a material and product design study that bridges disciplines and that links to both environmental and social change.

sustainable textile, haptic feedback, posture training, wearable robotics

1 Introduction

This research is built on three convergent technological, material and social trends: a) the increased proliferation of smart and electronics textiles in clothing and industry; b) the growing urgency to build more sustainable materials and production cycles for fashion and electronics; and c) the current interest in health and wellbeing via wearable sensors, devices and body-based training applications.

While we consider these three axes of innovation: technological; environmental; and human to be positive contributions to the design of the built and social landscape, we ascertain that a limited body of research on the intersection of these fields and their combined, and potentially contradictory impacts has been put forward. This paper aims to outline current research in the field of smart fabrics, sustainable materials and design, and health / wellbeing wearable devices. We propose a possible design solution via a case study of the Posture Awareness Vest (PAV) that integrates the *Textile Reflexes* fabric.

1.1 Textile Innovation & Sustainability in Fashion

Recent innovation in fibres and textiles have significantly transformed both their material structures as well as their sphere of use and applications in various industries from fashion, to architecture and industrial products (Braddock Clarke and O'Mahony, 1999; 2005; McQuaid, 2005; Peters, 2011; Quinn, 2010). Specifically, smart textiles and fibres are increasingly engineered with the integration of electronic circuits and sensors, which combine hybrid materials such as metals, plastics as well as chemical and biological coatings and substrates that substantially complexify the material composition of fibres and textiles. However, fashion, and apparel design is increasingly looking to innovation in textiles to differentiate its product value and uniqueness, as well as expand its functionality, life cycles, quality or costs. Notably sportswear has been developing high performance textiles to enhance performance, comfort and mobility for sports (O'Mahony and Braddock, 2002; Watkins and Dunne, 2015). In fashion, new forms of expressions stemming from the integration of electronics, 3D printing and kinetic systems is re-mapping the future of design and personal expression (Braddock Clarke and Harris, 2012; Genova and Moriwaki, 2016; Lee, 2005). Increasingly, fashion designers are looking to develop custom and unique textiles to create bespoke collections; design new consumer experiences and styles; as well as innovating with materials (Kettley, 2016; Pailes-Friedman, 2016; Schneiderman, 2016). The craft and DIY community has also been a strong proponent in teaching, supporting and facilitating the development of skills to experiment in hybrid material production that includes the integration of electronics in textiles (e-textiles) and the use of off-the-shelf electronics such as Arduino's electronic components such as Lilypad designed for e-textile crafting or desktop 3D printers for bespoke apparel and accessories (Ayala-Garcia and Rognoli, 2007; Buechley, 2013; Buechley and Perner-Wilson, 2012; Hartman, 2014).
However, current fashion production represents the second most polluting industry in the world, making sustainability an urgent concern for the industries of fashion design, apparel fabrication and textiles (Sweeny, 2015). Over the past ten years there has been a growing interest and concern in creating a more sustainable fashion industry, and as a consequence more sustainable, reusable and low-environment impact textiles. Fashion and textile design schools, private companies and designers are increasingly turning towards sustainable and recyclable materials and smaller or on-demand production chains to lower current carbon footprints related to the fashion industry and minimize its impact on the environment (Nidumolu et al., 2009). Sustainability in fashion is both a growing concern as well as a political engagement to produce better materials, products, and relationships with consumers and ameliorate the health of the planet and residents (Black, 2008; 2013; Brown, 2010; Caniato et al., 2012; Fletcher, 2008; Fletcher and Grose, 2011; Gardetti and Torres, 2013; Gwilt and Rissanen, 2011; Hethorn and Ulasewicz, 2008; Minney, 2012; Teunissen and Brand, 2013).

1.2 Pathways to Developing Sustainability in Innovative Textiles

While smart and connected textiles trace a pathway to new uses and applications for fabrics and fashion they also present new challenges for sustainability (Köhler, 2013; Köhler et al., 2013; Köhler et al., 2011). One of the key challenges in creating sustainable textiles of smart wear applications is the use of metals in textiles and the "possible end-of-life implications of textile-integrated electronic waste" (Köhler et al., 2011: 496). Not only is the separation and procession of hybrid materials complex, there is an added probability of metals and other electronic materials contaminating textiles and fibres. We know already that electronic waste (e-waste) poses an important problem and risk to the environment (Hilty, 2005; Kräuchi et al., 2005; Schluep et al., 2009; Widmer et al., 2005). Furthermore, many of the materials used to create conductivity and enhance the material function of fibres and fabrics are prone to leaching into water supplies when washed and thus polluting them with heavy metals that are difficult to filter (Köhler, 2013; Köhler et al., 2011). In light of these above points in regards to recycling an impact of use on the environment, it is worthwhile building an environmentally aware design strategy for smart fabrics and e-textiles that can effectively curb the harmful effects of the materials used, and provide conscientious methods for end-of-life use and recycling. It is these concerns that we aim to address and render transparent in the design of the *Textile Reflexes* dynamic material and the Posture Awareness Vest (PAV).

A way in which designers can act on the issue of fashion and textile waste is through their role of 'active makers' of materials (Myers, 2012; Karana et al., 2015; Rognoli et al., 2015). This paper will demonstrate a case of how the development of a new textile material sparked further innovation into a robotic textile and its implementation in a health and wellbeing context. We will first outline how the new textile material; *Textile Reflexes*, was developed. Subsequently, we will describe how electronics were integrated into this textile material and we will demonstrate a first use application of the developed robotic textile. Finally, we will discuss how this project is both an example of how multidisciplinary collaboration can further advance the development of smart and electronics textiles and of sustainable innovation touching on different societal challenges.

2 Textile Reflexes: a textile that engages with material sustainability

The *Textile reflexes* textile is made of separate squares that are stitched together along with a string across the diagonals, connecting each square to the next in the corners. This way the corner remains a flexible point and the connected squares can open and close, each responding to the movement of the other. This way the textile can grow, shrink, fold and bend. The flexibility allows it to respond to the shape of the human body allowing for some flexibility in sizing and allowing freedom for movement. The textile works best though, on a flat, horizontal surface, where gravity has no effect on it. When applied vertically, for example, in a dress, gravity pulls the textile in its opened position. This can be adjusted with elastics where it needs to be tight, for example in the waist. Figure 1 shows the moving squares textile in open and in closed position.

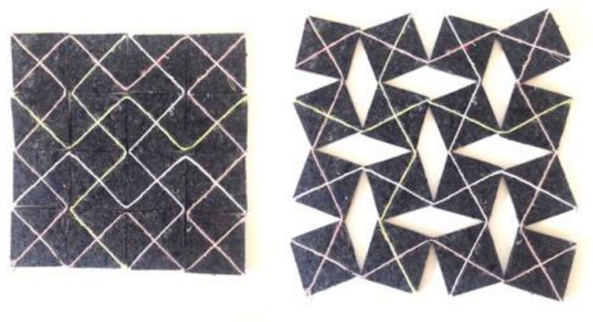

Figure 1. The moving squares material in closed (left) and open (right) position.

2.1 Development of Textile Reflexes

The development of *Textile Reflexes* started after an introduction to a recycled textile waste felt material. This material was made out of post-consumer textile waste. The felt was stiff, sturdy and had a surface that showed small patches of colour stemming from the different garments the textile waste was made out of. This interesting surface went unnoticed in earlier applications of the material. The material had so far mostly been used to isolate floors, in the automotive industry, and in other applications where it remained invisible.

Due to its stiffness, the material was not immediately suitable to make garments or fashion accessories. The development of *Textile Reflexes* started as an exploration to find a solution to that problem. How to make a stiff, sturdy textile flexible and suitable for creating wearable garments and accessories? The first and obvious thing to do was cutting it in pieces and gluing it on a base fabric with some space between the pieces. The result was a flexible material with largely the characteristics of the material it was glued on. The principle reminded too much of the well-known Prism Tote Bag by Issey Miyake. The next challenge was to find a way to make the felt flexible by its own and create an original design with it that would also make its distinct qualities more visible. In the end a similar principle of cutting the felt in pieces and putting it back together was used, but this time without a base material, just by stitching the pieces together in the corners. A string with a contrasting colour was used in the stitching to create a strong connection that also adds a playful effect that invites interaction.

The materials used in *Textile Reflexes* have a low impact on the environment. Next to not adding to the massive piles of textile waste that are already problematic, it also supports environmental consciousness by actually showing the recycled quality of the material and making people aware of the benefits of recycling textile waste.

3 Robotics innovation for textiles

Textile Reflexes is an innovative material but also a kinetic system. This unique quality of the material triggered the exploration of making *Textile Reflexes* a robotic textile. Robotic textiles as (elements of) garments could provide very different tactile experiences when compared to existing textiles. A robotic textile that changes shape could be compared to a soft muscle that can apply or release pressure. This type of interaction is what we wanted to create because it would enable us to explore new forms of feedback that can be intuitively understood and are arguably more comfortable.

3.1 Smart textiles, feedback and coaching / training

A robotic textile can change shape that allows for giving haptic feedback. It has (literally) a close impact on people. Given those opportunities, it makes sense to implement such a textile in a coaching or training context. Haptic feedback has a great potential because it provides physical input on the body and uses new channels for non-verbal communication. For applications such as posture improvement, we also expect that providing haptic feedback at the exact location of the body where a reaction (from the wearer) is needed, will require less cognitive load than, e.g. visual or auditory feedback that would require an understanding of what action needs to be taken considering the feedback provided. Moreover, haptic feedback is not only another way of perceiving information, it also includes another experiential dimension. People attribute meaning to signals they feel on their body as becomes apparent from language. We use phrases such as “a tap on the shoulder” to indicate approval, “back in the back” to indicate support and “hold me tight” to indicate a feeling of safety. See Ludden & van Rompay (2015) for a more extensive account of how touch can be experienced at different levels of experience.

In most available devices and applications that incorporate haptic feedback vibration motors are used, similar to those we find in, for example, smart phones. Their advantage is that they are cheap and easy to integrate. However, they only cover a very limited spectrum of tactile reception, even for vibration other frequencies or patterns can be sensed by humans. Pressure, which can be given through touch or as an embracement, is another dimension of haptics that can be explored. There are various experiments with inflatables creating pressure on the body (see, e.g., The, 2009; Neidlinger, 2017), but none of them seem to satisfy criteria on wearability since the compressors that are used for such application come at a considerable size and with a certain amount of sound.

