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Stella Boess, Ming Cheung, Rebecca Cain

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DRS President's Foreword

Rachel COOPER

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The Design Research Society is a unique organisation comprised of people dedicated to the value of design and design research and its value to our people and our planet. Without a dedicated group of volunteers, we would not exist; people who offer their services to the management of the organisation, people who host conferences and people who submit papers and their combined intelligence to further knowledge of design and its contribution to the world. This year the fragile nature of the planet, of human relationships and the basis of our economy and society has been illuminated (fires, floods and a virus). We have seen the effect of radical changes in patterns of behaviour; both positive influences on the environment and negative influences on health and wellbeing and livelihoods. There are many design challenges and design researchers have come to the fore. This conference is a triumph of that creativity and fortitude, embracing the virtual world and bringing together all those people who so want to exchange ideas. Many of the papers are pre-Covid, and whilst we should not forget the conversations and research directions before this pandemic, it will, of course, shape our future and our conversations. People make the DRS and whether online or in person the conversations will continue. Let us together build a wider, deeper and stronger global design research community.

As a foot note I would like to say that 2020 marks a turning point for DRS in so many ways, we have a new structure of the organisation, that is a new International Advisory Council and executive who are eager to continue to move forward. We have a new virtual conference and I would like to thank the conference team for such a triumph in changing format and delivery mode, and also to you the members and delegates who are embracing this with your attendance. Enjoy the conference and the future DRS.

Rachel Cooper
DRS President 2020

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DRS2020 Editorial

Stella BOESS, Ming CHEUNG and Rebecca CAIN

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Never before has a Design Research Society Conference happened in such uncertain and changing times. When we embarked on planning the DRS2020 Conference in Brisbane, Australia, we were in a different time, when unrestricted travel and meeting-up face-to-face at academic conferences was the norm. Then the COVID-19 global pandemic happened, which prompted us to rethink and reimagine DRS2020 in a new format.

In recent times, the debate around the sustainability of physical conferences has been starting to surface. This was an issue the DRS was starting to grapple with, but the practicalities of a blended or entirely virtual conference were still uncharted territory. Even before the pandemic was born, the devastating Australian bushfires were causing people to consider whether it would be safe to travel to Australia. Ultimately, the pandemic made a physical conference impossible, and the conference host Griffith University made a joint decision with DRS to convene DRS2020 as a virtual conference. DRS2020 marks an important turning point in the history of DRS conferences, being the first conference to go entirely virtual. We are very grateful to Griffith University for embracing this challenge, and for their leadership and management of the virtual conference in such complex and difficult times.

DRS conferences are international biennial events, held to further and promote design research. They are inclusive conferences, bringing together a wide range of disciplines and communities related to design research, with the aim of fostering new debates on the important issues of the time. Historically, DRS conferences have always taken place through gatherings of delegates in physical venues at a host organisation, with face-to-face presentations and discussions, accompanied by written conference proceedings. New collaborative formats have been added over time – for example, Conversations which were introduced in 2014. DRS2020 took on the challenge of transforming these formats into a virtual experience. Also worth mentioning, the DRS2020 Postgraduate Research Day is pioneering in that it is inclusive of both PhD and MPhil students and of their theory-driven and/or practice-led research projects. In this sense, DRS2020 becomes a prototype for a new type of virtual and inclusive conference experience and continues to build on the legacy of innovation from the previous conferences.

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The 144 papers in these proceedings were conceived of and written in our pre-COVID world. Just three authors were able to make late additions to their papers addressing the current situation (165, 398 and 402). These proceedings therefore provide an interesting juxtaposition, whereby what is written represents design research in the world as we knew it, whereas the discussion that these papers will promote during and beyond the conference will almost certainly be viewed through the lens of the complexities and challenges we now face. The discussions and reflections in the proceedings are a timely barometer for what the international design research community is thinking about and working on, and they will surely prove inspiring and thought-provoking for design researchers worldwide. We hope that you enjoy reading them as much as we have enjoyed curating them.

Themes

The overall theme for DRS2020 is Synergy – the coming together of people and disciplines in design research to create a positive impact. On the one hand, design research champions the uniqueness of disciplinary knowledge and creativity, yet on the other hand, the complex world we now live in demands a more synergistic approach to creativity and problem-solving whereby different mindsets, backgrounds and perspectives come together to realise transformative visions of the future. DRS2020 celebrates these emerging synergistic approaches to design research and seeks to explore their exciting possibilities for addressing multi-faceted problems, supporting participation, and transforming problematic situations into desirable ones.

For DRS2020, we used an emergent approach to the development of the conference programme, with a general call for papers around five themes – Situations, Impacts, Co-Creation, Education and Processes. These themes emerged in discussions between the Organising and Programme Committees at an early stage of the conference planning and were felt to capture a broad spectrum of current design research topics from which we would be able to build more focused themed sections. Continuing the collaborative approach to theme building, we asked the international reviewers to indicate to which of these themes (or others) each paper contributed. Following the acceptance of papers, the reviewers' indications helped us to cluster the papers into the rich programme we have here, with the main conference theme of Synergy being an interwoven thread throughout.

Impacts and Co-creation are the biggest theme categories, reflecting the design research community's commitment to applied research. Situations are an emerging theme reflecting the community's increasing awareness of diverse circumstances and contexts. With Australia as the host country for DRS2020, it is worth noting that 12 out of the 144 papers mention Indigenous communities (108, 135, 165, 166, 177, 187, 198, 228, 277, 278, 387, 402). 32% of the accepted papers are from Oceania, 18% from Asia and 33% from Europe, compared with 5% each from Oceania and Asia and 64% from Europe at DRS2018. Themes such as pluriversal design and diversity, design for global health and wellbeing, collaboration, sustainability and education continue to attract new directions in research and illustrate the

potential of design research to change the world for the better. The theoretical foundation of research into (design) Processes continues to be an enduring theme, the development of which can be traced back through all previous DRS conferences. Some sections were additionally clustered by domain, such as graphics, mobility, experience design or data. A point to note is that the paper clustering differs somewhat between conference programme and these proceedings, as the former also needed optimising by time zones to allow presenters from around the world to interact in their session discussion.

A further way we grouped the papers was around existing themes of interest within the DRS: those of the DRS special interest groups (SIGs). These open and dynamic groups of DRS members form around current and emergent issues in design research, and they welcome participation. The DRS SIGs are one of the main ways that the DRS drives forward debates and keeps a pulse on ongoing topics as well as emergent topics of the day. The DRS currently supports eleven SIGs, all of whom have contributed to these proceedings by selecting and grouping just over a third (55) of the submitted papers into SIG themed sections. Some of these sections are chaired as sessions by SIG members at the conference. This way, the SIGs hope to give authors the opportunity to get to know the SIGs and their members and to get involved. The eleven SIGs are Health, Wellbeing and Happiness, Global Health, Design Pedagogy, Pluriversal Design, Design for Behaviour Change, Experiential Knowledge, Human-Object Interactions, Inclusive Design, Sustainability, Networked and Embedded Technologies and Design Innovation Management. While the SIGs selected their set of papers because the papers speak to current and future themes of the existing DRS SIGs, many more of the accepted papers also relate to the SIG themes and all authors are welcome to engage with a SIG. DRS members are also free to propose new SIGs. One of the aspirations of the DRS conferences is to catalyse the creation of new SIGs, through the collective community building and knowledge sharing which takes place.

Review

Despite moving to a virtual conference format, what stays a predictable constant is the academic quality of the work presented at DRS conferences. Our standards remain high, through the excellent work of the authors, our Programme Committee and the community of reviewers. The Programme Committee is appointed by the DRS and chaired by a member of the DRS International Advisory Council. We are privileged to have many eminent scholars in the design research community within our reviewer pool, but also early career academics who are supported in writing peer reviews, a core part of their academic development, and who form our reviewer pipeline for future conferences. We endeavoured to match reviewers' expertise with papers through topic selection and automation, with some manual adjustments. The reviewers provided feedback to authors on how to improve their papers.

In total we received 280 full paper submissions in a one-stage submission procedure, of which 269 were viable to go to review. In total the 192 reviewers wrote 553 reviews, using reviewer guidelines. The reviews averaged 350 words. Each paper received two, sometimes

three reviews. 87 papers (32%) were accepted with minor revision and a further 57 (20%) accepted following (major) revision. This represents a 52% acceptance rate. As in previous conferences, we used the ConfTool system to manage the submission process. The ability of authors to rate and comment on their reviewers as in previous years, helps to drive up the quality of the review process. The authors rated 237 (43%) of the reviews with an average of 4.4 on a scale of 1-5 on the criteria *justified*, *constructive*, *encouraging*, *fair* and *convincing*.

Words of thanks

DRS2020 would not have been possible without the contributions of many excellent people who have devoted their insight and experience to the conference. We would sincerely like to thank the Local Organising Team at Griffith University for their remarkable work in transforming the conference into a virtual experience, and the extra time, effort and resources that this has involved. In particular, undertaking this transformation 4.5 months before the conference launch has entailed a significant level of creativity, courage and perseverance. We also thank the DRS for their expertise and guidance in the programme and review aspects of the conference. The authors, the Programme Committee and all the reviewers all deserve thanks for their valuable time and expertise in ensuring the high academic quality of this conference, as well as the SIG convenors for their role in curating themed tracks. Finally, we thank Griffith University and the Design Research Society for supporting the conference.

We hope that you enjoy these proceedings, and that they provide a thought-provoking and inspiring read.

Stella Boess, DRS2020 Programme Chair
Ming Cheung, DRS2020 Conference Chair
Rebecca Cain, DRS2020 Conference Co-Chair

About the Authors:

Stella Boess is the DRS2020 Programme Committee Chair and a member of the DRS IAC. She has a design background and is Assistant Professor of Participatory Inclusive Design at Delft University of Technology and Director of the Inclusive Design Lab.

Ming Cheung is the DRS2020 Conference Chair. She is Professor of Experience Design, Director of Griffith University Centre for Design and Innovation Research, Head of Design Innovation Lab, and recipient of multiple research/teaching awards, with rich senior management experience in industry.

Rebecca Cain is the DRS2020 Conference Co-Chair and a member of the DRS Executive Board. She is Professor of Transdisciplinary Design and Associate Dean for Enterprise in the School of Design and Creative Arts at Loughborough University, UK.

Volume 5
Theme Processes

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Editorial: theme Processes

Stella BOESS, Rebecca CAIN

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(Design) processes are an enduring theme at DRS conferences, the development of which can be traced back through all previous DRS conferences.

In relation to (design) processes, we anticipated contributions on topics including roles, expertise and multiple voices, inclusion, experience, participation and power distribution, the role of communities and public and private organisations, innovation and management, and the building of partnerships in and for design research. All of these themes were represented in the submissions, but some of them have also found a good fit in other themes, such as Situations.

The papers presented in this section address (design) Processes in two ways: the first two sub-themes address it through high-level perspectives on organisational change and innovation. The five sub-themes that follow address processes through detailed and specific foci within design processes.

The first sub-theme of three papers, **"Framing Change",** offers high-level perspectives on how design processes (and their study) need to change to address current and future issues in society, and to even become more than design processes: they become intertwined with strategy and organizational processes. Paper 130 calls for the consideration of impacts of design processes at strategy rather than project level. The argument is illustrated with reflections on a case from 10 years ago. Paper 132 fittingly adds a methodological perspective by proposing theory to study design processes across levels. Paper 355 closes the loop towards a reflection on organizational change and learning processes.

In the second sub-theme, **Innovation**, each of the three papers present a different point of entry for analyses: products, individuals and collaborative systems. Paper 155 uses analysis of a company's design process together with its products as a method to reframe the company's core design DNA, whereas paper 260 takes the approach of identifying individuals with overlapping expertise in design and strategy to argue their potential of strengthening company design capabilities. Lastly, paper 332 focuses on the role and qualities (such as trust) of collaborative systems in innovation in organisations.

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The other five sub-themes in this theme, in contrast, all propose theory and methods for specific foci of design processes. Each section highlights a particular focus for which the contributions propose design process improvements through theory and tools. These foci are Experience, Behaviour, Spatial Movement, Perception and Form.

The papers in the sub-theme **Experience** offer pointers to design processes that improve user experience: 158, the usability of product galleries during online shopping, 205, designing for subtle communication modes in wearables for long-distance couples, and 234, a method to capture the temporality of user experience.

The papers in the sub-theme **Behaviour** contextualise such experiences in research methods and theory on behaviour. Paper 223 presents the Activity Scenario Modelling method to capture the joint agency of people and artefacts. Paper 232 has the same aim, and applies a phenomenological framing to behaviour observation. In paper 255, the focus is on the effects of not just artefacts but also the surroundings: “domestic clutter”.

What unites the next sub-theme of papers, is their attention to **Spatial movement** in a virtual environment in the context of games. Within it, papers 174 and 400 develop and review design guidance tools for students. Paper 224 contributes qualitative and quantitative analysis approaches to the spectator experience of augmented reality sports.