As a first step towards integrating the innovative robotic textile into an actual coaching wearable, we decided to start from the most direct form of feedback, that of giving direct physical feedback as information. For this type, the feedback that is given on the body can lead to direct action starting from the actual position where the feedback is given. More specifically, we chose to integrate the robotic textile in a Posture Awareness Vest (PAV). A PAV is meant to provide support in posture correction by making people aware that they are slouching. Slouching means taking on a lazy posture that is characterized by excessive muscle relaxation and a bent head and shoulders. This could either be in a sitting, standing or moving mode. Slouching may result in headaches, pain in the back or in the jaws. A better posture is recommended to prevent these health-related issues.

3.2 Integrating electronics

To develop the electronics needed for the PAV, we had to design solutions focused on both sensing (sensing slouching) and actuating (making the *Textile Reflexes* material contract and thereby providing haptic feedback).

For sensing slouching different solutions are possible, e.g. a bend sensor below the sternum (Pfab, 2015), strain sensors on the back (Mattmann, 2007), or accelerometers, either single or multiple (see e.g., Wang, 2015). For this application we decided to use a combination of two sensor boards including both an accelerometer and a gyroscope. One reason is that we wanted to make use of an accelerometer for activity detection (for example, because we might decide not to provide feedback on slouching while a wearer is active). The decision for two accelerometers/gyroscopes was made because a single accelerometer cannot sense the relative position of the upper spine with respect to the lower spine, which we consider to be a main characteristic for posture. A single accelerometer might only detect whether the shoulders are in correct position, which still allows for many different ways of poor posture. Because of this, using only one accelerometer might result in both too many false negatives as well as false positives.

Solutions to actuate the textile are also diverse, and all come with different disadvantages. In a series of experiments, illustrated in Figure 2, we explored motors, DC (rotational) and linear ones, and air muscles (also known as McKibben artificial muscles or braided pneumatic actuators). General disadvantages of motors are that they are bulky and make noise, which makes them less useful for integration in a textile material and which might also impose problems when used in daily life.

A property of *Textile Reflexes* is that the locally actuated movement of one or more squares propagates over all other squares, i.e. moving one square results in all other squares also moving. However, when wearing the textile, friction with other garments limits this property, excluding solutions for actuation that only move single squares. A more adequate solution would therefore be to actuate a full length of squares that have to be pulled together. We found that this could be done by using the McKibben artificial muscles (see far right image in Figure 2).

The exploration of possibilities for actuation in this project is ongoing and will include other actuation mechanisms with motors, more elaborate experiments using McKibben air muscles, linear magnetic actuators, and, most promising, knitted artificial muscles (Maziz, 2017). The latter seem to fit smoothly to the required full-length actuation, can easily be integrated in a textile material because they are made of textile material themselves, and are silent.

Figure 2 actuation with a DC motor (both left), a linear motor, and a mcKibben air muscle.

4 Posture Awareness Vest (PAV) Using Textile Reflexes

In the previous section described the haptic feedback that the robotic textile could provide when applied in a garment and how it might be used in a coaching context by way of a Posture Awareness Vest. Other researchers have explored posture correction through wearable technology as well via commercially available products such as the Lumo Lift (Lumo, 2017). Drawbacks to many of these existing devices and wearables can be found in how they apply feedback (vibration) at different points of the body (often at the upper front body) than where the posture correction is actually needed (the lower back and shoulders). To explore the benefits of using a different type of feedback (pressure rather than vibration) at a more suitable location (at the direct location where action should be taken) we performed a first user evaluation study with a prototype of our PAV.

4.1 Usability and Testing Results for PAV

For our purposes, we created a first prototype of a posture vest that uses the robotic textile in the back and that will in this way be able to give direct feedback at the place where users of the vest should start correcting their posture. We aim the first user evaluation at determining the best position for tactile feedback on posture using the *Textile Reflexes* vest. Additionally, the study was aimed at obtaining a first user evaluation on the perceived quality of the tactile feedback. Quality of feedback includes comfort, noticeability, distraction, and effectiveness. Finally, we aim to understand people's willingness to wear a vest for posture feedback.

4.1.1 Stimulus and participants

For this study we have used a first prototype of the *Textile Reflexes* vest (Figure 3). This prototype did not have electronic actuators but was operated manually. For this, we integrated strings in the vest that, once pulled, contracted the vest for tactile feedback. The vest allowed for tactile feedback at three different locations in the back panel of the vest: the upper part, the middle part, and the lower part. The textile reflexes vest was designed for women. Therefore, the participants of this study were all women. We invited twenty female students, aged between 19 and 25 (mean age 21) to participate in our study.

4.1.2 Procedure

The experiment consisted of three phases: an introduction phase, a test phase, and an evaluation phase. Participants performed the evaluation individually. In the introduction phase, the participants were introduced to slouching. Through a short questionnaire, the participants were asked about their experiences on slouching and their willingness to correct their posture. The participants were then, in the test phase, asked to put on the *Textile Reflexes* vest. The participants were wearing the vest over their normal clothing but coats and vests had to be taken off. Participants were asked to sit down and type out a text on the laptop that was standing on the table in front of them. When the participants started slouching, the experimenter would pull the upper strings of the vest, for upper back feedback. The participants were afterwards asked to assess the upper back feedback on four seven-point scales to assess comfort, noticeability, distraction, and effectiveness of the feedback. General comments that participants gave were noted. This procedure was repeated for the middle back feedback and the lower back feedback. Finally, in the evaluation phase we again asked participants which of the three locations for feedback was preferred and assessed their willingness to correct their posture using the vest.

4.1.3 Results

The introduction phase of the experiment indicated that all our participants are aware of their own slouching and would like to improve their posture. 14 out of 20 participants indicated that they experienced pain in their bodies that could be the result of slouching. Of all participants, 8 indicated to be willing to use a technological aid to improve their posture. On a seven-point scale, the willingness to use a technological aid was rated 3,75 average.

Figure 3. First prototype of PAV (top) and location of strings used in user evaluation test (bottom).

Table 1 shows the results of the test phase. It illustrates how participants rated the types of feedback given on three different locations of the back on the scales that measured the quality of the feedback.

Table 1: participants' appreciation of three types of feedback

	Upper back	Middle back	Lower back
Comfortable	5,58	5,21	5,11
Noticeable	4,55	5,30	5,45
Distracting	4,45	4,40	4,30
Effective	3,20	4,35	4,60

From Table 1, we can see that the feedback at all locations was perceived as rather comfortable (scores range from 5,11 to 5,58) and noticeable (scores range from 4,55 to 5,45). Moreover, the three types of feedback were almost equally rated as moderately distracting. In terms of how much the feedback invited participants to sit straight, (i.e., the effectiveness of the feedback), the feedback given at the lower parts of the body seemed to work better than the feedback given at a higher position (scores range from 3,20 for upper back feedback to 4,60 for lower back feedback).

Finally, the evaluation phase of the experiment illustrated that 1 out of 20 participants preferred upper back feedback, 10 out of 20 appreciated best the middle back feedback and 9 out of 20 valued most the lower back feedback. Further, whereas in the introduction phase only 8 participants out of 20 indicated to be willing to use a technology for posture improvement, now 15 out of 20 participants said to be willing to use the *Textile Reflexes* vest for the improvement of their posture. Ratings about willingness to use wearable technology for posture correction were as well slightly higher after participants had experienced the tactile feedback of the vest than before (3,75 before and 4,35 after). Comments that participants gave, indicated that they would prefer to use the vest at home and that the behaviour of the vest should be controlled so that it will not be annoying ("The vest should not correct me every time I am slouching").

4.1.4 Conclusions

As participants perceived slouching as a problem, they were willing to improve their posture. A minority of participants was willing to use a technological solution to improve their posture before the experiment. After the introduction of the *Textile Reflexes* vest, the majority of participants were willing to use the vest for posture improvement. The *Textile Reflexes* vest was appreciated for its intuitive feedback and its nice and inviting aesthetics.

First, the participants of the experiment mentioned that the feedback at the place where users should start correcting their posture, felt intuitive ("It just makes me sit straight"). Being stimulated in the bending parts of the back, made users automatically correct their posture. Especially stimulation at the lower parts of the back felt most intuitive. The intuitive feedback felt more effective than a non-intuitive feedback. Moreover, the participants appreciated the feedback for feeling subtle.

Second, participants' improved willingness to use a technology for posture correction after the experiment had to do with the design of the *Textile Reflexes* vest. Participants indicated to be willing to use the vest because of its aesthetics ("The piece of clothing looks nice"). Participants' conditions on use refer to price ("If I could afford it, I would love to use it"). As well, it should be mentioned that some of the participants would not like to wear a posture correcting technology that is visible to others (“When it was more an undershirt I would like it more”, “I would use it when it is invisible under my clothes”).

Participants finally indicated that they believed that their response to feedback on posture would change when becoming habituated to it. Participants on the one hand believed that becoming habituated to the vest´s feedback would make them unconsciously improve their posture directly. On the other hand, participants indicated that becoming habituated to the feedback would make it ineffective. This should become clear in future studies.

As a conclusion, a *Textile Reflexes* vest could contribute positively to users’ posture. Feedback right on the bending spot, at the lower part of the back, creates an intuitive type of feedback that feels comfortable, yet is noticeable. It is creating a right amount of distraction to stimulate posture improvement. The textile squares make the *Textile Reflexes* vest look nice. This invites more for use than unpleasant looking technologies. Yet, some of the participants prefer to keep invisible to others their use of a technology for posture improvement.

5 Discussion

In this paper, we have brought together three convergent trends that emerge from larger societal challenges: technological, material, and social innovation with sustainability. From this convergence of trends, and emergent challenges, we have introduced the development of a PAV using the *Textile Reflexes* material. By doing so, this project serves as an example (albeit on a modest scale) of how material innovations can lead to innovations that contribute to better materials and methods for the benefit of society. Though our design and impetus emerges from structural concerns of material sustainability and physical well-being, we are also interested in how such a holistic approach to design might propose “emotional” durability in design (Chapman, 2003; Chapman, 2005; Flores and Roldo, 2012; Stead et al., 2004).

5.1 Considerations on multidisciplinary

We believe that current concerns in the environment, health and wellbeing, and technological advancement are interconnected and interdependent. It is for this reason that we approach our design inquiry and prototypes to reflex convergent interests and concerns. A multidisciplinary approach, such as we propose with the Textile Reflexes-base PAV provides a starting point to tangibly test the viability of a sustainable technology. We believe that the future of textiles and material innovation will become increasingly complex and hybrid; and for this reason, we wish to lay out pathways to pre-emptively interconnecting issues (environment; posture) that are not often considered in an equally weighted fashion.

The development of the PAV was a joint effort of designers and researchers from different disciplines; fashion and textile design, (interaction) design and computer science. The combination of disciplines was essential to drive the innovation put forward and could only work because the while all researchers had a specific background, there was also considerable overlap in expertise which allowed mutual understanding (for example, both the interaction designer and the computer scientist had worked on wearable technology before and had a maker attitude, while the textile and fashion designer had a clear interest in research on smart textiles). To further advance research and development in smart and electronics textiles as well as to further explore how material innovations can spark sustainable innovation, working multidisciplinary while being open to learning is essential.

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Change Matters: theories of postdigital textiles and material design

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This paper identifies examples of postdigital practice in textile and material design and uses the theories of New Materialism and the concept of the New Aesthetic to understand contemporary practice methods and outcomes. In the context of Zygmunt Bauman's *Liquid Modernity* it seeks to develop a theoretical context for designing textiles and materials that may be crafted algorithmically, that are alive with agency and pervasive in our subjectivity. Using key examples of contemporary designers, this paper identifies the deepening relationship between textiles and material design practice in the postdigital era. It begins to trace a legacy that asserts a continuity from textiles and material design practice in more traditional conventional formats to future and emerging design that engages and elicits both the physical and digital aspects of our culture in fluid times.

Keywords; postdigital, textile design, design theory, materials

1 Introduction

It's never not going to be like this.

Everything feels new and exciting for once.

I think in texture, shape, colour, big swathes of fabric flowing and almost having a liquidus texture to them. Molecules that are burstable, kind of mutate and turn into their own chemical reaction…and then I go on the computer and I make them.

The words above, from designer Lucy Hardcastle (Mandelup 2016) describe a new type of practice in the field of textile and material design. The clamour of industry approval for Hardcastle's stunning sensual storytelling, meant that she began working with international brands whilst still studying her Masters in Information Design. Originally trained in textile design, Hardcastle's practice typifies the post-digital approach to design. She is a maker. Making in materials and making in code.

Hardcastle uses glass blowing techniques, 3D printing, flocking, hand dyed fabrics, 3D rendering, digital animation, photography and sound effortlessly to create *“real and imagined touch, visual illusions and sensual aesthetics”* (Hardcastle 2017).

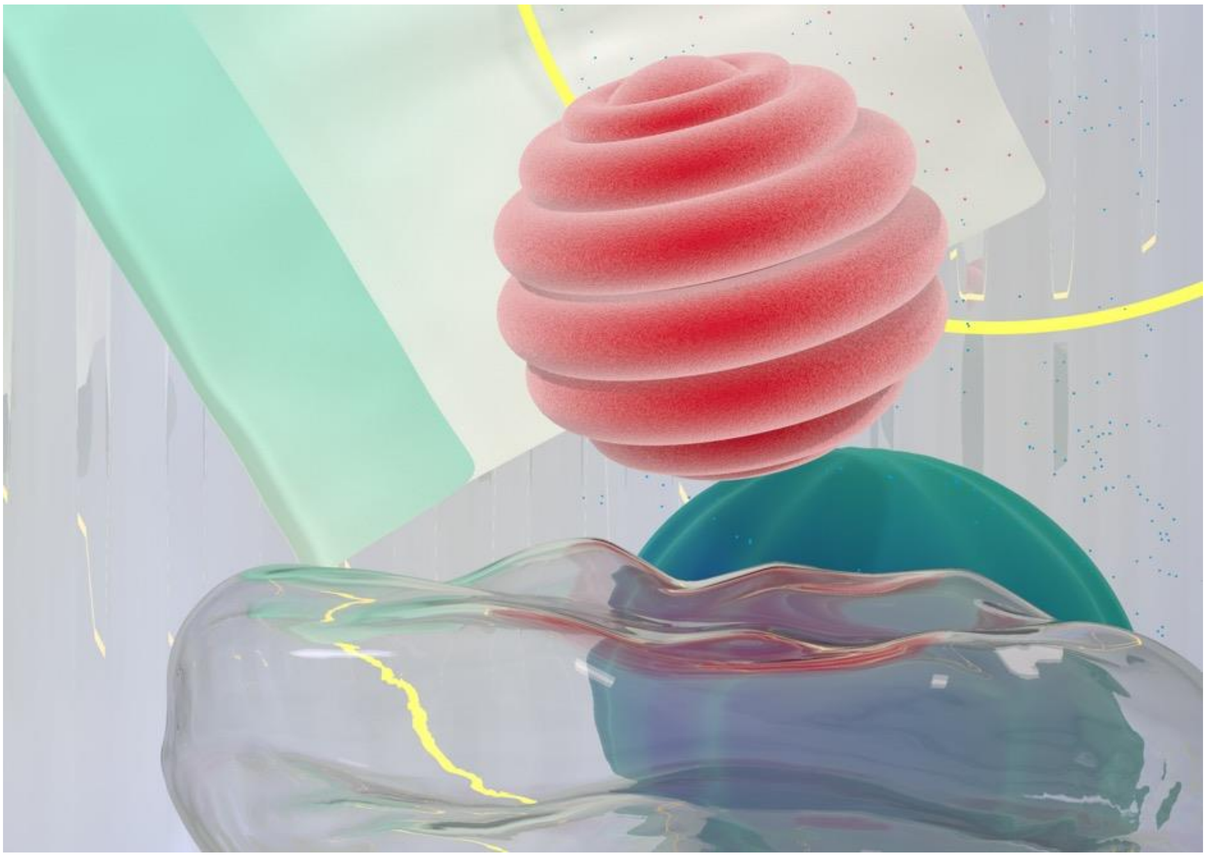

Figure 1 Conflate: A Celebration of Craft and Process for Blacks Visuals (2017) by Lucy Hardcastle Studio. Source: Lucy Hardcastle

Zeitguised are another design studio specialising in the creation of ‘exquisite realities’. Zeitguised describe their work in the film GEIST.XYZ from 2016 as having a ‘synthetic, ecstatic aesthetic’ created through “handcrafted algorithmic textiles and procedural surfaces” (Zeitgeised 2001 – 2017). The work of Hardcastle and Zeitguised exists in two collaborating modes of understanding; the physical and the digital. In their work the two are inextricably blended in the product of what some are calling ‘*phygital’* design.

Nimkulrat, Kane and Walton (2016) present a publication that begins to explore what it means to be *‘Crafting Textiles in the Digital Age’.* They note that textile practice is currently in a transitional phase, not only in regards to the aesthetics of crafting with or in the digital but also with due concern for the economic, social and environmental implications of that practice (Nimkulrat et al 2016, pg3). We know that design sits in a nexus (Kimbell 2012), and does not only have implications for but exists in a complex and tense relationship with the social, economic, environmental and the personal. The changes we see in design, in designing textile and materials, is itself a manifestation of changes in social, economic and environmental changes.
At The Design Research Society’s Experiential Knowledge Special Interest Group conference in June 2017 entitled ‘ALIVE. ACTIVE. ADAPTABLE’ the premise was to discuss the collaboration between the physical and the digital in the design of materials. The organisers recognise that as materials acquire more possibilities for interaction, algorithmically, biologically or chemically, and gain increased digital or organic connectivity that we must begin to understand a design practice that deals with these agential materials (Karana et al 2017).

Figure 2 Still from Geist.XYZ: An exploration of handcrafted algorithmic textiles and surfaces (2016). Film available at http://www.zeitguised.com/things/geist-xyz Source: Zeitguised

This paper seeks to begin to develop a theoretical context for designing textiles and materials that may be crafted algorithmically and alive with agency. I ask how, in an age when 'its never going to not be like this', can we understand the deepening relationship between of textiles and material design practice? How might we trace a legacy that asserts a continuity from textiles and material design practice in more traditional conventional formats to future and emerging design that engages and elicits both the physical and digital aspects of our culture?

2 Postdigital materiality

> *At its broadest,* (nonetheless), *new materialism can be said to concern a series of questions and potentialities that revolve round the idea of active, agential and morphogenetic; self-differing and affective-affected matter.* (Parikka & Tiainen 2010)

Explorations into material agency (Karana et al 2017) and the expansion into interactivity and that of 'the smart' within the field of textiles align with the non-human turn of the concept of New Materialism. Its basis is in the rejection of the dualism of people and things and acknowledges an ontological hybridity in our reality (Gries 2015). In *Postdigital Artisans* (2015, p5) Jonathan Openshaw describes how we are "…reformulated by the digital moment, and where a digital mind-set is inextricably entangled with our existence…" The concept of New Materialism (Parikka & Tiainen 2010, Cole & Frost 2010, Gries 2015) draws on a broad range of schools of cultural theory, and has in some ways given birth the concept of the postdigital. Openshaw believes that we now often experience a frustration with conventional material forms. We know that the material world is alive with possibility, the digital world has taught us to expect this, yet outside of the screen we can feel let down by materiality. The artisanal work that Openshaw showcases in his publication collaborates the digital and physical; this is the essence of postdigitality. Our past heroism of the digital, and indeed the handcrafted, are cast aside to explore and debate new working methods and outcomes of design.