In the sub-theme **Perception**, paper 162 presents a careful analysis of the elements that influence the recognizability of graphic representations of bird species, a valuable building block when design engages with nature. Paper 311, a study conducted in the context of education, investigates architecture students’ visual attention with regard to various digital representations of spaces. Paper 395 complements the other papers by developing a theoretical model of similarity judgement.

Finally, in a sub-theme **Form**, Paper 164 proposes a morphological analysis process for rapid design using fuzzy analytics, applied to the design of consumer drones. Paper 382, again set in an educational context, contrasts the previous approach by emphasizing local values, usage patterns and rituals to a form finding process for tea glass sets in the Turkish context. Paper 383 develops a systematic design approach to nature-inspired product forms.

Following these focus-specific sections, two DRS Special Interest Group sections highlight papers that pertain to special interest areas of the SIGs Experiential Knowledge and Networked and Embedded Technologies. The SIG conveners highlight these papers in their editorials.

In reflecting on our expectations in calling for papers on (design) processes, we note that there is an emerging stream of papers within DRS2020 that seek to address the wider organizational context and how design researchers can tackle it. At the same time, the design research community consistently devotes attention to method and detail in the design process, thus supporting design expertise and competence.

DRS2020
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SYNERGY

Reframing and Strategic Transformation

Kees DORST[a]*, Rodger WATSON[a]*

[a] University of Technology Sydney, Faculty of Transdisciplinary Innovation, Australia
*Corresponding author e-mail: kees.dorst@uts.edu.au
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Abstract: As the problems and opportunities facing our organisations are becoming more open, complex, dynamic and networked, professionals are turning towards the designing disciplines to find inspiration for new ways of working. To really embed innovation, the impact of design should move beyond the project level and impact the strategy of the organisation, and possibly its processes and structures. In this paper we use a case study to investigate what design can do to help create such deep changes. The case study is an early social design project, which allows us to take a longitudinal perspective: ten years on, what has actually happened with the new frames and ideas of the initial project? What has followed? Has this project influenced strategic innovation? Or did it all come to naught? We discuss the lessons learned in this project to inform our understanding of the real impact of design, and its limitations. This leads us to posit a practice-based 'theory of change'.

Keywords: framing; social design; strategic transformation

1. Introduction

As the problems and opportunities facing our organisations are becoming more open, complex, dynamic and networked, professionals are turning towards the designing disciplines to find inspiration for new ways of working (Dorst, 2017). This is a sensible thing to do: after all, design situations do tend to be ill-structured and 'wicked', and as a result, designers have had to develop a set of practices, methods and tools to help them create novel solutions within such problem situations. But the need for new practices goes beyond the project level. To really embed innovation, the impact of design should move beyond the project level and impact the strategy of the organisation. To support such novel strategies, the organisations' processes and structures will have to be transformed in turn.

Thus, the challenge to design is to help create such deep changes, to create radical transformations on all levels. While the designing disciplines have a lot to offer that might be useful in such processes, there is a real danger of design over-extending, going beyond what it can do. Then promise and hope all too easily turn into pretence.

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As a first investigation of what design CAN do, and what the limitations of designerly ways of thinking are, we will perform a critical post-mortem analysis on a well-known social design project, executed by the Designing Out Crime research centre in Sydney. The case study of this early social design project has become an often-retold story that captures the imagination of designers and innovators around the world. But ten years on, what has actually happened with the new frames and ideas of the initial project? What has followed? Has this project influenced strategic innovation, and led to structural transformation? Or did it all come to naught?

We will discuss the lessons learned in this project to inform our understanding of the real impact of design, and its limitations. This leads us to posit a practice-based 'theory of change' (a model of the dynamic interrelationship between reframing and strategic transformation), as well as an agenda for areas in which further research is needed to bolster the impact of design on strategic transformation.

2. Context: Designing Out Crime

In 2008, the New South Wales government's Department of Justice established a Designing Out Crime (DOC) research centre together with the University of Technology Sydney (Dorst et al., 2016).

The DOC centre's remit is to use design practices to revolutionise the way we achieve safety and security in society. Prevalent problem-solving strategies in the area of safety and security are focused on the creation of countermeasures, introducing preventive measures and using strong-arm tactics to force people's behaviour away from unwanted/illegal patterns (Boutellier, 2011). Central to the Designing Out Crime approach is the pledge to avoid the creation of countermeasures, as these create a climate of wariness and fear that destroys the social fabric of our public spaces and our society. In its projects, the Designing Out Crime centre sees crime as a symptom and takes aim at the 'upstream' causes. The initial briefs formulated by the DOC partner organisations are often a direct result of their earlier problem-solving attempts, and these questions are almost always aimed at symptoms, rather than core problems. Questioning and reframing these briefs is the key to achieving innovative solutions.

Research into the way designers manage approach problem situations in new ways, has led to a frame creation methodology (Dorst, 2015). This starts with the acknowledgement that a problem has its roots in a specific context. To create a new frame that context needs to be critically looked at, its assumptions need to be challenged and it needs to be extended into a broader Field. The creation of new frames can be modelled as a process of nine steps (See figure 1).

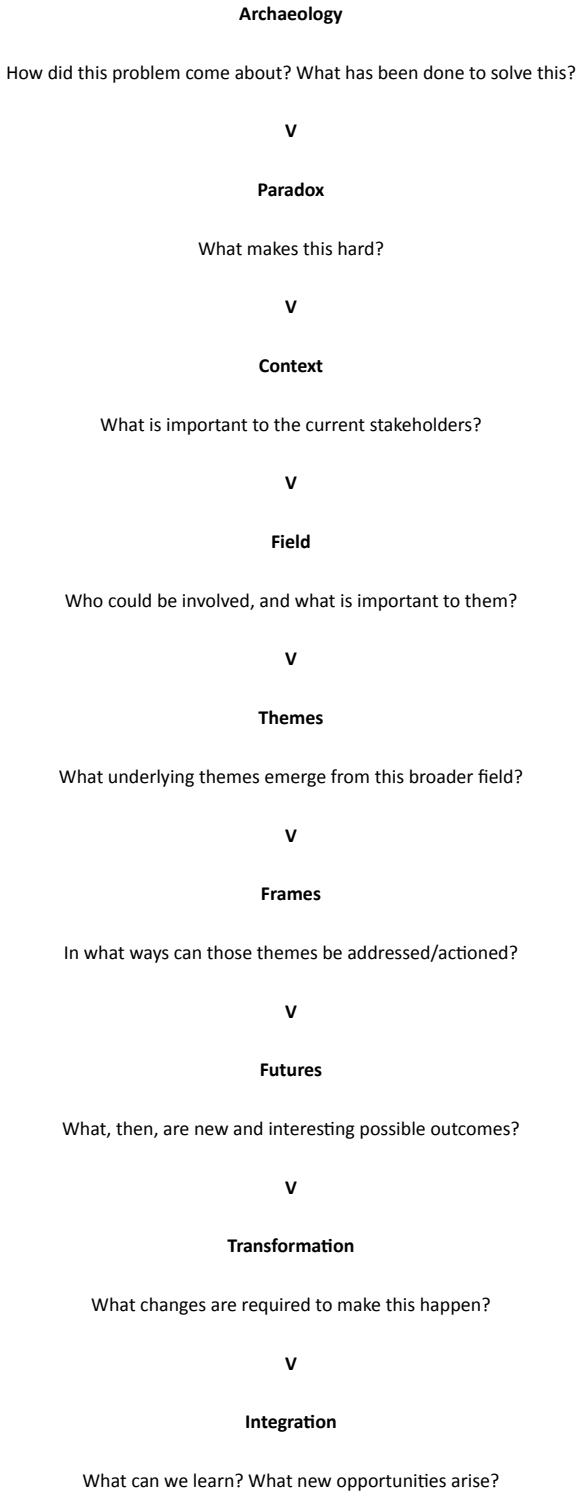

Figure 1 The nine steps of a Frame Creation process

Frame Creation is a process of thinking around the problem rather than confronting it head-on: it is the expansion of the problem space that allows new patterns to emerge. Central to the process is the fifth step, where an analysis of the values of the broader field of

stakeholders leads to the Themes from which new approaches (the Frames) can be created. The first four steps lay the groundwork, the latter steps explore the implications of the potential frames and proposed solution directions. For a detailed step-by-step description of the reframing methodology see Dorst et al. (2016, pp 162-179). The core of the Frame Creation process can be compressed in a workshop that itself normally lasts two to four hours. But this is a bit misleading: in a complex problem situation such a reframing workshop takes months of preparation and after the in-principle adoption of a frame, the path to action is often hard and long. New frames invariably disturb organisational cultures, processes, and structures that have been set up to support the conventional problem-solving in an organisation. Frames can also cut through organisational boundaries in unexpected ways – then there is a need to build a new network of organisations to support the creation and delivery of the chosen solution.

3. Research Method

This paper presents a *case history* (Bordens & Abbott, 2002) of the Kings Cross project. It draws on policy documents, public submissions to a government enquiry, media and consultancy reports and academic publications to put forward our observations of the evolution of the problem over a ten-year period. In putting forward these observations we also propose a theory of change model. This theory of change model provides a framework by which to critique the original Kings Cross project, identifying where things went wrong, or could have been done differently. The authors of this paper were leading the research centre at the focus of this study for the first 10 years of its existence. The case history and theory of change model in this paper are put forward as a meta-analysis of a body of work spanning more than 10 years, and the changes in how crime in the night-time was approached by governments over this time.

4. The original Kings Cross project

In 2009, the Designing Out Crime research centre was approached by the City of Sydney (the local council at the core of this big international city) to look into the problem of 'alcohol related violence' in Kings Cross, an entertainment district. The original project was led by staff from the Designing Out Crime research centre and involved a student group from the University of Technology Sydney's Faculty of Design, Architecture and Building under the mentorship of Sarah Gibson (Dorst, 2011).

The project in a nutshell (for a much more detailed description of this project and its outcomes see Dorst et al. (2016, pp: 14-19, 48-51, 162-179).

> The problem situation centres around Kings Cross, an entertainment quarter in Sydney. This particular area with its bars and clubs attracts about 30,000 young people on a good night. The issues include drunkenness, fights, petty theft, drugs dealing and later in the night, there is also sporadic violence. Over the years, the government has been using 'strong arm tactics', increasing the police presence and the putting in CCTV cameras. Clubs have been required to

hire security personnel. All this extra security has made for a grim public environment, yet the problems have persisted.

Designers from the Designing Out Crime centre quickly realised that the issues were presented to them by the local council as law-and-order problems, needing law-and-order solutions (this is the initial framing). The designers took a broader approach and studied the behaviour of the revellers in more detail. Key themes that emerged were that the people concerned are overwhelmingly young people (non-criminals) wanting to have a good time, and that they were becoming increasingly bored and frustrated as the night progressed. Paradoxically, they were not getting a good experience at all – a problem that was not helped by the security measures in place. The designers framed what were originally presented as crime issues differently by studying the themes in the broader problem situation and proposing a simple analogy: that this problem could be seen AS IF they were dealing with organising a good-sized music festival. This analogy immediately allows further exploration: what would one organise if one were to organising a music festival? This exploration in turn leads to new scenarios for action. Just to name a few, out of about 20 design directions that were sparked by this frame:

- Transportation. When organizing a music festival, one would make sure that people would be able to get there, and also leave again when they wanted. In this entertainment quarter, the peak time of young people coming into the area is about 1AM, and the last train leaves at 1.20AM. Getting a taxi takes about 2 hours, later in the night. So, once you are in the entertainment quarter you are basically crammed into a single road until the trains start running again at 6 AM. That leads to boredom, frustration and aggression. Apart from running more trains, the designers proposed as a fall-back position a system of temporary signage on the pavement, helping the party-goers to get to Town Hall station that has buses running throughout the night.

- Crowd control. In organising a music festival, one would also create chill-out spaces and continuous attractions, to make sure that people's experience does not completely depend on what happens on a single big stage. As it happens, this entertainment quarter has a few big clubs that form the main attractions. Young people that have visited a club and spill out on the street might find that the queue for the next one is too long and wander along with nothing to do. The designers proposed that this can be minimized by providing an app that tells people how long the waiting time for the next club is before leaving one. Some of the laneways around the central street can be opened up as rest areas, with water fountains and a relaxed "lounge" atmosphere.

- Safety and wayfinding. In organizing a music festival, one would have staff around to help people and keep an eye on safety. Over the years, the clubs have hired more and more security personnel and bouncers. The designers proposed a system of very visible young 'Kings Cross guides' in bright T-shirts, that help people find their way through the area and that are also approachable when help is needed.'

5. Impact on strategy, and structure and the sector

By its very nature, such a radical reframing (from 'alcohol related violence' to 'a music festival') cannot be implemented without having deep repercussions for the organisations involved. Such a reframing implies a change agenda for the stakeholders that have earlier framed the issue, defined the problem and kept it in place. For lasting impact, the Themes

and Frames that result from the frame creation process should lead to changes in the strategy of the organisations, and possibly their structures and processes. Radically new Frames can become harbingers of a new paradigm, they have the potential to transform the unwritten rules of the game in a whole sector (in this case: influencing the criminal justice system by presenting alternative crime prevention strategies).