The space between the haptic and the computational; the glitchy, awkward space between analogue and digital formats is the realm of the 'New Aesthetic'. This is a term that goes hand in hand with the postdigital and has been attributed to James Bridle, who in 2011 began collating imagery on his blog new-aesthetic.tumblr.com

> *Whether a frame from an online video, or a screen capture of an online map (remember, digital maps are animations on pause), or fragments of code or spam; all of these are snippets, they are only momentary representations of ongoing processes – as indeed the New Aesthetic is intended to be. Each image is a link, hardcoded or imaginative, to other aspects of a far greater system, just as every web page and every essay, and every line of text written or quoted therein, is a link to other words, thoughts and ideas. Again, in this the New Aesthetic reproduces the structure and disposition of the network itself, as a form of critique. (Bridle 2013)*

The 'New Aesthetic' was coined with little thought or understanding of the theory of aesthetics or to the significance the term would go on to garner. Bridle's explanation simply describes an experience, visual but perhaps moving or virtual, of that which is digitally networked. The New Aesthetic, although developed to describe a type of visual imagery, has some use for us in describing new forms of materiality and textility that are networked or seek to represent and critique it as it happens. In recent decades, the proliferation of smart textiles and materials bound up in our networked world show us that an internet of *soft* things is already in existence ('The Internet of Soft Things' is a project by Kettley et al 2016).

3 The tension of oscillation; the uncertainty of liquefaction

Recognising the ever-fluctuating position of design in and between the nexus of the social, economic, environmental and the culturally subjective/objective is a trait of postdigital designers. The notion of a version of modernity that is in flux was developed by sociologist Zygmunt Bauman in his theory of '*Liquid Modernity'* (2000). He questions the postmodern era, criticises the speed at which it was named and posits that society moved from a 'solid' modernity to a 'liquid' modernity rather than into a postmodern state. He argues that contemporary ideas and ideologies are unlikely to be given enough time to solidify, and cannot serve as frames of reference for human actions. (*Bauman* 2007, pg 1)

In the use of metaphoric material terms to describe ways of being, Bauman's texts can be given a certain reading by those working in the field of textiles and materials. In the foreword to '*Liquid Modernity'*, entitled *'On Being Light and Liquid'* Bauman explains the development of his theories from the phrase famously used in The Communist Manifesto *'melting the solids'*. The solidity of the pre-modern state was to be dissolved and reconstituted to make way for a new and improved solid, one that would last, be reliable, predictable and manageable (Bauman 2000, pg 3) in a truly Modern age.

Bauman outlines how we have come to a second modernity, a modernity that has turned back on itself, not another melting or reconstitution but a liquefaction of our previous state, principally moving from 'system' to 'society' and from 'politics' to 'life-policies' resulting in an individualised, privatised version of modernity. He highlights patterns of dependency and interaction as a key area for liquefaction in this epoch. Old concepts still exist in a type of zombie-like limbo, neither dead or alive, but in our fluid state, it remains to be decided whether these concepts continue to exist, reincarnated or whether they must be laid to rest.

Bauman reminds us of the relationship between time and state of matter. Solids, with clear dimensions, holding their shape and resist time, while for liquids, it is time that counts. Fluids do not keep any shape for long, they are prone to change; in shape and flow, holding a shape but for a moment. Fluids are mobile, able to splash or ooze, drip or spray. When solids and liquids meet, liquids move around them or infiltrate them, while solids become drenched or moistened, requiring a lengthy process of renaturing. *"Descriptions of fluids are all snapshots, and they need a date at the bottom of the picture."* (Bauman 2000, pg 2) This line from Bauman feeds the justification of the post-digital and the New Aesthetic.

The cultural theory of the meta-modern is an explanation of contemporary society and culture as reflexive, uncertain and oscillating. Vermeulen & van den Akker developed the theory in 2010 as notions of the postdigital era also began to be concretised. Vermeulen (2012) has described the metamodern as an 'open source document' not a philosophy but an attempt at a vernacular. Indeed, metamodernism has developed through an online prescence with multiple contributors posting examples and critiques of art, fashion, literature and music that represent that vernacular relevant to contemporary culture which postmodernism is inadequate for. Metamodernism describes a culture between and beyond, a position which is in a constant, yet unbalanced state of change. It is clear that postdigital design practice aligns with the fundamental concepts of metamodernism.

I have posited the notion of *'textasis'* (Igoe 2013) as a text-ile in tension, recognizing the etymological and metaphorical connection between text and textile, thinking, speaking, writing and making. It represents the definition of textile thinking in its interconnection of the material and immaterial in *tasis*. Textasis suggests a movement between *stasis/enstasis*, that which is unmoving, immobilised, subordinated, standing firmly within oneself, to *ex stasis*/*ekstasis,* flow, excess, ecstasy, joy, insubordination, to be outside of oneself, the transgression of boundaries. In *textasis*, textiles (as a disciplinary area) is in a tension between its material form and how it performs and what it represents beyond the tactile. How is textasis manifested through the New Aesthetic and New Materialism of the postdigital?

The postdigital defines a time in which the novelty of the digital has been overcome and its value is becoming fully integrated, embedded, into our lives. But what actually defines the digital? Etymologically, the digital merely denotes something divided into discrete units; digits; fingers. A digital system can be basic or highly complex, but it is systematic and traceable. The shared reference points and language of the digital and the textile have been stated clearly before (Plant 1997) but it is worth reiterating and unpicking this in the postdigital era.

Cramer (Berry & Dieter 2015, pgs 17-18) reminds us that the digital need not be electronic and the analogue can indeed perform computationally. He gives the example of the meme of 'the hipster and the mechanical typewriter' as an artefact-in-use which could be considered postdigital; a digital system in its predetermined set of letters, punctuation marks and numbers, yet simultaneously and colloquially, analogue, performing as if flaunting its 'wireless' technology. The information the typewriter creates varies on a continuum; the quality of mark made dependent on how much use the ink tape has had or how many times the keys have been struck. Cramer's example hints at the notion that the perception of an artefact as digital or analogue can be dependent on how we interact with it. Unused on a desk, the typewriter remains elementally digital in an analogue context. Well used, on a park bench in 2013, it performs a commentary on the digital while romanticising the analogue.

Textiles, in their typical form, can be understood as digital at the time of their production; numbers of counted warp strands, a predetermined number of stitches. What makes them analogue is our relationship with them, the way we interact with them, wear them out, imbue ourselves into them. Yet, once out of use they can be unravelled, each strand or row once again can be counted. Cramer (2014, p18) points out that *"The structure of an analogue signal is determined entirely by its correspondence (analogy) with the original physical phenomenon which it mimics."* As is understood, textiles and cloth were often historically created to mimic natural surfaces such as hair, fur and skin, not only for their function but for their sensorial qualities. And so, (elementally) digital textiles ape the analogue qualities of the body. This analogy then evolves ambiently to becomes a sort of meta-analogue surface. Textile designers of the New Aesthetic are taking these postdigital, meta-analogue surfaces into a new realm of (post)digitality. Their work, situated in and embracing a glitchy, oscillating era exposes and manifests this process of becoming in the context of fluid modernity.

Lucy Hardcastle and Zeitguised's work extends this oscillating process dimensionally. Real surfaces, materials and fabrics are created, photographed, enhanced, digitally rendered and animated. Hardcastle works in the analogue as she dyes and drapes them, makes them digital by modelling them, we make them analogue by our experience of them (albeit currently a dissonant one via screen). At that point, her experiential knowledge as a designer and ours align on a varying continuum in our longing for the seeming simplicity (yet indescribable sensorialism) of the analogue in the disorientating complexity (yet algorithmically traceable nature) of the digital. In their uncanny nature, the hyper-realness of her work reveals the unfamiliar hidden within the known.

In 2016, textile designer Nadine Goepfert collaborated with Zeitguised in the development of 'Distort & Transform'; a project aiming to integrate digital research and the exploration of experimental textiles in 'real' haptic objects. The outcome was a rug which explored imagery from the Zeitguised film from 2016 'GEIST.XYZ'. The outcome of this collaboration is an abstract rug, hand knotted, sculptural in shape with varying texture, sumptuously colourful, textured and well crafted. It sits, inviting an experience but struggles for attention in comparison to the hyper-real, multimodal lusciousness of the digital work itself. The tangible, haptic object is arguably less enticing, less stimulating and too real.

Figure 3 Geist.XYZ rug by Nadine Goepfert (2016) Source: Zeitguised

> *The ways in which the New Aesthetic mediates rely on a complex framework of human and non-human 'actants' that are socially networked, act upon natural resources and the social fabric, and create new variations of semiotic construction (in the sense of agency that produces meaning.)* (Paul and Levy 2014, p41)

Paul and Levy refer to the New Aesthetic's socio-ontological foundations in Latour's Actor Network Theory (2005) which rejects the hierarchy of human existence over that of objects and delegates agency to the non-human, linking the natural, social and semiotic. Textiles and materials operating in the postdigital area have the prescence/agency imbued by the cultural history of the surface as a (designed) object with the significance of the networked representation. The interface of the screen, currently provides a dissonance between the activity and depth of our online experience and the physical sedentary of sitting at a computer. Screens will become materials in a co-poeisis of design, set in tense relationship, questioning where or if there are any boundaries, becoming more ambient as well as more unreal, awe-inspiring and dis-orientating. This questioning of the boundaries between nature and culture, between subject and object underpins theories of 'New Materialism' (Gries 2015).

4 Changing state

Notions of transitions and transgressions between textiles and material design and the jolting oscillation or powerful flow of the liquid state of our era fosters instability. Postdigital practitioners explore and critique this instability. However, just as things move together, they can also move apart. Openshaw (2015 pg 9) comments that society does not want the gap between the digital and the physical to be closed completely; just as our hunger for the digital experience has grown we have also seen a desire to rediscover some of the most tactile and analogue forms of human culture. Benjamin's concept of the lost aura in the age of mechanical reproduction can be applied to defend this dissonance.

Bridle (2013) recognises the power of the aura of the object and insinuates that the New Aesthetic is concerned with representing the nature of the aura through agency, stating that,

> *…the New Aesthetic is concerned with everything that is not visible in these images and quotes, but that is inseparable from them, and without which they would not exist.*

This statement flows the digital and analogue back towards each other one again. The politics of the networked aesthetic of the New Aesthetic relates to real, human experience. Auras include traces, that of the way something is made and used. Robbins, Giaccardi & Karana (2016) discuss the socio-ecological context of material traces; the convergence and reciprocity of people, practices and materials and advise that designers must engage with the critical value of traces as we design in more layers of digital capabilities.

Nonetheless we experience a significant proportion of postdigital culture via screens. These interfaces are reformulating our view and experience of our worlds and our ability act on it and within it (Openshaw 2015 Pg 9). Our screens are now mostly hard, flat glass. Our tactile relationship with them is limited but yet the glass absorbs and transforms us; like it absorbs heats and refracts light. This screen has power at and on its (currently) unmalleable surface.