A number of remarkable people within the City of Sydney local government quickly picked up on the possible role that they could play within the 'Music Festival' frame, and recast their organisation from being centred around the conventional local government roles, provision of infrastructure and rule enforcement, to become a 'conductor' of night life in the Kings Cross area. From this much more active, creative role they recalibrated their relations with a wide group of stakeholders that could be involved in shaping the future of the Kings Cross experience.

And they even went much further: the Music Festival frame is a nice metaphor to think with, but it has obvious limitations: (1) many elements of the complex Kings Cross environment cannot be captured within this frame (e.g. the experience of local residents), (2) this frame only applies to Kings Cross (which is only a couple of streets), and merely to a couple of nights per week, mostly in the summer months. For the City of Sydney to become a true conductor of nightlife throughout its local government area, it would need frames or development agendas for all of its different neighbourhoods – some are local entertainment oriented, others more touristy, and yet others are residential. These would need to be based on evidence as to the current state of the night life there, and of course involve the participation of citizen, local businesses and other societal stakeholders. The City of Sydney commissioned research into the night life (City of Sydney, 2011) and consulted with residents and stakeholders about appropriate ambitions and frames for the various areas going forward. This resulted in a comprehensive Open Sydney strategy (City of Sydney, 2013) that captures the local ambitions and translates them in hundreds of action points for the short, medium and longer term. These action points in turn resulted in more projects being commissioned to explore possible futures in Kings Cross and other parts of the city.

Some of the new Kings Cross projects that the Designing Out Crime research centre was involved in built on the original reframe (the 'music festival'), others were much more detailed and specific. For instance, one project focused on the problem of violence: to a degree the groups of young men get into fights because they want to fight, as part of their specific group culture as they establish a hierarchy within and between groups. The reframing here was based on the realisation that the key Theme behind this behaviour is competition, not violence per se. Creating other arenas for competition, like urban sports, helps them achieve these goals by less violent means. And as it turns out, they are quite happy to compete in these less harmful ways.

The original 2009 Kings Cross project was done in collaboration with the Safer Sydney unit of the City of Sydney as the commissioning party. In the years after the project, this unit spun out the 'The Night-time Economy team'. This team takes a much broader and more

comprehensive and inclusive view of the meaning, significance and the value of nightlife in a big international city like Sydney. The dollar value of the economic transactions of the city at night has also become part of the bottom line, in 2019 Sydney's night-time economy is $27.2 billion per annum (Deloitte, 2019). The Night-time Economy team set about implementing many of the recommendations of the Kings Cross project.

The Kings Cross case study story has travelled really well, in professional practice and in academia as an early example of social design, and a successful case of design contributing to public sector innovation (Bason, 2018). It has had a widespread international influence.

The project itself has had direct influence on the thinking about nightlife in cities like Vancouver, New York, London, Cardiff, Manchester, Edinburgh, Paris, Amsterdam, Berlin. Direct follow-ups for the Designing Out Crime team include invitations to projects in Amsterdam, Eindhoven, Seoul, Hong Kong, among other places. The founding director of the Night-time Economy team at the City of Sydney won a Churchill fellowship to study best practices around the world (Matthews, 2009). In parallel, the Night Mayors movement emerged to help cities think about the importance and potential of the nightlife in a city. In 2019, this movement had spread to 40 cities across the world (Seijas & Gelders, 2020). This in turn has led to an international series of 'Global Cities after Dark' conferences, sharing practices and lessons on the creation of a thriving night-time economy from around the world (www.globalcitiesafterdark.com). Through the impact the movement is having and the discussions it is enabling, the movement is sharpening the emerging role of the Night Mayors. Part of this discussion is recognising the various roles that they play (regulatory, advocacy, etc.) in curating the night-time as a space for 'trust and identity building' (ibid).

6.Tragedy strikes

6.1 Incident and response

But then in 2012 and 2014, two young men were killed in separate unprovoked one-punch attacks in Kings Cross. These very tragic deaths were of course discussed in the media, which put pressure on politicians to create new countermeasures to clamp down on the 'alcohol related violence' in Kings Cross. In response, the state of New South Wales introduced so-called "Lockout Laws" (not changing the mandatory closing times, but basically preventing people from (re)entering a pub, café or restaurant after a certain time and limiting the service of alcohol) that covered a large part of the City of Sydney local government area including the city centre and Kings Cross. These laws served to make these areas very unattractive (no smoking outside, no pub crawls, not getting food), and effectively killed the nightlife. Restaurants, cafes, nightclubs, pubs and shops left the area or went bankrupt. In total, 176 establishments closed as a result of the lock-out laws (Taylor, 2018). The changes in Kings Cross meant that other, more suburban areas of the cities became busier, stretching the local infrastructure. Clearly a case of shifting the problems, rather than resolving them – although inadvertently, this shift might actually have brought down the overall violence in

the Sydney metropolitan area, as youth from the different suburbs stopped using Kings Cross as a central arena to meet.

The sad irony behind this state of affairs is that the Lockout Laws would not have prevented the two one-punch attacks, as those were both earlier in the evening before the lockouts would have taken place. Yet in the political scheme of things, that did not seem to matter.

The introduction of the Lockout Laws led to ongoing protest from Sydneysiders, the community and business owners in the area. A political party was created to advocate for their repeal. This sparked an impassioned societal discussion on what being an 'international city' actually means, what the role is of night entertainment in the life of a city, and how we as a society support young people going through the confusing years then they are coming of age, etc. The City of Sydney actively facilitated these discussions through platforms like *sydneyyoursay.com.au › openandcreative* while advocating for 'Sydney as a 24 hour city', commissioning research on the state of the 'night-time economy' to benchmark with other major cities around the world. The New South Wales Government also commissioned its own research into the matter. After a public inquiry that attracted more than 200 submissions, see for instance City of Sydney (2019), the Lockout Laws were largely repealed in 2019.

6.2 Reflection: what happened?

There are a number of lessons that can be learned from this unfortunate course of events.

In retrospect, there were three flaws in the original Kings Cross project… (1) The DOC centre designers had not realised that in commissioning this project, the City of Sydney was taking on a responsibility that was actually shared with several departments in the New South Wales government. Not involving those departments turned out to be a fatal omission. (2) Secondly, the DOC centre designers didn't involve the media in the project, and hence didn't influence the societal discussion on Kings Cross. When the tragic deaths happened, that discussion naturally started where it left off - from the old frame of 'alcohol related violence'. (3) The most influential voice in the whole societal discussion were the emergency room doctors at nearby St Vincent's hospital – they advocated for the Lockout Laws with all of the moral authority that comes with their profession. Again, the DOC centre designers had not involved them in the original Kings Cross project.

These hidden assumptions in the original project were called out. In the years since, the societal discussion has moved on, and the NSW Government has been reflecting on the appropriateness of the Lockout Laws as a response to the situation in Kings Cross. It is clear that there now is a much more resilient and robust societal discussion and a better context to really change the situation in Kings Cross for good.

7. A theory of change

There are several sides to the Kings Cross project story: on the one hand, there is the emergence of a compelling frame that captures people's imagination and leads to success

on project level – but on the other hand, we can see how difficult it can be to create real and lasting change.

Thoughtful design projects in which the frames we use to define the problem in the first place are called into question and alternative framings emerge can and should lead to changes in the practices of the organization, strategy of the organization, and inform changes in its structure and processes. Radically new frames have the potential to transform the unwritten rules of the game in a whole sector (see Figure 2).

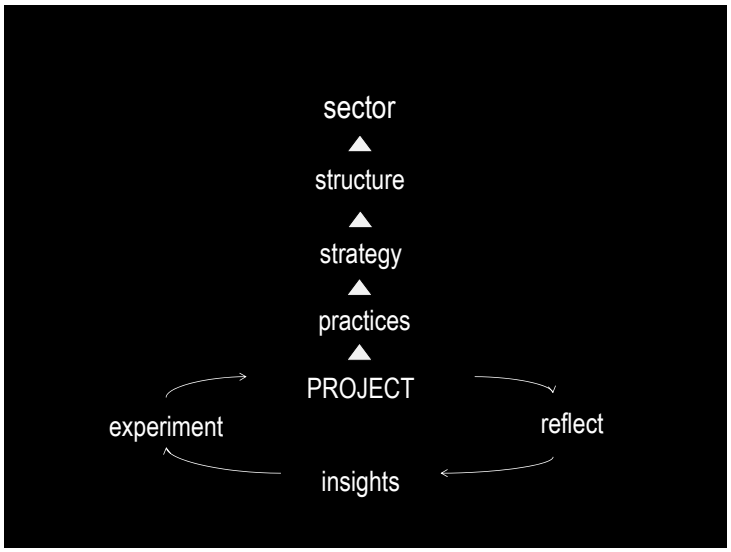

Figure 2 From reframing project to impact

But this hardly ever happens because these great insights come from bottom-up, while the strategic thinking is usually determined in a top-down process: the sector or organisation reacts to what is sees as its relevant context (the 'Field'), and adapts its structures and strategies accordingly (see Figure 3).

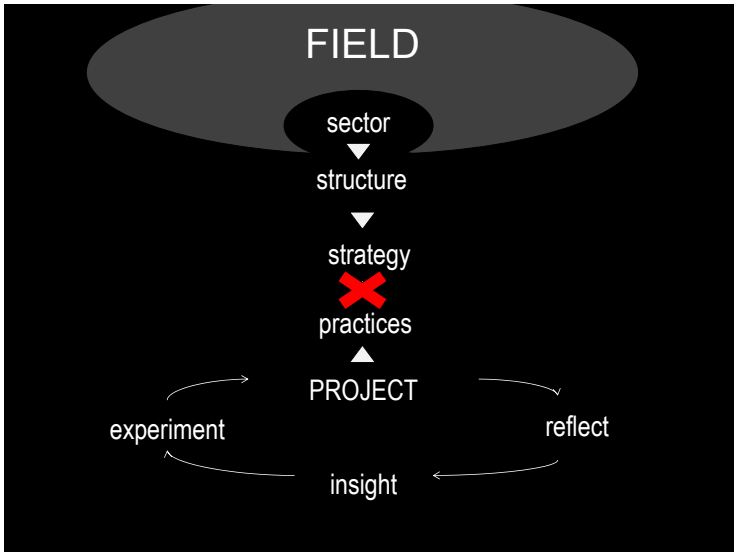

Figure 3 The blockage that comes from the top-down approach to strategy formulation

This blockage in the innovation system can be bypassed by using the insights that come from the projects to directly influence the Field. This creates a new dynamic, combining the two movements: as the insights that come from the projects are used to create a new Field, the sector adapts to this new Field by using its normal top-down adaptive processes, and meets the bottom-up movement halfway (see Figure 4).

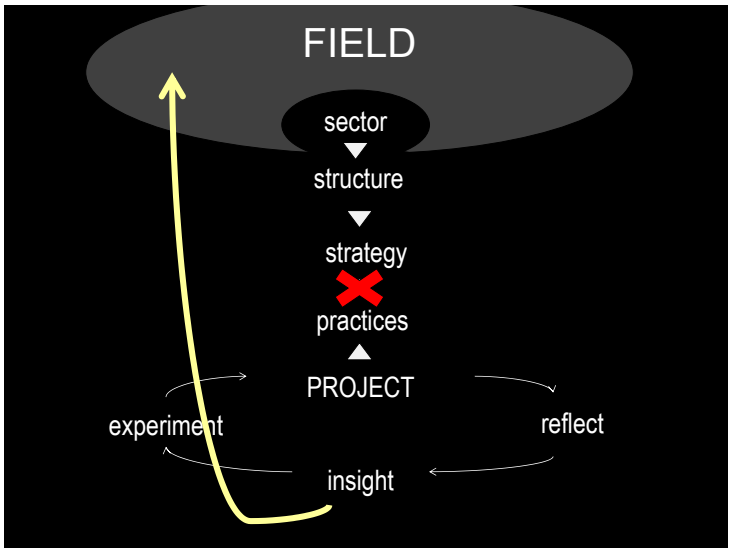

Figure 4 The Dynamics of Reframing and Strategic Transformation

We have encountered the different levels of this model at play in the aftermath of the Kings Cross project.

8. Conclusion: reframing and strategic transformation

What are the lessons we can draw from this extended case study-cum-aftermath to help us

understand what design can bring to such open, complex, dynamic and networked problem situations, what are the pitfalls, and where do we need practices from other fields to augment what design can bring?

In retrospect, we can now see clearly that in the initial project, as designers we made the familiar mistake of being too focused on the project level. And as we have said earlier, the project team completely missed some of the major stakeholders – never a good idea (see section 5). And the vulnerability of the solution was exacerbated by the fact that they weren't very inclusive of the stakeholders they did work with, not really pulling them into a co-creation process. This was not by accident – they were making the classic design call in trying to get away with it, by staying under the radar, and assuming that the elegance of the reframe and the resulting ideas would be so compelling that this in itself would create the space for change needed for implementation. In a way they were lucky that the City of Sydney had a much more inclusive approach. But even so, despite with the positive developments in the aftermath of the project, including the advent of the Open Sydney strategy and the organisational shift to the Night-time Economy (incredibly rare), the solutions proved to critically vulnerable because the societal discussion had not moved on. For real change to occur, all levels in the model of Figure 4 need to shift into a new alignment. This means that if design is to have lasting impact, it will need to learn how to strategically work across these levels.

For design to reach its full potential to reframe issues and create real change it needs to rethink some of its own assumptions, that come from its long history as a professional field (this is only natural: after all, dealing with such complex social issues we are using design practices for something they weren't conceived for). We have already outlined some of these above, in describing the shortcomings of the original Kings Cross project – but the list of assumptions is much longer. They include, an underestimation of the importance of the client role (Dorst, 2019), difficulty in allowing expertise from other professional fields to influence the course of the project, a potential problem in dealing with high levels of complexity, the fact that design tends to ignore the existence of power. Design tends to create a bubble in which a creative process can flourish, but in doing so it also creates a difficult interface with the broader organisation.

What is clear from this case study is that in order to achieve strategic transformation, design needs a theory of change beyond the project level and beyond the bottom-up approach that it traditionally applies. The fledgling model presented in Figure 4 can be a basis – at least it maps some of the layers to be traversed, and in this case study it has helped us build a close understanding of what could possibly go wrong. Other models from innovation management (Liedtka, 2017), change management (Schaminee, 2018), and public sector innovation (Bason, 2018) can all shed light on the position that design find itself in as it is moving into this important but incredibly complex problem domain. This is the moment to very closely collaborate with these fields.

To deliver on the promise of social design, (Tromp et al., 2019) design will need to change to

meet these challenges, move beyond project-level solutions to change the practices, strategy, structure, and change the thinking in the sector.

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About the Authors:

Kees Dorst, educated as an Industrial Design Engineer (TU Delft), founded the Designing Out Crime research centre at the University of Technology Sydney and is Professor of Design Innovation at that university's Faculty of Transdisciplinary Innovation. He lectures at universities and design schools throughout the world.

Rodger Watson, a practicing psychologist and criminologist, was Deputy Director of the Designing Out Crime research centre, University of Technology Sydney. He founded the Master of Creative Intelligence and Strategic Innovation there and is a Visiting Research Fellow at Central Saint Martin's College, University of the Arts London.

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The Future of Design Process Research? Exploring Process Theory and Methodology

Frithjof E. WEGENER[a]*, Philip CASH[b]

[a] Department of Design, Organization and Strategy, Delft University of Technology, The Netherlands
[b] Technical University of Denmark
*Corresponding author e-mail: f.e.wegener@tudelft.nl
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Abstract: Design processes are at the heart of design research. Current design research at the micro- and macro-level has led to profound insights about designing. However, missing are design process research approaches that are able to theorize between (meso-level) and beyond levels of analysis. This fragmentation of process research and theory across levels hampers research synthesis and theory development. In this paper we illustrate the limitations of current design research methodologies to analyse and theorize process. Specifically, the issue lies in the challenge of analysing and theorizing the temporal embeddedness of data in the overall design process. We introduce a Process Theory agenda for future design process research focused on the meso-levels as the mediator of interactions between design processes across levels. As such, this paper contributes a novel characterisation of a critical challenge in design research, proposing process theory for addressing this.

Keywords: design process; research methodology; process theory; conceptual model

1. Introduction

Design process models, such as co-evolution (Dorst & Cross, 2001) or the double diamond (Design Council, 2015) have had a profound impact on both practice and scholarship in design. Thus, process research critically shapes the work of practicing designers as well as students, and forms a fundamental aspect of theory development in design research (Daalhuizen, 2014).

Despite the importance of design process research, there has been significant fragmentation in the literature across levels, particularly between micro-level design cognition and macro-level design management perspectives (Cash, Skec, & Storga, 2019). This has led to three major challenges in current design process research. First, lack of meso-level studies that connect across levels. Second, a corresponding lack of research method development at this level, particularly in contrast with developments at the micro- and macro-levels (Cash

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et al. 2019). Whereas protocol studies may be robust for analyzing aspects of shorter design sessions (around 90 minutes), and ethnographic and narrative approaches may be strong for analyzing a complete design process (several months), what is missing are approaches that can link the micro strength of protocol studies with the macro strength of ethnographic and narrative approaches. Third, the above challenges have led to a lack of theoretical sophistication at the meso- level. Even if data is collected about the design process, analysis and theorizing of such data tends to either adhere to a variance analysis leaving out the process elements, or lack the empirical grounding and reflexivity needed for a deeper process analysis. This would require analysing and theorizing the design process, by appreciating how actions and their consequences in design have an influence over time, highlighting issues like path-dependency or interactions across levels of analysis. These limitations of existing design methodologies hamper research synthesis and theory development, as well as negatively impacting our ability to deliver design theory that considers interactions across levels (Cash et al. 2019). Thus, there is a critical need to better understand the nature of these challenges in design research, and further, to identify potential lenses for developing integrative, meso-level perspectives on the design process. We argue that there are opportunities for more process analysis and better theorization from data

Given this need we aim to develop a framework for better understanding the fragmentation of perspectives in design process research, and subsequently identify potential ways forward rooted in meso-level process theory (see e.g., Cash et al., 2019). Based on methodological review, ‘for which we picked the dominant research methods for studying design processes to illustrate the point and show the research space. The review is not intended to be exhaustive, but rather a conceptual development approach well suited to situations where current theory is sparse (Handfield & Melnyk, 1998), we contribute a novel characterisation of process research in design, as well as proposing a new theoretical lens for addressing this. This both extends design theory in this area, and points to critical opportunities for improved design support across levels.

The structure of the article is as follows. We first develop a conceptual framework of different design process levels and delineate variance from process theory. Based on this framework, we then develop a typology that describes current approaches to the study of design processes as well as their strengths and weaknesses in light of our conceptual framework. Following this we develop a process theory based agenda for future design process research.

2. Conceptual Framework: prospects for bridging micro- and macro-level theorizing about the design process

In the following, we introduce a conceptual framework for understanding perspectives on study of design processes. For this we delineate micro- and macro-level processes and introduce the relevance of meso-level interactions between micro- and macro-level. Next,

we delve deeper into process analyses and theory as a distinctive form of theorizing. Our aim here is not an exhaustive review, but an illustration of the larger point of a lack of meso-level research and how this relates to the issue how to analyse and theorize process itself. Given the relevance of insights from psychology and organization studies for design, we mainly draw from there to illustrate our conceptual framework.

2.1 From Micro-Level to Macro-Level Design Processes

Generally speaking, we can differentiate between the content process of design and five hierarchical levels that influence both content and each other. We build a conceptual framework to delineate these processes as micro-, meso- and macro-level (Cash et al. 2019). Critically, this multi-level conceptualisation allows for interactions between individual cognitive processes and organisational managerial processes (Leenders & Dolfsma, 2016), with emergent effects developing as smaller level phenomena propagate into larger level effects (Marks, Mathieu & Zaccaro, 2011; Wiley, 1988). For example, interaction across levels could be here at the individual level the staunch actions of a designer, who engaged in user testing and found the prototype not to be working as expected. At the meso-level these results lead the team to discuss the way user testing was done, convincing them that they need to redesign parts of the prototype. However, at the organizational level when management heard of this they decided that this costs too much time and money and to go ahead, seeing that the user test only involved ten users. Thus, these levels are differentiated for analysis, yet closely linked.

On the micro-level of the design process, we have the content of design, the individual designer, their activity (Kozlowski et al., 2016; Wiley, 1988) and the situation they are facing (Suchman, 2006). The content of design refers to the design itself as it changes over time. This process is often tightly interwoven with the individual level. For example at the individual level, we can study the design process that an individual goes through the role of uncertainty perception and how this leads to prototyping (Cash & Kreye, 2017; 2018).

At the meso-level, work in psychology (for a review see Hülsheger, Anderson & Salgado, 2009) or organization studies (Garud, Tuertscher & Van de Ven, 2013) has shown the importance of teams. To illustrate for example from a more organizational perspective, the meso-level plays an important role as organizations struggle with their core rigidities (Leonard-Barton, 1992), teams and projects allow an organization to develop and try new approaches, products or services. From an psychological perspective, here we go beyond the individual to look at the design process that a team goes through, especially interaction between individuals in a team (Kozlowski et al., 2016) and emergence in team processes (Kozlowski & Ilgen, 2006). Learning plays another vital role here, but this learning becomes more explicitly social process (Elkjær, 2004). Next to learning, we find here the team dynamics as well, with politics, identity or conflict making a pronounced entrance into the design process.

At the macro level the unit of analysis changes. Here the focus on the interactions between

teams/departments/functions (Kozlowski et al., 2016; Wiley, 1988), the interactions with the organization and wider social structures (Gorman, 2014; Salvato & Rerup, 2011). While not all of the organization might be involved in the design process, the design process is influenced by the organizational situation that surrounds it. Think here for example of the way decisions are being made that impact the design process, the way that culture and existing ways-of-working might clash with a design process, or how organizational capabilities can help and hinder a design process. Especially in the last decennia, the role of design beyond a single organization and design in systems have played a more important role. As design increasingly happens in between organizations and in systems, we see new dynamics occurring in the design process Cash, Škec & Štorga, 2019). In design research, such processes are studied under the umbrella of networked innovation, open innovation or innovation ecosystems.

2.2 Variance Theory versus Process Theory

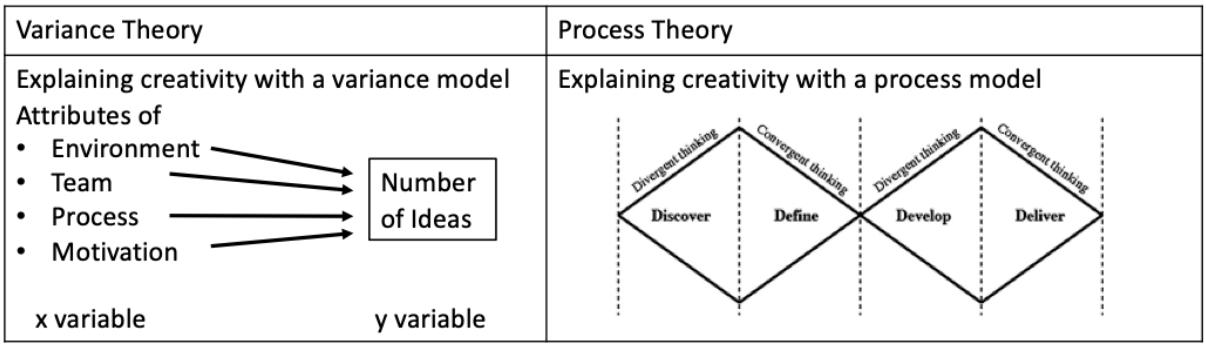

Figure 1 Comparison of Variance and Process After Mohr (1982), Langley (1999) and Design Council (2008/2015)

Generally speaking, the majority of research approaches follow a variance analysis. Scholars investigate the co-variance between dependent and independent variables (e.g. effect of X on Y). Underlying such research is a perspective on reality, where reality is made up of "things" studied as "entities". Such a perspective highlights outcomes, products, and continuity. Variance analysis is strong at testing theoretical propositions and through that well suited for theory testing. Variance analysis relies on statistical generalization to go from specific data to general implications for the phenomenon under study (Langley, 1999). For example, much of the work on shared understanding or creative constraints has been variance-based.

Instead, a growing movement of scholars in a wide range of scientific fields like strategy (Langley, 2016), innovation (Garud et al. 2013), or learning (Gheradi, 2006), have started investigating phenomena from a process perspective (e.g. analysing design process over time). Process analysis excels at developing theory while being relevant to practice through staying close to practice (Langley & Tsoukas, 2016). A key challenge though in process research is developing research methods that allow for appropriate analysis and theorizing

of processes (Langley, 1999). Trying to analyse and theorize a process, but applying variance methods is inappropriate, as process research requires different modes of thinking, analysing and theorizing (De Cock & Sharp, 2007; Helin et al. 2014).

Regarding methods, while quantitative process research is possible, process research tends to rely on qualitative methods for data collection over time and use theoretical generalization. Process theorizing puts process central to investigate how issues emerge, change and disappear over time (Langley & Tsoukas, 2010; 2016). The hallmark of process theorizing is starting with "how" questions, rather than "what" or "why" (Langley et al. 2013). By taking time and timing serious, process theorizing takes into account relationships, path dependency and focuses research on how things change (Langley & Tsoukas, 2010; 2016). To illustrate, think of how the initial framing and reframing during a design project by individuals can help the reframing process of a design team, but such reframing might be more difficult when facing the political realities of pitching a design at a top management team. To be able to understand this process, requires analysing the process in a way that is analyses the temporal order and theorizes how certain actions led to certain consequences. Rather than seeing things as static entities, process research focuses on the dynamic, the ephemeral, and the novel (e.g., Leenders, Contractor, & DeChurch, 2016; Navarro, Roe & Artiles, 2015).