> *The postdigital, as an aesthetic, gestures towards a relation produced by digital surfaces in a bewildering number of different places and contexts. This interface-centricity is not necessarily screenic, however and represents the current emerging asterism that is formed around notions of art, computation and design. In this conception, the postdigital is not purely a digital formation or artefact – it can also be the concepts, networks and frameworks of digitality that are represented…* (Berry 2014 pg 44)

Figure 4 Composite image from Assimilation (2016) by Molly Smisko. 'Assimilation' is a mixed reality design work. The image in the top left shows the arms and hands of a user who is wearing a virtual reality headset in the physical environment. The main image shows what that user is correspondingly experiencing in the digital, virtual environment. Video available at https://vimeo.com/176478169 Source: Molly Smisko

Postdigital design in textiles and materials is often centrally concerned with this very relationship and expresses a form of the 'New Aesthetic'. From the hyper-sensuality of Hardcastle's untouchable imagery to Amy Winters' work in the field of HCI where she develops responsive surfaces, organic user interfaces and transitive materials to soften our relationship with the computational (Winters 2016); and further still to the work of Molly Smisko a textile designer working in mixed realities. In works like 'Assimilation' (2016) Smisko immerses us in the interface using a combination of 'passive, haptic' materials and virtual worlds to deepen sensory experiences and at other times create a glitch-like disconnect that prompts us to question what we are experiencing.

All of these works force us to question where the interface begins and ends; On the screen? On our eyes? On our fingertips or skin? Inside our heads? Through the postdigital's 'interface-centricity' we must confront the notion of the subjective-objective boundary. I use Ettinger's matrixial theory to support the inherent relationality of textiles thinking and the complex relationship we have with textilic materials, both when designing and interacting with them (Igoe 2013). Ettinger's theories were developed in the context of feminist film theory but establish the gaze as a trans-subjective encounter which extends into other sensory realms. Ettinger emphasises the co-poiesis at play within the encounter which serves as transgressional and yet productive as it forges new linking;

> *…a process of interpsychic communication and transformation that transgresses the borders of the individual subject and takes place between several entities. Ettinger (2006 pgs 181-182)*
>
> *Through this process the limits, borderlines, and thresholds conceived are continually transgressed or dissolved, thus allowing the creation of new ones. Ettinger (1992) cited in Pollock (2009 pg 3)*

Ettinger's extension of the Lacanian gaze into a matrixial, (networked) subjective encounter encompasses the politics of the New Aesthetic of the postdigital age as well as New Materialsm's questions surrounding morphogenesis in the context of our Liquid Modernity.

5 Thin Machinery

Berry's text, *The Postdigital Constellation,* (Berry & Dieter 2014, pgs 44-45) provides an exploration of the surface as performative, calling them *"thin machinery, containing not just the possibility of a hermeneutic encounter but also an agency drawn from computation itself."* In the postdigital, the New Aesthetic work exposes and at times roughs up the grain of computation into an analogue form. Postdigital textiles and materials can provide this in reverse, providing a hermeneutic experience through its analogous agency with the potential for a digital encounter which may enhance and/or make uncanny the experience altogether.

So what of textiles and materials in this epoch of 'The New' – materialism and aesthetic? Hardcastle in calling one of her projects '*Intangible Matter'* and Zeitguised with their use of the 'phygital' are both trying to capture something which transgresses current boundaries of thought. Work which exists in two modes of understanding, but yet is also a snapshot, its meaning is transient. They are trying to express the nature of something which has two states at the same time. By its nature, this practice is diverse and difficult to label (for very long).

Other emerging designers working at the interstice of design, craft, science and computing include Lauren Bowker, founder of The Unseen. She is a textile design scientist developing colour changing dyes. Bowker is a self-styled witch, channelling 'magick' in order to visualise the data that surrounds us and that we create with our own bodies. Bowker hides the science behind the spectacle. She labels her work not as design, nor chemistry but alchemy. Anna Neklesa, having practised interior design and textiles creates 'molecular tailoring' and she too calls herself a 'haute couture alchemist'. Neklesa works with scientists to develop her 'living cotton' materials which rely on time as an essential dimension to the outcome. Neklesa's work represents textiles in *textasis* in our liquid times. Aligning with Vallgårda's notion of 'computational composites' (Karana et al 2017 pg 8) the familiarity of cotton cloth is made uncanny and given a different, unnerving performativity through its voluntary movements. It is indeed alive.

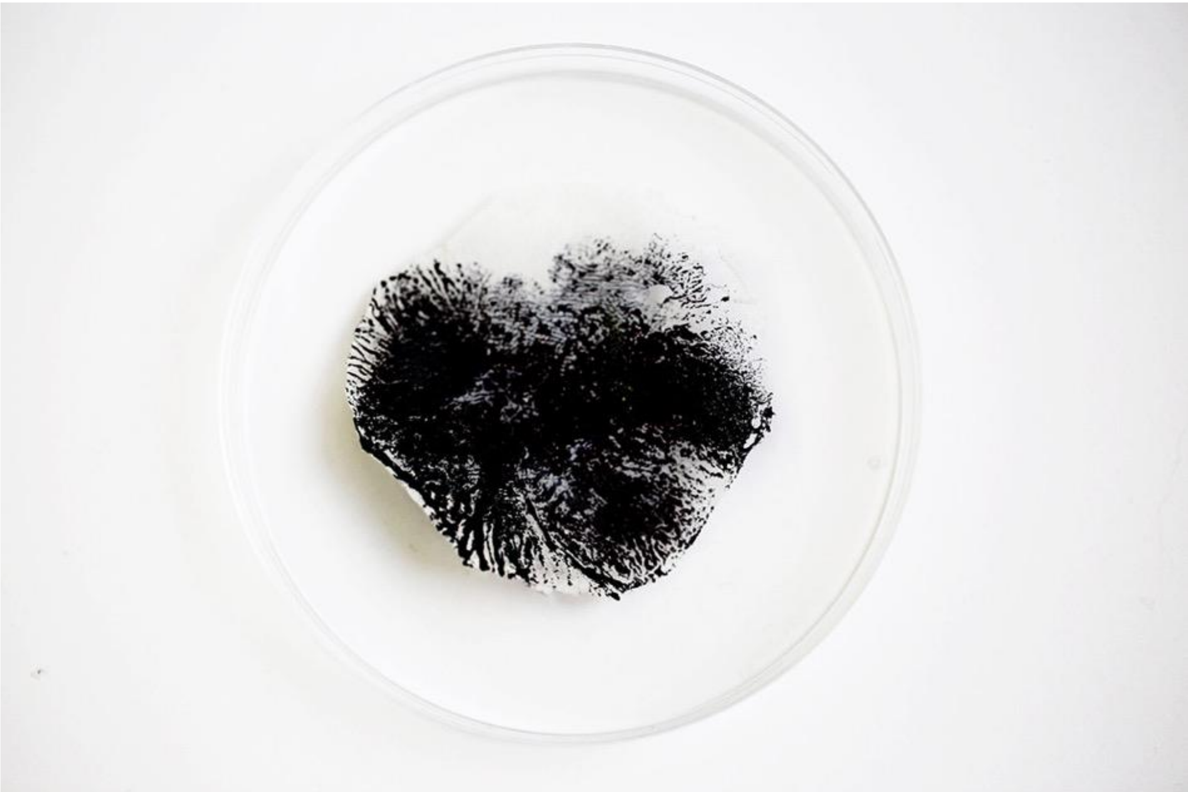

Figure 5 Living Cotton (2017) by Anna Neklesa. Video available at https://vimeo.com/222661585 *Source: Anna Neklesa*

Caroline Bassett (Berry & Dieter 2015 pg 146) sets out a critique of the postdigital in feminist terms and calls for a technophile feminism, but one that does not operate in quasi-mystical terms, such as does Bowker and Neklesa with their alchemist monikers that hold on to zombified ideas of how their practice can be understood. Bassett calls for a feminist approach that,

> *…deals in new materialities and that seeks genuinely new subjectivities… and …new intersections between different forms of thinking about the relationship between weird matter and the fantastic forms of objects and bodies under capitalism.*

Pioneering postdigital practice for almost two decades, Carole Collet has been a key figure in exemplifying practice which performs in the way Bassett describes above. Her 2012 *BioLace* speculative design project exists between synthetic biology and textile design but does not adopt a 'Mother Nature' persona. Photographs of hydroponically grown black strawberry plants whose roots have grown into a formal and recognisable lacy structure prompt us to question what we are looking at and how do we understand it and how can we take it and use it?

Figure 6 Strawberry Noir (2012) part of the Biolace series. Source: Carole Collet

Miriam Azaria works through design activism to synthesise material science and textile design to develop new models of design for circularity. Her 2014 DeNAture project envisages fibres encoded 'like tree rings' for the purposes of future cyclability. In the space she has manifested between fibre and computational code, she used a short film to communicate her ideas.

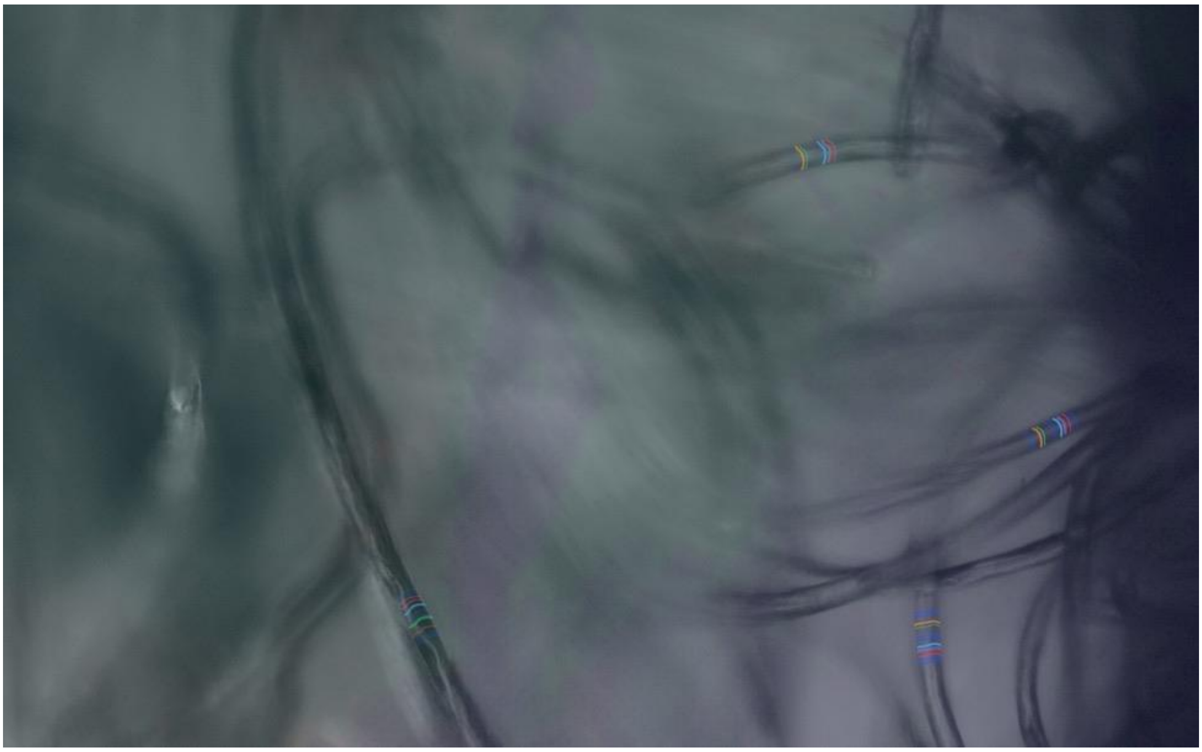

Figure 7 Still from DeNAture by Miriam Azaria (2014). A visualisation of encoded fibres. Source: Miriam Azaria

I have intentionally made no categorisation between the types of works of textile and material design that I discuss in this paper. They exist along a continuum of postdigital practice under labels which do not helpfully describe their purpose or action. They all sit at the interstice of digitality and materiality, exemplifying textasis in their oscillation between the objective, subjective and aesthetic. The corroboration of aspects of the New Aesthetic with the gravitas of the developing canon of New Materialism is interesting and useful when examining postdigital textile and material design. This work exists in a merging blur between the two. The New Aesthetic dealing with the politics of image and New Materialism with the politics and subjectivity of matter. The point of convergence is the space of debate and creative opportunity; a 'swell in the flow' of our liquid times. Nimkulrat et al (2016, pg 9) suggest that textiles cannot exist without material outcomes and can never exist solely in digital space. With this understanding that design and the act of designing is occurring in a social epoch of state change, we must accept that our current concept of what textile and material design are today is a zombified thought, we must decide whether it will flow in the liquidity or be flooded out. My aim here is to encourage a liquefaction of the notions of 'textile' and 'material' in this slippy-dippy state we find ourselves in.

The notion of the 'textile' is in particular danger of solidifying. The last two decades have seen an exponential diversification of practice in the field of textile design fed by new technologies, addressing changes in interactions between humans and with our environments. Practitioners educated in the field of textile design are working within material innovation design, and certainly are beginning to prefer to use the label of 'material designer' when describing their working practices. They, as designers, along with their work are in positive liminality. Which way to turn in this postdigital liquid modernity?

Textiles? Too decorative, too quick, too familiar, too often ignored.

Materials? Too impersonal, too slow, too plain, too performance oriented.

Postdigital design practitioners in textiles and materials work in a way which critiques the status quo and exposes the anomalies, riding the waves of our liquidus state. It is the job of the theoreticians of postdigital textile and material design to interrogate and expose our networked state and keep an eye on the horizon for the next surge.

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Responsive Knit: the evolution of a programmable material system

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Programmable knitting presents a new class of behaving textiles, responsive to environmental stimuli and programmed to change in shape as humidity levels in the environment increase. It is a hierarchical system that exploits the inherent functionality of textile fibres, yarns and fabrics to integrate shape change behaviour into the intrinsic structure of the material. The research applies a biomimicry methodology, with insight derived from the structural organisation of plant materials; specifically, the control of hygromorphic actuation for seed dispersal. This biological model has produced transferable principles for application to responsive textiles and it has been critical to the success of the research. But how can this research advance thinking on the design potential of programmable materials? This paper explores how the complex hierarchies that exist within textiles can be used to engineer a unique class of programmable systems. This challenges conventional smart interfaces that rely on mediated responses via electronic control. Instead this paper demonstrates how an alternative approach informed by biomimicry can generate a new class of smart-natural materials.

programmable materials, knitting, biomimicry, the responsive environment

1 Introduction

Digital fabrication tools have transformed the way designers are thinking about materials. The ability to manufacture directly from computational models using 3D print technologies and robotics have presented a challenge to reconsider the potential of the underlying materials themselves (Tibbits, 2017:14). New classes of materials are emerging that have been designed with the ability to sense and respond to a range of stimuli, producing intelligent responses to changes in heat, light, moisture or pollution levels in the environment. By directly connecting with environmental stimuli, these materials have the ability to act as physical sensing systems, reducing the need for mediated systems using electronic control. Whilst many of these active, programmable materials are composed of smart and synthetic materials, there is class of these materials that utilise the inherent properties of conventional materials like wood, metals and textiles.

This research positions knitted fabric as a unique programmable material system with which to engage with the responsive environment. The research question asks how programmable knitting can advance the field of programmable materials for the responsive environment. The aim of the research paper is to analyse knit production processes from a hierarchical perspective, highlighting how this can be used to develop programmable materials. In addition, the paper identifies the significance of a textiles logic and identifies how it differs from other advanced manufacturing production.

Whilst smart textiles conventionally utilise either smart synthetic materials or additional electronic components to generate shape change functionality in fabrics, this research discusses how the application of a biomimicry methodology has informed fabric development. Through mapping the hierarchies that exists in plant materials against those fundamental to knitted fabrics, the ability to engineer shape change functionality directly into the fabric during production has been established (Scott, 2015). By positioning the environmental stimuli at the centre of the research, constituent materials engage directly with the stimulus. In so doing this research uses knitted fabrics, composed of 100% natural materials as a shape-changing interface to reflect and respond to the dynamic nature of the responsive environment (Scott, 2015).

The significance of the research is how the underlying principles of knit design and technology have been exploited to produce a unique behaving textile. Whilst other programmable materials utilise 3D print technologies or CNC tooling, this system originates from an understanding of textile fibres, yarns and fabric structures, and exploits the complex hierarchies inherent to knitted fabric as a foundation for the programmable material system. The application of hierarchy in the design of programmable knitting sets an important precedent with implications for the design of alternative programmable material systems.

2 Context

Interior and exterior space can be digitally mapped according to parameters including heat, light and moisture in order to understand the underlying patterns of energy flow. The interior environment is subject to the same physical elements as those which create weather systems outdoors. In a contained space hot air rises and cool air sinks. Water evaporates into the air, and condenses back against cold surfaces. Evidence of these patterns of energy transfer are all around us, for example the heat radiating from electrical devices, or a liquid transforming to gas when boiling a kettle. Despite the ability to digitally monitor these energy patterns, the aim of conventional heating and ventilation systems is to mitigate localised changes in energy behaviour and to generate a standardised environment at the scale of a building (Addington and Schodek, 2005:64). Sensing and response systems are conventionally utilised to fully automate control of heating and ventilation, so that the interior climate can be maintained regardless of the weather outdoors. Maintaining ambient temperatures is energy intensive process that requires an input of heat during cold weather and the use of mechanised cooling systems during hot weather.

2.1 The Responsive Environment

An alternative approach is to engage directly with the responsive environment and use the pattern of energy flow as a design tool for interior or exterior spaces. Working with modelling systems such as thermal mapping, designers have produced new methods to re-imagine architectural space using the interior microclimate as the primary driver (Rahm 2006:118). In order to realise material systems that operate within this active and responsive design space new materials are required with the ability to sense and respond to environmental change. Here smart and programmable materials offer the potential to provide a dynamic interface between themselves and their surroundings:

> Whereas standard building materials are static in that they are intended to withstand building forces, smart materials are dynamic in that they behave in response to energy fields. (Addington & Schodek, 2005:4)

The introduction of these materials provides the ability to generate localised interventions in response to the natural pattern of energy flow. This presents the opportunity to redefine an interior space from the perspective of discrete stimuli that change and adapt over time.

2.2 Programmed Behaviour using Passive Responsive Materials

Materials that respond intuitively to environmental stimuli enable designers to produce climate sensitive architectures that react in real time to environmental change. Passive responsive materials change their shape directly as a result of environmental stimuli. The stimulus could be chemical, thermal, or mechanical; however, these materials act directly with the stimulus, they do not require any electrical power. Two examples are thermobimetals and wood veneer. Thermobimetals are a composite of two different metals laminated together, which have different thermal expansion properties. When heat is applied the passive component expands at a lower coefficient of thermal expansion, and the active component resists expansion up to a higher coefficient of thermal expansion. As the two materials react differently the outcome is that the metal sheet bends (Ritter, 2007:53). A recent installation, Bloom exploits this shape change functionality at an architectural scale (Sung, in eds. Ng & Patel, 2013:95). This piece, composed of 14,000 different tiles was designed to manage the thermal impact of solar energy; each tile would open and close in response to temperature changes generated by direct sunlight. The system operated autonomously in response to the changing weather conditions.

Whilst thermobimetal curls in one specific direction, it is possible to engineer natural materials to curl in different ways. Wood veneer curls when exposed to water. This is because wood is an anisotropic material and it swells and shrinks by different amounts in different directions. (Tsoumis, 1991:145). The way that it curls can be manipulated through the direction of cutting in relation to the direction of the grain. It is therefore possible to programme the material through the direction of cut. Wood veneer cut as a strip along the grain will bend top to bottom, cut against the grain will bend from the sides, whereas a diagonal cut across the grain will twist when exposed to water (Scott, 2015).