Theory and methodology are importantly intertwined. Regarding theory, there are several existing theories in design that follow this process analysis, reflecting the importance of the design process to design research. The double diamond (reference) has played an important role in design practice, especially in design education. An example of a process theory is co-evolution, where a process perspective on problem and solution co-evolution points out how both problem and solution not only change throughout the process but also that the changes often relate to each other, as new insights about the problem can point out new possibilities for solutions.

Building such process theory requires research methodologies that allow for process analyses and theorizing. An example would be Linkography (Goldschmidt, 1995), which is explicitly interested in the design process. Two aspects are important for process methodology. First, to be truly process though, data needs to be collected throughout the design process and the temporal embeddedness of data needs to remain central in analysing the data. Throughout the theorizing process, the temporal order of events is central and theorizing focuses on how events at different times in the process affect later parts of the process. This means that even if data was collected of the process, this process element of the data can get lost if analysis and theorizing of the data do not take into account the process nature of the data. Therefore, a process perspective is arguably well suited to study the dynamic, ephemeral and novel aspects of the design process. In the following, we discuss existing approaches to study design processes and highlight the limitations regarding micro- versus macro-level and their interactions as well as variance versus process analysis and theorizing.

Thus, we are again able to distinguish research perspectives between variance and process

analysis. Bringing this together with the levels described in Section X we are able to critically evaluate current work in design research on these two dimensions: variance vs. process & micro- vs. macro-level.

3. Current approaches and their limitations to study design processes: levels, analysis and theorizing

There are three major approaches to the study of design research that we will discuss in this section in reference to our proposed conceptual dimensions: protocol studies, ethnographic approaches and narrative approaches. We chose these three approaches as they are prominent approaches to study design processes, but as we will argue, the way these methods are currently applied are problematic regarding dealing with levels, analysing and theorizing of the design process itself.

3.1 Protocol studies

Building on the work of Ericson and Simon (1993) protocol studies have had a profound impact on design studies. Protocol studies investigate design processes in terms of verbal exchanges, cognition, and behaviour (Hay et al. 2017), primarily of individuals but also teams. This typically covers processes enacted in a matter of seconds, and with study durations in the range of minutes to hours. As such, protocol-studies are concerned with micro-level processes in design. In terms of analysis, protocol studies typically rely on detailed statistical analysis, drawing on variance analysis. This has resulted in, for example, work on design cognition highlighting conjecture-based problem formulation, problem solution co- evolution, analogical reasoning, mental simulation, fixated solution generation Ball & Christensen, 2019) and the role of uncertainty perception in the design process (Cash & Kreye, 2018).

Strengths:

- Due to the variance analysis underlying such protocol studies though, protocol studies are better suited for testing theory, rather than constructing new theory
- Protocol studies excel at analysing the micro aspects of design sessions

Weaknesses:

- Methodologically protocol studies are challenging to scale-up to include more participants or longer time-frames (Hay et al. 2017)
- Theoretically it is difficult to relate insights from the micro level of protocol studies to the macro level of longer design processes

3.2 Narrative approaches

Next to protocol studies, a different approach is narrative methods. Here, design scholars capture a narrative of the design process as it develops over time, highlighting the moments

that were impactful for the overall narrative of the design process. Data analysis often done qualitatively and inductively. Where protocol studies excel at finely grained micro-level analysis of individual sessions, narrative approaches are better suited to study the macro-level of longer design processes, e.g. 6 months Going from descriptive narratives to good theory, requires a deeper sensitivity to the underlying processes at work (see e.g., Pentland, 1999; Langley & Tsoukas, 2016; Pentland & Feldman, 2007).

Strengths:

- Developing rich theoretical insights, by connecting the dots across a longer lasting design process
- Narrative research is close to the experience of designers, meaning such theorizing can be more relatable and meaningful (Weick, 1999)

Weaknesses:

- Lack a detailed account of how the narrative is grounded in the empirical data, especially considering the plurality of narratives that different people would tell
- While the content is there, it is not clear how the content process and the narrative have influenced each other

3.3 Ethnographic approaches

Lastly, we have ethnographic approaches. Originally stemming from anthropology to study cultures and drawing on fieldwork of finely grained analysis from observations, interviews and fieldnotes, ethnographic approaches in design have led to a better understanding of the social and practice elements of design. Ethnographic approaches can be used at different levels. For example at the micro level ethnographic methods can be used to study design practices and the situatedness of these practices. At the macro level, ethnographic methods can also be used to better understand design processes. See e.g., Lok & De Rond (2013) for an example of process ethnographic approach. Data analysis happens inductively, but not necessarily analysing the process explicitly.

Strengths:

- Develop rich theoretical insights that are useful for theory construction
- Strong situatedness of design and descriptions of actions of designers

Weaknesses:

- Ethnographic approaches as currently applied within design studies leave time largely out of the analysis
- Ethnographic approaches were invented to capture collective culture. When applied to design, ethnographic approaches can lose the role of the individual

3.4 Positioning Current Approaches on the two dimensions

Bringing these insights together we are able to position each approach with respect to our dimensions in order to highlight a number of key challenges for design process research. We argue that protocol studies excel at analysing micro-level processes using variance analysis, that lack analysis and theorizing across time. While current ways of applying ethnographic and narrative approaches excel at studying macro-level processes. Here we argue that ethnographic approaches are more inclined to employ atemporal analysis akin to variance analysis, while narrative approaches are inherently temporal, but the necessary analysis and theorizing of the process itself is missing. Studying "process" requires an analyses of the temporal embeddedness of that data. Or the other way around, just collectinf data during the design process and depicting a theory as a process, does not mean that the data was analyzed and theorized regarding its temporal embeddedness in the design process. Therefore, we argue that all three approaches as currently employed in design studies have serious limitations regarding the prospects of furthering our understanding of the design process. Figure Y positions current approaches in respect to our typology.

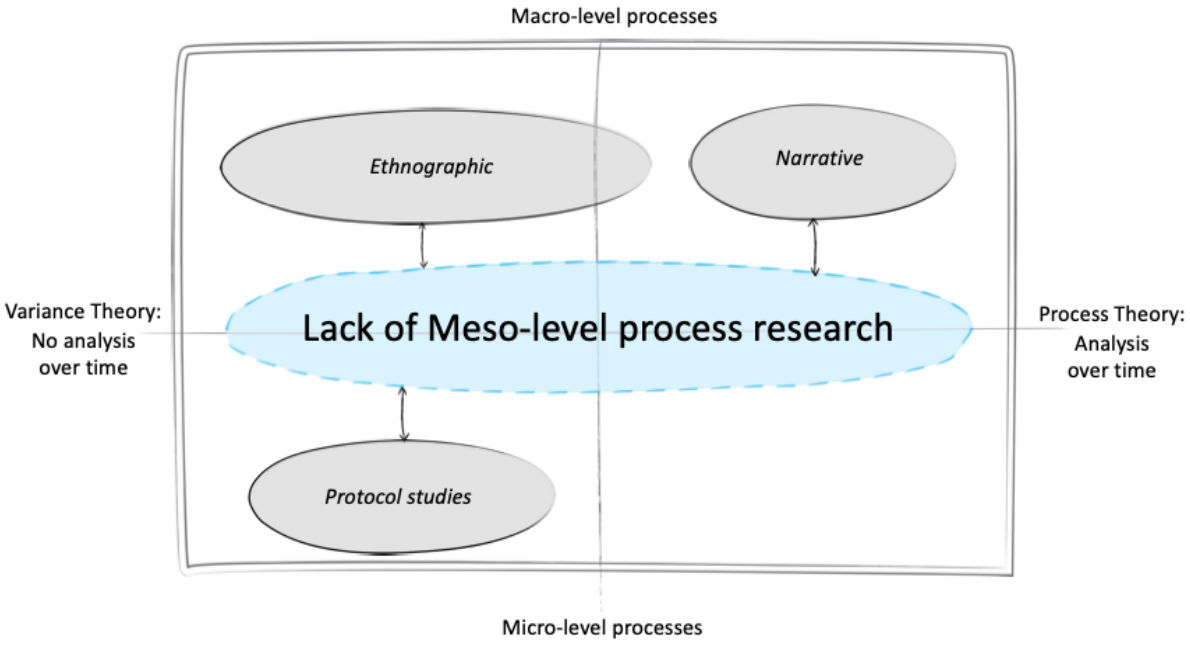

Figure 2 Overview of typology and methodologies

We conclude that there are four major research challenges for furthering our understanding of the whole design process. First, we need to develop research methodologies for design studies that take time, timing and temporality more serious, by empirically grounding research in time. Second, a consequence of the first challenge is that we need a more sophisticated theorization of path-dependency and emergence throughout the design process. Third, we need a better understanding of interactions across levels in the design process (Cash et al., 2019). Fourth, we need to develop or adapt research methods to

capture the design process in ways that are meaningful to practitioners and theorists alike (e.g., Wegener & Lorino, *in press)*.

3.5 Limitations

Before we continue with the future research agenda, we need to address the limitations of our current paper, some of which can be addressed by future research. The most important limitation is that the paper is not intended as an exhaustive review of the literature. Given the word constraints of a conference paper, such an exhaustive review was not possible. This would have required a more systemic reviewing approach, which would be a next step. Both on the issues of process theory and process methodology a more in-depth analysis is required to work out the differences between current research methods and their applications in design and what is required in methodological innovation and theorizing. By developing an illustration of a new perspective on research and design processes, we want to highlight the issues, rather than a building an exhaustive argument on what process theories and how to apply it to design research.

4. Towards a future research agenda for studying the design processes

Given the challenges and position outlined in Section 3 it is possible to identify process theory as a potentially important perspective for design research, allowing design scholars a more comprehensive understanding of the whole design process and creating theory that captures the design process. Discussions of the role of the design process and its relation with methods has a long history in design studies (see e.g. Jonas et al. 2010). We see an opportunity similar to the work of Karl Weick (e.g., 1977; 1979; 1995; 2004) for organization studies, whose work took organization studies from focusing on the outcome "organization" to highlighting the processes of organiz*ing*. This seemingly simple change has led to profound repercussions in how organizations were understood, leading to work highlighting the process in strategy (Mintzberg, 2007), innovation (Van den Ven, 1992: Van den Ven & Poole, 1995; 2000) decision making (March, 1994) or organizational change (Pettigrew, 1985; 1990). In order to generate such process theory though, required methodological development. Existing research approaches needed to be adapted for studying the process of how the phenomenon unfolds over time. For example regarding innovation the work of Van den Ven (1992) and Van den Ven & Poole (1995; 2000) was an important stepping stone, as their work was initiated by the conceptual questions on what process is and how to design research in line with a perspective of what organizational processes are (Van den Ven, 1992). This was followed by a theoretical discussion of processes of change in organizations (Van den Ven & Poole, 1995). Their work culminated in an extensive research program of what the management of innovation entails, comparing processes across different contexts (van den Ven & Poole, 2000).

Here we need to contrast our future research agenda from other research that seems similar,

but has other goals. To illustrate, we employ a recent paper combining ethnographic with narrative approaches (Celikoglu, Krippendorff & Ogut, 2019). While interesting in itself, this study shows that although data is collected during the design process, in the analysis the design process itself is not analyzed, but contingency analysis and qualitative content analysis. Both analysis approaches turn qualitative process data into quantities that are analysed according to a variance logic.

We think that the field of design is also ripe for a similar development to organization studies, where instead we take the notion of "design process" more seriously and adapt existing methods to capture, analyse and theorize the process more extensively. Theorizing process in design, would mean going from a focus on the outcome of design–"the" design–to focusing more on the design*ing* and how the designing and the design interacted over time. Process theorizing is therefore interested in how a design changes through the design process, in the flow of design, in the agency of the designer and prioritizes the design process over only focusing on the outcome (Langley & Tsoukas, 2010). Regarding analysed the design process, it would mean that the temporal embeddedness of data, what comes before and what comes after, has to become central to the analysis process. This leads to a number of changes for theorizing. First, process theory is focused on the events in a design process (e.g., Leenders, Contractor, & DeChurch, 2016) rather than the change of variables. Second, process theory strives to understand the final causes of how a design came to be, rather than understanding efficient causes as variance theorizing does (Mohr, 1982). Last, process theorizing takes timing seriously, meaning that the order of time in which events happened becomes crucial for understanding the design outcome (Langley & Tsoukas, 2010). This switch we call for is nicely summarized by Garud, Jain & Tuertscher (2008): "This suggests a change in the meaning of the word 'design' itself — from one that separates the process of design from its outcome, to one that considers design as both the medium and outcome of action." (p. 351). Taking this together with our review of current approaches it is possible to identify four major themes for future design process research. For each we first describe these four themes and provide two exemplary research questions.