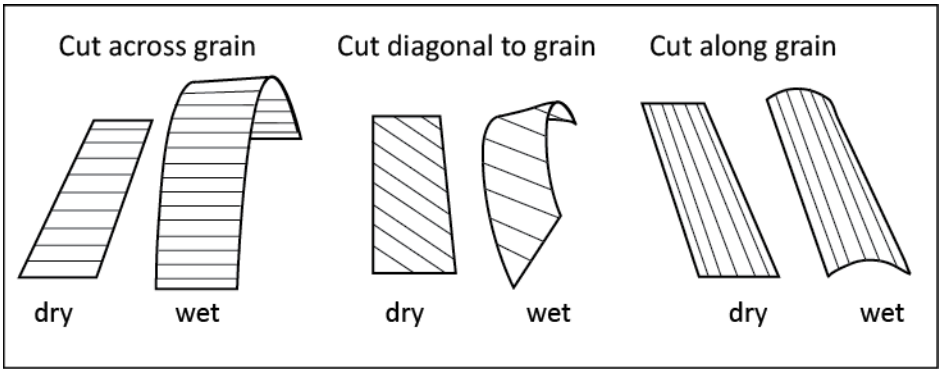


Figure 1 Illustration describing bending achieved when different cuts of veneer are exposed to water. Source: Scott.

The potential for veneer to produce environmental responsive architectures has produced a range of innovative outcomes. Techno-Naturology combines wood veneer with SMP to actuate a laser cut surface, producing heat activated shape change (Yan Ling, 2011:137), whereas Responsive Expansion (Maisonet and Smith, 2013:25-32) and Responsive Surface Structure II (Menges and Reichert, 2012:58) both utilise the moisture active properties of wood veneer in order to produce environmentally sensitive actuation. Wood veneer can be engineered to curl in specific ways by carefully controlling the way it is cut; the key consideration is the relationship between the structure of the material (the grain of wood, and direction of growth), and the geometries of cutting (the shape of the piece, and the angle of cut in relation to the structure of the material). This is significant as it demonstrates how a 100% natural material can be used to generate not only one, but a series of different shape change behaviours.

3 Methodology

Whilst innovation developing programmed behaviour using passive responsive materials has increased with progress in materials science and digital technologies, advances in biology research across a variety of scales from nano to macro has also provided a catalyst for the development of programmable material systems (Tibbits, 2017). In fact, nature presents an excellent model to inform research within this sector. The ability to sense and respond to changes in the environment is an essential characteristic of all living organisms. Plants are sensitive to a variety of changes in the environment and tropisms (directional movements) can be stimulated by light (phototropism), sunlight (heliotropism), water (hydrotropism) and chemicals (chemotropism) (Scott, P, 2008:161). As a design methodology biomimicry provides a systematic method to translate functional models from the natural world into effective, sustainable design solutions (Vincent, 2008:3140, Pawlyn, 2011:2, Bennyus, 1997:4).

3.1 Biomimicry

Biomimicry presents an opportunity to transform specific functions from nature into design. This paper focuses on analysis of sense and response systems in plants, in particular tissue structured to generate specific passive actuation in response to environmental changes. In order to apply the functionalities observed in natural materials in the design of programmable knitted fabrics, a method to formally abstract and translate the models is required. This methodology applies a direct model of biomimicry, using a problem based approach which begins with the questions of how to engineer shape change into the structure of a textile. The methodology (figure 2) is adapted from Knippers and Speck (2012).

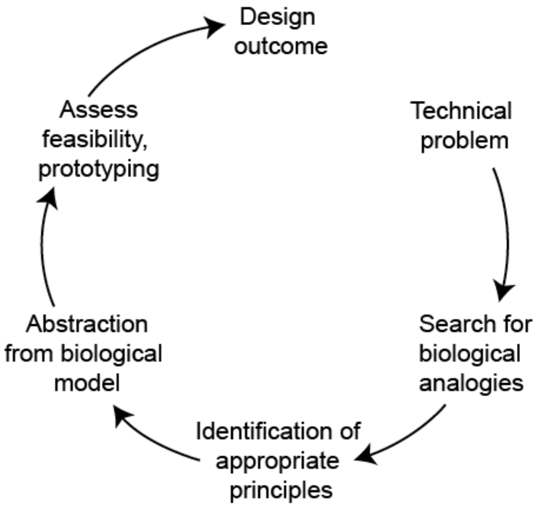


Figure 2 Biomimicry methodology using a problem based approach (adapted from Knippers and Speck, 2012:6, Figure 5). source: Scott.

In order to apply the methodology specific biological models are required to act as design principles to abstract into research, experimentation and prototyping. In this paper passive actuation systems in plants provide the biological analogies for application in textile design research.

3.2 Actuation systems in plants

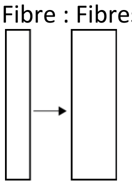
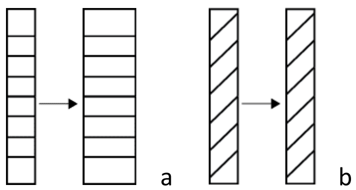
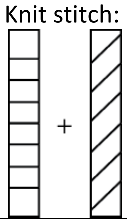
As we have seen in the example of wood veneer, some plant materials have the ability to change in shape even when the material is no longer living. For example, pine cone scales are able to open and close repeatedly. The scales open in dry weather, revealing the seeds inside, and close in wet weather (Dawson et al, 1997:668). This action can be observed even after the pine cone has fallen from the tree, suggesting that the mechanism to control the shape change is inherent to the structure of the material itself.

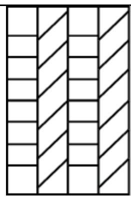
This kind of passive actuation in plants is generated as a result of the composition of the material. It occurs where the structure of the material is composed in such a way that it is programmed to bend or coil when triggered by an external stimuli such as moisture or touch. Many passive movements are caused by the differential swelling and shrinking or specific parts of the plant tissues. This hygroscopic movement is used to control seed dispersal (Abraham and Elbaum, 2013:584). The movement is controlled by the differential structure of the plant cell wall. The plant cell is composed of stiff cellulose microfibrils embedded into a flexible matrix of hemicellulose and lignin. The contrasting mechanical properties produce a bilayer effect, controlled by the orientation of the cellulose microfibrils in the cell wall (Burgert and Fratzl, 2009: 1546).

To generate shape change, water is absorbed into the cell wall causing the tissue to expand. The flexible matrix swells with the influx of water and shrinks as it dries out; however the stiff cellulose fibrils do not swell and shrink to the same extent. As the two tissues are attached to one another, the way each material behaves is effected by the other material. The expansion is therefore anisotropic and causes a bending movement in the plant tissue.

These effects are generated across different scales within a pine cone scale; by mapping the impact of scales from nano to macro against those of a knitted fabric that the opportunity emerges to engineer shape change into the structure of a knitted fabric. Table 1 illustrates the key hierarchies and their role in the passive responsive system of the pine cone hygromorph as well as the opportunity that this presents for shape change in knitted fabric.

Table 1 Table Illustrates hierarchies observed in plant materials and pine cone hygromorph, and how this translates into requirements for shape change in textiles (Developed from Gibson, 2012 1-8, and Dawson et al, 1997:668).

Hierarchy	Application to Pine cone Model	Requirement for moisture activated shape change
Biochemical **Cellulose**	Dimensional changes occur in pine cone scale as water is absorbed. This is regulated by different cell and tissue structures.	Fibre : Fibres change dimension when water is absorbed. 
Ultra-structural **Cell Wall**	Variation in winding angle relative to the long axis of the cell. High winding angle allows fibres to expand and contract (a). Low winding angle prevents this (b).	Yarn: Winding angle alters dimensional changes. 
Microscopic **Cells**	The pine cone scale is composed of two types of cell: sclerids and sclerenchyma fibres.	Knit stitch: Multiple unit (stitch) types required. 
Macroscopic **Tissue**	Arrangement of sclerids and sclerenchyma fibres allows scale to open and close. As the sclerids expand the scale is forced to bend due to resistance from sclerenchyma fibres.	Fabric structure. Arrangement of different units form a continuous material.

4 Materials and Processes

The hierarchical approach outlined above highlights specific opportunities to develop shape change behaviours. This section evaluates the components of knitted fabrics in order to identify how these principles can be implemented within knitted fabric design. The four hierarchies of biochemical, ultrastructural, microscopic and macroscopic translate into a knit fabric as fibres, yarns, knit stitch and fabric structure. Each section highlights how responsive behaviour can be engineered into the resultant fabric at the particular stage of construction. It is critical to note that whilst dimensional change in response to moisture can be observed at a fibre level, in order to control and manipulate the dimensional change into an overall shape change behaviour, careful control of the parameters of yarn, fabric and form are also required (Scott, 2015).

Yarns for knitting are composed of a mass of individual textile fibres twisted together. All fibres are long, fine and flexible; however their specific properties vary considerably depending on their chemical composition and physical structure (Wynne, 1997:1). All natural fibres have dynamic moisture absorption properties; fibres swell and increase in volume and density in the presence of moisture. These dimensional changes impact the yarns and fabrics made from them; changes in size, shape, stiffness, and permeability occur. This has a direct impact on their mechanical properties (Morton & Hearle, 1986:159). As the fibres swell polymer chains are moved apart as the water molecules are absorbed. The swelling of fibres in water occurs at different rates in different directions. Swelling can be considered in terms of an increase in length (axial swelling), or an increase in diameter (transverse swelling) however fibres swell more across their diameter than along their length.

> *All the moisture absorbing fibres show a large transverse swelling, but in the axial direction swelling is very small, so that the swelling anisotropy is high (Morton & Hearle, 1986:227).*

The difference in the amount of swelling across the diameter of a fibre in comparison to along the length is critical. In the biomimetic model of the pine cone hygromorph, the transverse swelling of individual fibres causes the scale to open because of the arrangement of fibres within the scale (Fratzl & Barth, 2009), and it is this principle can be transferred to knitted fabric design. However, it is critical to manipulate this anisotropic swelling in order to achieve shape change behaviours at the macro scale of the knitted fabric. To control of the dimensional swelling properties of fibres, it is necessary to consider the impact of both spinning processes in the construction of yarns as well as fabric structures and the overall fabric forms.

Whilst the orientation of fibres in a pine cone scale is determined through the growth of the material, fibre orientation in yarns is regulated during the spinning process. Here fibres are aligned and twisted together providing strength and flexibility to the resultant yarn. The yarns used for programmable knitting combine singles and folded yarns, which give contrasting balance within their structures. Singles yarns are naturally unbalanced because the twist in the yarn is always introduced in one direction only (referred to as s or z) (Wynne, 1997:59).