4.1 Exploring development of more process research methodologies fit for design studies

Similar to the methodological developments needed in other fields for process research to fulfil its potential (e.g. Langley, 1999), design researchers also need their own methodological development to further process research through process analysis and process thinking (De Cock & Sharp, 2007). Taking time and timing seriously is a considerable methodological and intellectual challenge (Langley & Tsoukas, 2016), which requires exemplars for design scholars to emulate and adapt in their own inquiries into the design process. Examples from Organization studies for narratives are Tsoukas & Hatch (2001), Pentland & Feldman (2007) or Pentland (1999). Examples for ethnographic approaches are Lok & De Rond (2013), Deken et al. (2016) or Cohendet & Simon (2016). Exemplary research questions here could be:

- How can design scholars adapt ethnographic approaches to incorporate process

elements more?
- How can design scholars ground narrative approaches more explicitly in empirical data?

Such research would require an explicit focus on research methodological work, thus not applying existing research methodologies from design, but rather learning from other process research approaches and exploring how to apply these to study design processes.

4.2 Exploring Path Dependency and Emergence in Design Processes

While there is a number of aspects that are problematic about not considering time as an element of the design process, the biggest issue is a lack of understanding path dependency. With this we mean an understanding how earlier events in a design process influence later events. A variance approach of statistical analysis essentially leaves out the timing of such events, merging the whole process into a couple of variables. Exemplary questions here could be:

- How do design reviews influence overall design processes?
- How do specific earlier design actions influence later design actions?

Here, the focus of analysing and theorizing would be on how the process during the design reviews might have influenced the overall design process. What considerations were raised in a design review and how were these addressed in the subsequent design process?

4.3 Exploring interactions across levels

Related to path dependency is the issue of a lack of analysis of how different elements of the design process influence each other over time. Think here especially of how the interaction in the team influences the individual designer, how the individual/team is influenced and vice versa influences the organization, how the content/artefact and the design process interact or how the situation influences and is influenced by the design process. All of these processes and their interaction require sophisticated methods to both capture data across time and analyse the timeliness of such data. A key challenge here is the inherent complexity of such interactions, but especially narrative approaches seem to be particularly suited to deal with such complexity (Tsoukas & Hatch, 2001). Exemplary research questions here could be:

- How do actions of individual designers influence the overall design process?
- How does learning of individual designers influence organizational learning regarding design?

Here, we would need research approaches that unpack the complex relationships between individuals, teams and organizations.

4.4 From retrospective accounts of design to prospective accounts of design processes

A limitation of current design research is the retrospective nature of much research (Weick, 1995). Even when data is collected in real-time, analysis approaches tend to employ retrospective hindsight to reinterpret the process that was studied. This means that the outcomes of such research tend to not align with the lived experience of the designers and other stakeholders that have been part of the process (Fachin & Langley, 2018). Instead, it is interesting to explore research that captures the ongoing sensemaking of participants engaged in the design process. Such accounts would help design scholars and practitioners better understand the uncertainties and ambiguities of the design process as experienced by practitioners (e.g., Wegener & Lorino, in press). We are inspired here amongst others by the words of William James:

> "What really exists is not things made but things in the making. (…) put yourself in the making" (James, 1909)

By putting ourselves as design researchers in the making/designing and finding ways to keep research close to the experience of making/designing, we believe that exciting new avenues for design research open up.

Exemplary research questions here could be:

- How can design scholars relate design practices used in specific situations to design processes?
- How can design scholars capture the prospective nature of designing?

Such research questions would require design researchers to become part of the process, to understand the emergent nature of the design process, to understand how designers navigate the uncertainty and ambiguity of the design process from the perspective of designers themselves.

5. Conclusion

In our paper, we set out to review how design scholars study the design process. Existing research methods in this area have delivered important insights into design work. We introduced a typology of design research approaches that sets out the dominant research approaches to study the design process across micro- meso-, and macro-level and variance theory versus process theory. Reviewing existing approaches through this typology led us to four main challenges for future theory design process theory development: temporality, path-dependency & emergence, interactions across levels, and capturing the lived experience of designers. We suggest a way forward through process theory and methodology in complement to existing protocol, narrative, and ethnographic approaches. We also identified opportunities to learn from other fields use of process narrative approaches (e.g. Pentland & Feldman, 2007) and ethnographic approaches (e.g., Deken et al., 2016; Cohendet & Simon, 2016). We hope with this framework for future design process research to highlight

key directions in this area and encourage other design researchers to take up the challenge of taking time, timing and process more serious.

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About the Authors:

Frithjof E. Wegener is a PhD candidate at the TU Delft on organisational designing. His research is inspired by pragmatism and process theory. He combines organization and design studies to explore the role of experiments in organisational designing.

Philip Cash is Associate Professor in Engineering Design at the Technical University of Denmark. His focus is on design activity, design team behaviour, and research quality in design. He published in Design Studies, Journal of Engineering Design and Design Science.

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Expanding innovation capacity in public sector by design projects

Francesca RIZZO[a], Felicitas SCHMITTINGER[a]*, Alessandro DESERTI[a]

[a] Politecnico di Milano, Italy
*Corresponding author e-mail: felicitas.schmittinger@polimi.it
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Abstract: The demand of a new generation of public services is leading to a systematic exploration of what design can do for public organizations. The article presents and discusses, with the help of 2 design projects conducted in the Municipality of Turin, a design based theoretical framework for organizational change by conducting long terms process of engagement and exposition of employees from public sector to design culture. The two cases show as the raise of innovation capacity in public sector based on the practice of service design projects must consider the necessity of coping with long-standing challenges, i.e. the innovation of public bodies; the peculiarities of organizational learning processes and of the absorptive capacity of the organizations; and the overall resistance to change in people and organizations instead of trying to circumvent them.

Keywords: public sector innovation; co-creation; organizational culture; experiential learning; innovation capacity; design thinking

1. Introduction

Confronted with a range of complex challenges, public administrations (PA) are faced with increasing pressure to improve their innovation capacity (Cavenago et al., 2016; Potts & Kastelle, 2010). The emergence of the “co-society” paradigm nurtured by open innovation and digital technologies has given way to completely new citizens behaviours (Garaud, 2016), such as mobilization for the “commons”, data sharing and service sharing. Hence, the user is no longer simply a receiver or a spectator but an actor (Fluicity, 2015). This new trend is questioning both the decision-making and the implementation processes in the public sphere and is putting increasing expectations of greater citizen participation in the design and delivery of public services and societal challenges that require new solutions. The demand for smarter solutions and for a new generation of citizen-centred services is growing both among citizens and within administrations, as a consequence there is an urgent need to promote innovation and experimentation in the public sector.

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As a response to these challenges, many public administration (PAs) have introduced design practices as tool with a particular emphasis on the development of a more citizen-driven approach to innovation in order to build a better society. The peculiarity of these structures is the adoption of diverse user-centred design approaches to idea generation and experimentation because their structure and mandate allows them to circumvent certain characteristics of the public administration often individualized as barriers (EU commission, 2013) to public innovation (Bason, 2010; Puttick et al., 2014; Tõnurist et al., 2017).

But innovation labs have several limitations that different scholars already pointed out. In particular, they appear too isolated from their parent organization. As the role of innovation labs is to provide an organizational structure solely focused on innovation they can be developed without requiring major change in the rest of the organization. As a consequence, while innovation labs develop internal innovation capacity they do not necessarily transfer the skills and competences to the rest of the organizations.

However, many barriers continue to prevent the development of an agile citizen-centric approach to innovation.

- Lack of specific skills to engage with users. Is there collaboration with citizens and public service end users? Do employees receive training for interacting with citizens? Do employees feel 'safe' in testing new ideas with citizens?
- Lack of competences to activate public organisation ecosystems. Is there collaboration with diverse actors? Is there communication across policy divisions?
- Lack of knowledge and infrastructures to exploit opportunities coming from digital technologies. How intensively do managers and employees utilise technology? How is technology shaping innovation processes within the local public administration? What is the role of ICT in innovation processes?
- Scarce presence of an innovation culture with a prevalence of the exploitation mindset (delivering of the everyday activity) instead of an exploration one (experimenting with new opportunities). Is there a 'zero error' culture or is risk-taking encouraged? Do employees have time and resources to develop new ideas? Do employees receive training for developing innovation?
- Scarce reactivity to the emerging of the societal issue primary dependent on the lack of a knowledge management system to collect and learn from the citizens and ecosystems feedback. Are there systems for acquiring, storing and utilising knowledge? Are feedback- and learning- systems in place?

The difficulties and barriers that arise from public services adopting new and alternative principles like co-creation that are rooted in design and represent a more horizontal approach are notably linked to their complex, vertical and often fragmented structure as well as their organizational culture.

Participatory activities for their nature contain a high potential to tackle exactly this complexity faced by governments and public institutions. They further have the premise to be able to include unused resources of knowledge and ideation into processes despite or

exactly because of their contrasting nature clashing with the existing culture and steady chain of processes. On the basis of these premises we argue that the focus on end-user/citizen's innovation skills (Bason, 2010) to address the need for an agile and citizen-centric culture in PAs poses the problem that little reflection is being made on how public organizations can internalize and integrate the new knowledge, and how the change process can be fostered or managed: this omission could easily lead to reject the new practices, or confine them to a cosmetic role (Deserti & Rizzo; 2014).

In this article the authors present and discuss the obtained results of a long term program of design projects they are developing in the municipality of Turin. The program aims to support the municipality to develop a system of innovation capacities, defined as the set of skills, knowledge and competences that public organizations have or need to utilize in order to generate, adopt or develop innovations. Such a set enables public organizations to reconnect their capacities to generate new solutions (new services, new business models, new policies) together with their capacities to implement, scale-up and deliver them.

The program is based on the assumption that the introduction of user centric innovation culture (Deserti & Rizzo; 2019) in the public sector must rely on developing a long term process of interaction between the public sector culture and the design culture of innovation.

In the following, the theoretical framework as the base for the implementation of the design program in the municipality of Turin is presented. Consecutively the application of the program through the implementation of 2 projects is discussed i examining the results with respect to the previous findings and the theoretical framework. Finally, conclusions are identified for the long terms framework experimentation.

2 Expanding innovation capacity in public sector through design projects: a theoretical framework

Even though there are evidences of an increased rate of experimentation of user centred innovation methodologies within the public sector (Bouwman & Grimmelikhuijsen, 2016), it remains unclear under which conditions these become institutionalized practices. How organisational environments authorise and legitimize innovation practices by way of learning and education remains one of the most relevant challenges. To address this issue the authors propose a program of design projects that relies on the idea that introduction of innovation capacities in the public sector, should be based on its practice, or else in a learning-by-doing framework that can be complemented with reflection to achieve a sustainable transformation. This is not only in line with generic organisational learning principles (Schein, 1999), but also with the construction of innovation knowledge and culture, which is historically bound to practice. In such a context, the role of experience, a core ingredient of the design disciplines, can be regarded as key to knowledge creation and appropriation.

The notion of design program proposes to combine advanced human centred service development (DT) with a learning framework to set up a learning environment (Beckman

& Barry, 2007) in which to make possible for a range of diverse actors operating in the municipality of Turin to experience the processes of innovation. In particular, a design program for capacity building in public sector should implement a learning cycle, based on Kolb's experiential learning framework (Kolb, 1984) representing at the same time the core structure of a DT process (which can be complemented with appropriate tools and applied to the co-creation of new services) and of an organisational learning process (which can be complemented with appropriate structures and actions and applied to the introduction and integration of new knowledge). If we interpret the organisation not only as a closed structure, typically represented by a core actor (a municipality, an hospital, a public transportation service provider etc.), but also as a network of actors the learning process must be regarded as extended to the whole network, and functioning through to the afore-mentioned interactions. DT is particularly effective in this perspective because of two main reasons:

- it grounds the innovation process in co-design activities that are human centred and involve multiple actors and perspectives, which is not only useful to better develop new solutions, but also to enable interaction, sharing of information and mutual learning;
- it is based on an experimental design/prototype/test/redesign loop, which can be effectively connected with triple loop learning, which is particularly valuable in connection with innovation within complex settings and organisations.

3. Design thinking for public sector transformation

Design Thinking (Owen, 2007) is today becoming a mantra in the different areas of innovation: including social and public-sector innovation (Manzini & Rizzo, 2011; Deserti & Rizzo 2014a). Design-led innovation approaches are currently being experimented to tackle societal challenges, trying to better manage complex participatory processes involving a large number of actors and stakeholders in a frame of tensions or open conflicts. These processes go beyond the established principle of designing for context-dependent problems, extending the idea of participation to include: 1) the relationship between the context of the problem to be addressed and the design of the network that will co-produce the solution; 2) the experimentation of different configurations of that network until a robust partnership is individualised and established in some institutional form. In this perspective, DT emerges as a suitable approach to user centred innovation.

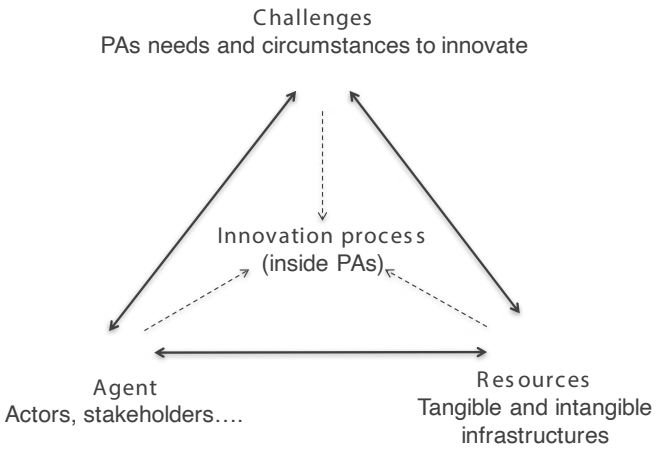

Figure 1 *Situated approach to innovation (Deserti & Rizzo, 2019; p.42). Innovation depends on the organisation internal capacities as well as on the capacities of the larger ecosystem in which innovation is developed.*

DT innovation cycle is based on 2 main pillars: (1) a human oriented approach to innovation that considers the end users of the solutions those who possess the fundamental expertise on the problem/challenge to be solved; (ii) a context based approach to innovation that considers actors from the external environment as well as the tangible and intangible PAs infrastructures and resources (people, processes, technologies, procedures, knowledge) as enablers or barriers to innovation. DT pursues the activation of the ecosystem as strategic in the process that move from innovation ideation to its real implementation. The design program interprets the real practice of the iterative design cycle as key for the introduction of design methodologies and tools to support the development of a co-creation culture in public contexts. To reach this objective the project integrates the DT methodology in the form of an iterative design process, with Kolb's (1984) model of experiential learning. The design program it is based on the idea that DT innovation process processes can be exploited to set up and pilot experiential learning within organisations. While co-design is widely recognized as a way to transform, improve or newly develop services involving all actors in the process, it is also discussed as a practice to transform organizations and even societies (Sangiorgi, 2010).

4. Organisational learning

The design program for the municipality of Turin relies on the ambition that the development of credible pathways and effective actions to support the raise of innovation capacity in public sector must consider the necessity of coping with long-standing challenges, i.e. the innovation of public bodies; the peculiarities of organizational learning processes and of the absorptive capacity of the organisations; and the overall resistance to change in people and organisations instead of trying to circumvent them (Albury, 2005). Innovation

labs proposition is that by operating in a separate but adjacent space from the rest of the organization, they are able to improve internal administrative efficiency and drive cultural change. Innovation labs are allowed to experiment with new methods and focus expert knowledge on innovation because they are somewhat shielded from the issues and constraints of the traditional organizational structures (Bason & Carstensen, 2002). In particular, the design program takes into account the idea that the introduction of new knowledge must be connected with the overall question of the cultural transformation of organisations and systems, with the development of new skills among staff and workplace innovation, which call for a deep integration between the introduction of the new knowledge and the management of systemic and organisational change. This question is particularly relevant if we look at emerging innovation challenges and at the general lack of attention that previous experiences have paid to the issues that the introduction of innovation capacity in new fields raises. In particular introducing user centric innovation culture in public sector means changing the scenarios and the ways in which the public services are not only conceived but delivered and used.

5. The Design Program in the Municipality of Turin

Awarded with the second prize as the European Capital for Innovation in 2016 the city of Turin has been undergoing an important path of transformation throughout the last years. On its way towards an open and innovative city Turin has notably invested in social innovation apart from its traditionally strong sectors like the automotive one and therefore providing a common ground for boundary research, open innovation and social impact. (Bezzi et al., 2019). For example, the Torino city lab is an initiative of the city enabling enterprises to test their innovative solutions directly with stakeholders and citizens closely collaborating with the municipality itself. This is just one example of many that are all an outcome of the city's approach and vision and do not just produce new services but its success leads to a deeper reflection on how services are developed in relation to policy makers, civil servants and citizens. Within this context the Municipality of Turin had identified the necessity of an outside-in transformation in the public sector with co-creation as one potential means to trigger and drive this shift of working methodologies and the acquisition of new skills and capacities.

Citizens, end-users and other stakeholders are to be engaged as co-designers not only as new and unused resources in development mechanisms but to initiate a general process of transformation towards a user-centred culture in public services. In this effort, the strategic vision and willingness to implement this transformation happened in close collaboration with the alderwoman for innovation of the city, currently Minister for innovation of the Italian government, through a strategic dialogue on building and internalizing innovation capacities in the Municipality of Turin. This dialogue started thanks to the first design project, part of SIC Horizon 2020 funds (an experiment on a smaller scale developing one single service) and resulted in a second, more extensive project, conducted to improve the access to the services in the Central Registry Office.

6. First project: TO-Home a service for vulnerable citizens at risk of eviction

Turin is the third largest Italian city well known in the world as the hometown of FIAT automobiles. The crisis of the automotive sector that started in 2007 led to the delocalisation of the production and to a relevant increase in the level of unemployment, which has become the biggest challenge for the city. Under these premises, one of the objectives of the Municipality in 2017 was to develop TO-Home a service meant to responds to the complex needs of vulnerable citizens at risk of eviction (families or individuals that received an eviction notice or are at risk of receiving it) due to insufficient income. Politecnico di Milano mentored the Municipality through a service co-design process as a way to develop innovative solutions based on an integration between the employment, housing and social services, which are traditionally approaching the risk of eviction with different perspectives (a labour issue vs. a housing or a social one). The mentoring run through 4 phases: analysing the challenge, envisioning new solutions; detailing the design, prototypes. In phase one participants where supported to understand the challenge from the end users perspective. In the second phase participants were guided to the envisioning of new solutions with end users and co-design rough concepts for the new service. In phase 3 the focus was on moving from ideation to its implementation in the context of the organisation. The last phase included the support to prepare the tender to implement the service and the design of the service experimentation with end users. The analysis of the Turin experience shed light on a few critical issues: (i) the difficulty of the employees to assume the point of view of the end users as an alternative perspective from which to analyse the current services and design the new one; (ii) the employees' difficulty in overcoming internal resistance to change and barriers bound to the current organisational structure; (iii) the difficulty of the employees to reconnect the design of the new service with its real implementation. In particular, during the design of the service blueprint participants were unable to come out with effective solutions to four main problems, which could ultimately affect the delivery of the new service: (i) how to individualise the competences of the operators that should deliver the new service; (ii) how to make the service visible and how to communicate it to the end users; (iii) how to obtain the availability of enough houses to accommodate fragile families; (iv) how to engage the users of the services in co-production mechanisms.

7. Second project: the redesign of the register services

Being reputed one of the Italian excellent centres of innovation, the city of Turin aims to improve its public services providing new ways of accessing remotely and improving the general access to fundamental services for citizens. The Central Register Office in Turin provides a range of services directly to the citizens that involve a wide range of different public entities on diverse regional and national levels. Services provided are regarding the civil status, the registration and change of residence and the issue of identity cards. Offering a range of fundamental services not just for Italian citizens but for all residents in the city, the context is multi-ethnic, multilingual and hosting citizens of all ages. Following the

growing need of citizens to carry out procedures remotely, different from most other Italian cities, several services to the citizens are offered online supported by the national digital authentication system, but the system still lacks integration with the services provided on-site, that are left behind. Having a strong connection behind the scenes of on- and offline procedures, conflicts cause all operations to slow down or face obstacles. Long waiting times for service delivery are paired with more practical problems on site linked to the building itself, its organization and spaces. Having been constructed as a psychiatric hospital the monumental building has been reconditioned to host the central public offices of the registry office. Hence the architectural structure of the building itself bears a challenge in managing and organizing the spaces according to its new purpose without changing the landmarked structure itself. The project aims at facilitating the citizen's access to the offered services and the comprehension of the procedures. The project, divided in different phases starting from an introductory workshop with employees, followed by a period of user research, further workshops to co-create the new services with the stakeholders and a final phase of development and implementation. The potential and critical issues identified in the first project conducted in 2016-2017 have been used as a foundation of this new one. Having already gained a set of insights on existing and potential barriers in the systems of the Municipality, a knowledge base was available for the set-up of the following activities. Different from the first project, the second one, extensively reported in the following, is aiming at improving and eventually complementing a wider range of existing services in the Registrar's Office in Turin.

7.1 Project methodology

The entire project is informed by different techniques of co-design applied to innovation in the public sector following 4 key principles:

1. Co-design with users

Perceiving users as a resource of knowledge and ideas instead of treating them as passive objects not included in the development process.

2. Analysis of the context of interaction

Gaining a broader knowledge on the context of research and including users in the examination to be able to apply all activities in an appropriate way for the organization.

3. Approach based on piloting

Testing the solutions developed with the possibility to reflect on and refine the outcomes as well as studying the influence of design on the existing culture.

4. Service design as a driver for organizational change

Exploring the effects of integrating service design in the specific organization – its effects and reactions.

The central sources of the data have been authentic observations made by the researchers

themselves during the process along all of the phases and interviews with the civil servants. The report shared with all participants at the conclusion of every phase did not just function as a summary of activities and results but at the same time as an additional source of data being a method for reflection on the activities conducted, reactions provoked and potential improvements in the strategy of applying the methodology. Being a single case study not as a part of a greater project or conducted parallel to other studies the data retrieved is exclusively qualitative not having enough data provided for a significant sample or comparison.

7.2 Project description

The entire project is oriented towards a redesign of the access to the public services in the central Register's office in Turin set up as collaboration between Politecnico di Milano and the Division of Innovation of the city of Turin.

The reason for this is that major difficulties have been found in citizens facing difficulties in identifying, accessing and comprehending the services leading to dissatisfaction and confusion. The main services provided by the Register's office are the change of residence, the issuing of identity cards and official certificates. The services are offered in the central office in the city center and 13 smaller, decentralized offices spread over the different districts. All of these services are producing documents do not just allow citizens to identify themselves and benefit from other services in the city, but the services themselves, their organization and planning is therefore closely linked to various different entities and designed and delivered by different and specialized team of employees not connected among them. These highly specialized teams are usually focused on one specific element rather than working in groups with mixed competences. With respect to these observations the aim, apart of improving the actual services, is breaking out from old schemes of designing services and introducing new ways and instruments that are following the 4 key principles described in the previous chapter. The project for the register office was set with a duration of 13 months, from January 2019 until February 2020 including execution and testing of the pilots. The research and design phase was to be concluded in July 2019. The objectives were on one hand to redesign the access to the services provided in the building while introducing competences for design-driven innovation and collaboration across co-design processes inside the organization. The project developed from 2 initial assumptions coming from literature (Cilliers & Greyvenstein, 2012; Stone, 2004) as well as from the evidences of the first project:

- the quantity of the entities necessarily involved in the entire service delivery is one of the main barriers in adapting to change;
- the strong organizational culture characterizing public services based on silos is completely opposite to the principles of design.

The second project was also meant as a learning environment were to cope with these two main barriers to transformation. The entire project is divided in three main phases, at the

moment only the first 2 have been implemented specified as:

1. Research and design;
2. Execution and
3. Piloting and testing.

The first phase is itself subdivided in three different phases of research and design which were all conducted in direct contact with the stakeholders from the municipality and related offices.

1. Co-design workshop

The workshop functioned as an introductory element to reclaim the methodologies established in the previous project and newly introduce them to employees that had not participated in such activities yet.

2. Analysis of the context as a whole and of existing touchpoints

Having a phase of user research allowed the researchers to deep-dive into the project, the surroundings and its issues while leaving space for users to contribute to the final outcome. The user engagement mentioned earlier is taking place in this second phase, that are laid out in the same period of time and involving them in a process of user research characterized by shadowing and user interviews. There were already crystallizing main issues linked to unsuitable spaces, confusions on processes and routes as well as difficulties with the style of language and communication causing difficulties of comprehension.

3. Co-design of the new services

Keeping a strong connection to the previous phases, a customer journey elaborated as a starting point together with four dimensions of intervention identified together with users have been tackled together to collaboratively ideate solutions for the problems found confronting and balancing among departments and institutions. Especially this phase of research and design allowed the exploration of the collaboration among different departments and internal dynamics. In conclusion of this phase, four areas of intervention for the most critical points identified have been proposed: 1. Spaces, 2. Communication on-site, 3. Forms, 4. Remote communication.

The development phase has been concluded in July delivering an executive project plan for three of those four dimensions (postponing the 4th one, remote communication, to a second moment having the ICT systems undergoing a complete transformation at the time).

7.3. Project outputs

As an outcome, three of the four suggested dimensions of intervention have been tackled. The first one linked to the physical space that creates discomfort for users and an improper working environment for operators. Dividing the spaces of the operators strictly from the waiting areas the issues with privacy, noise and distress are tackled (Figure 1). A system of digital and physical wayfinding is creating a friendlier atmosphere eliminating handwritten

notices and supporting the user in finding his way through the labyrinthine building (Figure 2). To support comprehension and transparency, the forms have been redesigned (Figure 3) indicating the important elements for the user supported by an informative leaflet with a checklist of documents applying gamification for assistance throughout the entire procedure. The executive project delivered in July 2019 has been highly appreciated and given into production to then run a testing phase after summer. Following some difficulties in the actual implementation as well as retrieving the necessary budgets, some elements of the executive project have been postponed. Some reasons for these complications are to be analyzed also with respect to the theoretical framework and the previous experience in the following section. At present, the first parts have been implemented and gone through first testing procedures while others are still in the production process.