The amount of twist in a yarn also varies during yarn production, this is recoded as the turns per metre (tpm) for a given yarn depends on the fibre, count (a measure of the thickness of a yarn determined by the ratio of length to weight) and final application of the yarn. High twist yarns (also known as over-twist and crepe) have more twist inserted than standard twist yarns. Programmable knitting combines high twist and standard twist yarns; varying from 430tpm to 1180tpm. These yarns, predominately designed for weaving often snarl and untwist themselves, trying to achieve a more balanced state. These yarns are also prone to shrinkage because the fibres are compacted within the yarn (Taylor, 1999:172).

In order to develop programmable knitted fabrics, the configuration of knit stitches needs to be engineered to create the potential for 2D to 3D shape change. Knitted fabrics are composed of loops of yarn, and many of the characteristics of the fabric derive from the loop construction process. It is well known that knitted structures are highly extensible; in addition, knitted fabric have excellent deformation and recovery compared to other textiles (Spencer, 2001: 45).

Knitted fabric can be produced as flat-shaped pieces or as three-dimensional forms. Fabric shape can be altered by increasing or decreasing the number of stitches knitted in any course by transferring the individual knitted loops. Increasing the number of stitches at different points along a horizontal course changes the geometries of the fabric considerably. 2D, 3D and hyperbolic forms can be generated through varying both the number of needles knitting and the transfer points across a knitted course.

Figure 3 classes of weft knit fabric; plain knit, links/ links and partial knit. source: Scott.

The knitting process generates particular behaviours that are consistent across any knitted fabric. For example, a plain knit fabric will always demonstrate the same curling behaviours (figure 3), because individual knitted loops are intermeshed in the same direction. For programmable knitting this directional behaviour is exploited in order to generate shape change behaviours. By manipulating the way that the plain fabric curls by changing the orientation of stitches using stitch transfer both complex geometries and programmed shape change can be engineered directly into the knitting structure (Scott, 2015). The manipulation of the curl of knit fabric is a fundamental principle for programmable knitting.

In addition to this the knitting process can be described as additive; fabric is generated on a stitch by stitch basis, providing the opportunity to combine multiple structures and geometries within one fabric. The flexibility of knitting also allows the fundamental properties of loop length, yarn type to be altered during knitting which makes the production of a knitted fabric extremely versatile. Through analysis of the properties of natural fibres, yarns, fabric structure and form outlined above, a design system has been developed which produces shape-changing actuation using only natural materials and conventional knit technologies.

5 Design Application: Programmable Knitting

To analyse the success of the biomimicry methodology an interior installation piece, Skew (Scott, 2014) is evaluated. Designed and manufactured using Shima Seiki CNC knit technologies, *Skew*, is a

1m x 2m interior panel combining structural patterning at different scales across the full dimensions of the piece.

Figure 4 Skew: Montage of images illustrating the process of shape change behaviour. source: Scott.

Figure 5 Skew: Before Actuation source: Scott.

Figure 6 Skew: After Actuation source: Scott.

Figure 7 Skew: detail of 3D profile showing shape change at edges and different scales of patterning. source: Scott.

5.1 Fabric Construction Process

The work was programmed using the SDS1Apex system, and manufactured on a Shima Seiki NSSG 5gg knitting machine. A major advantage of programming materials using the knit production processes is that they are constructed using yarns with standard properties required for knitting (good flexibility, strength and elastic recovery (Spencer,2001:4)), so the fabrics can be manufactured using a range of knitting technologies. This piece is composed of 1/24nm s twist linen. The capabilities of the Shima Seiki programming system allow unlimited stitch transfer sequences across the full dimensions of the fabric which would be difficult and time consuming to achieve on hand operated equipment. Fabric width is determined by the width of the needle bed; and control is provided through computerised takedown and tensioning systems. This provides a mechanism to regulate fabric production and minimise faults during knitting.

5.2 Analysis

Skew is composed of a complex configuration of knit stitches organised into links/links patterns across a variety of scales. The smallest scale is five wales and five courses of face stitches opposing five wales and five courses of reverse stitches in a links/links configuration (5x5). Across the fabric the scale increases: 10x10, 25x25 and 50x50. The intention of the fabric design was to explore what happens when scales interact and whether the pace of shape change could vary dependant on the size of the repeats. It was anticipated that smaller repeats (5x5) would produce a rippling effect across the fabric on actuation whereas larger repeats would emerge as 2D to 3D forms across the fabric length.

The fabric was tested as a hanging panel, actuated using a cold water spray. In machine state the fabric hangs flat. Whilst it is possible to identify front bed and back bed stitches on the fabric, the repeats appear as a pattern of squares and there is minimal disruption to the smooth surface (figure 5). On actuation spiral peaks of different sizes form all over the fabric. The spiral peaks vary in height from 1cm (10x10) to 7cm (50x50). This causes an overall change in dimensions; the fabric lifts up from the bottom and shrinks in at the sides (figure 6). The edges of the fabric also change; in machine state the fabric is rectangular, however on actuation the edges shear to produce zigzags (figure 7).

On application of moisture the fabric instantly actuates as water is absorbed. There is a significant difference in the speed of actuation for areas with smaller repeats (10x10), transforming from 2D to 3D in three seconds whereas larger areas (50x50) transform in ten seconds. This produces a rippling effect and a sense of motion across the whole piece in addition to the overall change in form and dimensions.

When the fabric is hanging, shape change is most dramatic in the bottom half of the fabric (figure 6). This is visible as an overall effect as the fabric distorts and appears to lift up. There are two reasons for this; firstly the top of the fabric is secured in position (for exhibition a Perspex rod was used to hang the fabric) preventing movement at the top of the fabric. Secondly as moisture is absorbed, the linen becomes heavier. It is therefore harder for the shape change to occur at the top of the fabric as it is weighed down by the bottom (figure 6). Despite this, the overall change in dimensions is significant; the fabric measures 65cm x 220cm in a dry state, and 30cm x 190cm on actuation (Width measurement 20cm from bottom). Spiral peaks form all over the fabric. These vary in height from 1cm to 7cm. Shape change is also reversible. As the fabric dries it returns to a flat state and can be re-actuated with water.

Of particular interest within this piece are the edges which distort to form a zigzag up the fabric, and the sections where different scales of patterning interact (figure 7). In some places the disruption in the pattern counteracts the 3D transformation and the fabric does not change shape, however in other areas new 3D shapes are generated.

This piece was first exhibited in March 2015, as part of RTD2015 *Research Through Design,* at the Microsoft Research Centre in Cambridge. This event combined a conference and exhibition. During discussions of the work during a testing session the conversation discussed potential applications for the technology as a sensing system within the environment. Delegates commented on the potential for the material system, illustrated through Skew, to define an alternative rhythm or timeframe for architectural space (Author,2015), The suggestion is that shape change could be representative of the changing environmental conditions within the interior environment. This would provide a direct connection to microclimates that emerge within an interior space as a result of both the natural energy patterns in a space and human interventions. Examples discussed included utilising programmable knitting to monitor moisture in bathrooms and kitchens where levels vary considerably during the day and night.

6 Conclusions

The context of the responsive environment is critical to this design research; it provides an active design space which demands a material system that can directly engage with changing environmental conditions over time. In this research the design space is explored in relation to humidity and moisture levels, using textile fibres with the ability to swell, changing in dimensions when exposed to high levels of moisture. Other moisture responsive are identified including responsive wood architectures (Reichert and Menges, 2015) and superabsorbent polymer composites (Tibbits, 2014), however what is unique about programmable knitting the way that the dimensional changes at the level of the fibre are translated into an actuation motion at the level of the fabric.

The application of a textile logic in the development of programmable materials adds significant opportunity for materials development. The textile system introduces three or four levels of complexity in relation to the hierarchical system. Here shape change is determined through the relationship of fibre, yarn, fabric structure and fabric form, and changes at any level of hierarchy will produce different results in the actuated form. Each of these textile components provide the opportunity to engineer the dimensional change in an individual fibre into a macro scale shape change. Directionality introduced when yarns are spun offers the potential to translate the individual dimensional changes at the level of the fibre into an actuation motion at the level of the fabric. The infinite variety of configurations of knitted stitches provides a huge variation in the resulting shape change achievable. Programmable knitting offers not only a variety of shape change responses articulated through 2D to 3D transformations in fabrics, but a variety of speeds of responses; each fabric articulates an alternative timeframe for the responsive environment dependant on the constituent materials and configurations of knitted stitches.

In conclusion this work offers a series of examples which could be used for further research into programmable materials. Firstly, the work demonstrates that additional functionality can be designed into materials using conventional manufacturing processes such as knitting. This presents an interesting question for research that has been traditionally led through advances in materials science and technology. Instead this work provides a precedent for re-evaluating the potential of current technologies from a new perspective.

Secondly, advanced manufacturing systems for the design of programmable materials, (such as 3D print) use additive manufacturing process which, like knitting design materials from the bottom up. This presents huge opportunities to reflect the way that natural materials grow, embedding complexity into the structure of the material itself. The model of structural hierarchy derived from plant materials is significant as an example of how to analyse behaviour at individual scales across multiple hierarchies, and analysis of materials at the microscale of an individual fibre provides insight into how a material could behave at the macroscale of a fabric.

Finally, the application of biomimicry motivates inherently sustainable design choices. In this research material selection is exclusively 100% biodegradable natural fibres and by programming shape change into the fabric itself there are no additional components required for shape change to occur. Smart synthetics and electronic control have become redundant within this programmed textile system. This is the ultimate challenge working within the context of the responsive environment; the development of sustainable tools to maintain and support interactions with the environment at a material scale.

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Jane Scott is a UK based designer and academic working at the intersection of biomimicry, programmable materials, textile design and technology. As a knit specialist her research challenges the established understanding of smart materials; applying principles derived from plant biology to the development of programmable and environmentally responsive textiles. Her work has been presented internationally at conferences and exhibitions including Massachusetts Institute of Technology, Make/Shift (Craft Council), the Microsoft Research Centre, and The London Design Festival. In 2016 she received the 2016 Autodesk ACADIA Emerging Research Award (projects category) for her work Programmable Knitting.

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