Figure 1 Waiting room developed for the intervention in space

Figure 2 Wayfinding system designed to improve the communication on-site

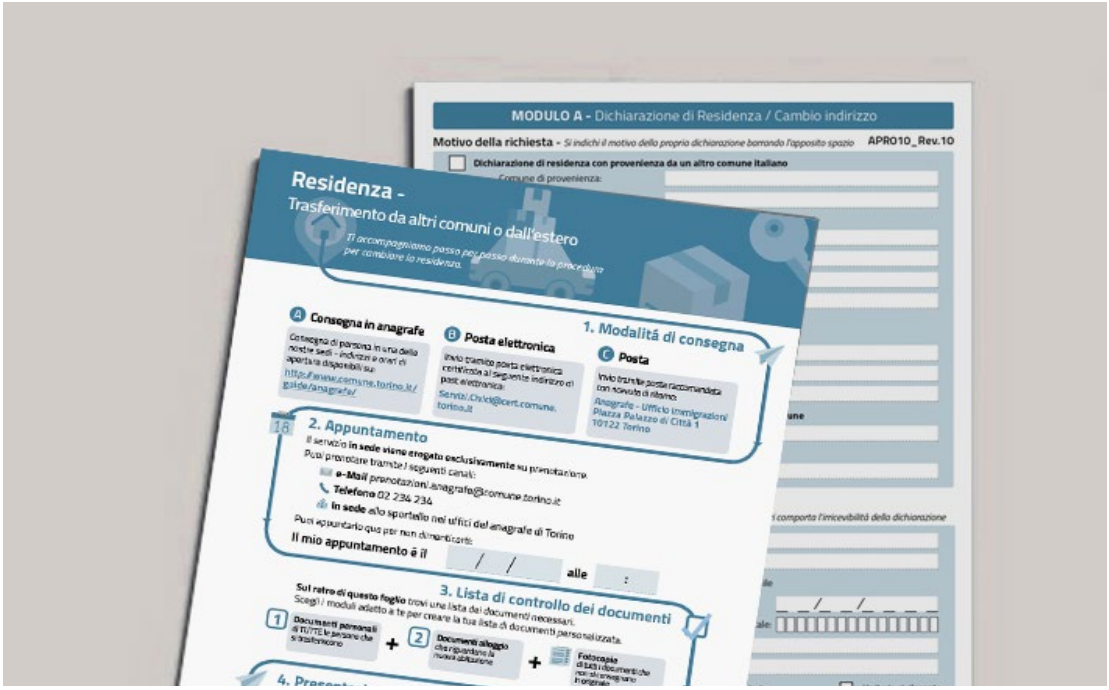

Figure 3 Form and leaflet guiding through the procedure

8. Main findings and issues emerged

Especially the research phase and the transition from design to implementation shed light on some issues demanding a closer look and analysis. Already the initial research phase zoomed

in on the disconnected and highly fragmented structure of the public office that later on appeared to be interconnected to several other obstacles found during the process. Some of these elements are listed in the following to be then explained further.

- Vertical hierarchical structure;
- Missing culture of holistic planning;
- High specialization.

8.1 Vertical hierarchical infrastructure

For the first insight the authors notice that the structure being organized in a strictly vertical hierarchy did seem to hinder the building of new capacities especially at the level of civil servants. Having the impression of being purely executing other's decisions and plans has found to be a barrier to the building of new capacities. Building the team/s with the skills and motivation to develop the solution/s was one of the biggest challenges for the project. The employees who had actively participated in the workshops but did not feel enough incentive to keep developing the solution deciding to take a role in driving the development. In this second project the development of the innovations were taken on by a smaller group of actors, who were willing and asked to commit to a longer term process of developing and testing the innovation. The larger groups of employees that participated in the phase of ideation did not take part in that of implementation. As consequence the project failed in creating a sense of ownership of the as the level of engagement decreased moving from ideation to implementation of the innovations. In particular, the top management of the register officer became the leader of the project. This insight reflects a larger phenomenon in the process of co-creation that often sees the phase of ideation being characterized by an intensive and active involvement of all the employees but, as soon as the process move to implementation decision, responsibility and power remain in the hands of the top management impairing the opportunity to transform the organizational culture (Sangiorgi, 2010).

8.2 Missing culture of holistic planning

The second insight tells about the absence in the municipality of the practice of a systemic approach to innovation at the level of the middle management to oversee complex processes and thinking across disciplines but fragmenting and splitting them instead has found to be one of the main barriers in the adoption of the design culture, which claims holism one of its pillars (Stickdorn, 2011). The redesign of the register office has been based on the attempt to match the grassroots experimentation with the larger strategic vision of the municipality of introducing a user centric prospective where the public actors, the citizens and the local stakeholders work together in envisioning and co-producing new solutions. This attempt has been driven by the strategic dialogue with the top management of the organization and the deputy of major to innovation. The implementation of this strategic approach has, in turn, questioned the cultural transformation of the organization as the development of new skills

among staff and workplace innovation called for a need to overcome silos. The insight then shows that having a strategic vision and a plan to implement it can be not enough if the introduction of the new knowledge is not complemented with the management of systemic and organizational change.

8.3 High specialisation

The last relevant point the authors identified is the evidence that high specialization of departments, typical not just for public organizations (March, 1991) prevented the adoption of different points of view like the one of users or stakeholders and from considering all necessary factors. This difficulty to change the perspective from where to develop services is closely linked to a topic noted mainly in the implementation phase of the project regarding the non-perception of the various parts of the project (as those presented in figure 1, 2 and 3) as interconnected elements of a whole to make available a coherent experience for the citizens. The management of the register office has in fact decided to modify significantly what has been designed together with the researchers and the designers in the phase of ideation because the budget available for the implementation was not sufficient. Furthermore, official procedures like public procurement obliged to split the execution in parts realized by different entities which requires a high level of attention and holistic coordination not always applied by the management in charge of the realization of the project. The remaining interconnection, even not executed by the same entity, of the various elements and its importance for the functionality of the designed experience has hardly been perceived mainly because of the lack of experience of the management in the service implementation phase. As already stated in the first experiment during the SIC project the passage from ideation to implementation (Deserti & Rizzo, 2018) is rarely run by the internal competences of public organizations. The heavily introduction of the process of externalization as a strategy to cut costs in public sector has negatively affected the capacity of the employees to follow a cycle of design-implementation and redesign transforming them in merely executors of solutions conceived and implemented somewhere else from their workplaces. In this case especially the struggle to allocate human resources, overcome unplanned architectural hurdles and retrieve financial resources for the realization of fundamental elements notably impacted on the executive phase and showed the difficulties in linking and uniting the research phase with that of the project development with actually putting ideas into effect.

9. Conclusions

This article discusses a design based theoretical framework to face organizational change by conducting long terms process of engagement and exposition of employees from public sector organization to design culture. The framework combines advanced human centred service development (DT) with a learning framework to set up a learning environment in which to make possible for a range of diverse PAs and actors to experience processes of innovation. What is clearly emerged from the 2 projects is that the process of transformation

of the public sector towards a culture of innovation cannot be exclusively driven by the practice of innovation as a bottom-up process delegating it to marginal sectors of application as well as to organizational structures that never affect organization core processes and functions. This is especially true for public sector where little reflection is being made on how public organizations can internalize and integrate the new knowledge, and how the change process can be fostered or managed: this omission could easily lead to reject the new practices, or confine them to a cosmetic role. The authors proposal relies on the ambition that the development of credible pathways and effective actions to support the raise of innovation capacity in public sector must consider the necessity of coping with long-standing challenges, i.e. the innovation of public bodies; the peculiarities of organizational learning processes and of the absorptive capacity of the organizations; and the overall resistance to change in people and organizations instead of trying to circumvent them (Albury, 2005; Brown & Osborne, 2013; Sørensen, & Torfing, 2012). The approach proposed claims that a possible solution to this problem is to reduce the gap between the strategic management and governance structures of public organisations and the everyday implementation of innovation by developing internal processes, spaces, procedures, profiles within public organisations to better integrate the two levels. These spaces should allow a system enabling exchange and dialogue, via an intermediate "exchange" layer, like the program of design projects suggested in the article, to be designed between top-down innovation strategies and policy that should learn from the every-day innovation implementation and viceversa.

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About the Authors:

Francesca Rizzo, Ph.D., is Full Professor at Politecnico di Milano, Department of Design where she teaches Digital Design Studio. She is expert in co-design applied in the fields of: service design, interaction design, social and public sector innovation.

Felicitas Schmittinger, Masters in Product Service System Design she is a research fellow in the Department of Design, Politecnico di Milano. She worked on projects in healthcare and the public sector exploring the influence of design and organisational learning.

Alessandro Deserti is full professor of Design at Politecnico di Milano where he teaches at the School of Design. His research is focused on design-enabled innovation processes, methods and tools combined with systemic and organisational change.

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Reinterpreting Tradition to Digitalize: Framing the Design DNA of LEGO House

Linda Nhu LAURSEN[a]*, Louise Møller HAASE[a]

[a] Aalborg University, Denmark
*Corresponding author e-mail: linda@create.aau.dk
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Abstract: In this paper, we study how designers reinterpret the framing of previous successful products and new digital products to design products that make sense of new technologies. Through an in-depth case study of the 'City Architects' attraction in LEGO House, we provide insights into the process of reinterpreting a firm's design tradition, their core design DNA, to reframe it and renew in light of digitalisation. The study illustrates how designers: 1) analyse the firm's past successful products to frame the core design DNA, 2) reframe outdated elements of the core design DNA, 3) identify the framing of digital aspirational products and 4) reframe principles of digital aspirational products to update the core design DNA. As such, the study contributes to design and innovation research by displaying how the design process may be understood as a reinterpretation where a firm's past products and aspirational technology products are framed and reframed.

Keywords: framing: tradition: reinterpretation: design dna

1. Introduction

Firms today recognize that they must be attentive to technological progress to remain relevant (Christensen, 2013). Typically, designers are already aware of recent technologies; that are due to launch or achieve mainstream usage in the near future. Indeed, technological progress, such as digitalization, three-dimensional (3D) printing, virtual reality, drones, artificial intelligence, robotics, the Internet of Things etc., comes as no surprise to them. At the present time, numerous technologies exist that are readily developed and widely known, although their respective usefulness and relevance remain to be discovered. Hence, designers need to figure out, how such technologies may make sense.

While many studies look at how to search for new knowledge, such as new technologies, when creating new product innovations (Argote, 2012; Christensen, 2013), as old knowledge may become obsolete and not reflect the current contexts needs and expectations (Sorebsen and Stuart, 2000). We argue many designers, often already are familiar with

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new technologies, their challenge is rather to figure out how such technologies make sense for exactly their firm. In other words, the firm specific design and interpretation of new technologies. We build on the research on 'innovation through tradition', to argue that firms need to build on and innovate from their tradition, when embracing new aspects, such as digitalization (Masis et al. 2016; Messeni, Petruzzelli & Albino, 2014). Take as an example LEGO, a toy company, which specialises in designing creative building bricks sets. It comes as no surprise to LEGO that kids are spending an increasing amount of time in digital universes. Their imperative challenge is to figure out, how to design a LEGO product, that interpret and adopts digitalisation in a LEGO way. Thus, a key challenge for designers is not simply to gain new knowledge of e.g. new technologies, but to to figure out how to integrate it into the firms' tradition.

To study how designers reason to reinterpreted, we tend to framing theory. Prior research shows, how framing is key in the way designers process, synthesize and make sense of observations, inputs and new aspects (Beckman and Barry, 2007). While several studies have worked with how to frame and reframe the problem (Dorst, 2015) or different dimensions of the product concept, such as the problem, experience, technology, interaction or expression (Haase and Laursen, 2018) we suggest looking back and framing the firms design tradition, may be central basis for a meaningful reinterpretation of new technologies. Coupling the 'innovation through tradition' with the 'framing' literature, we build a theoretic model, that propose framing as a reflective device to capture firms' design tradition, and reinterpret it in light of new technological developments. The model proposes framing firms 'traditional' or typical design principles - the design DNA - may be foundation for making sense of new technologies.

Photoset 1 *Photo1, LEGO House, Denmark. Photo2,3, City Architects (Lego House Media, 2018, own shots)*

Empirically, we research this through a close longitudinal case study at the LEGO Group. The product of study is the newly developed LEGO House, which has been acknowledged by the LEGO organization itself, as exemplary in how it adopts and bring meaning to new technologies. More specifically, we did an indepth examination of how the framing of the 'City Architects' attraction, as the 'City Architects' have been recognized by the LEGO

organization itself, as iconic for LEGO House and exemplary in how it makes sense of digital technologies. We did observations, interviews and workshops to understand, how design experts at LEGO worked with framing the Design DNA of past LEGO products as well as digital aspirational products, to design 'City Architects'.

2. Theory

2.1 Reinterpreting Tradition

While much research on 'how to search, and integrate knowledge in design and innovation' are biased to focus on novelty, to avoid rigidness, fixation and path dependence etc. Recent studies suggest knowledge from a firms tradition, may be an equally important source of innovation (Katila and Ahuja, 2002; Nerkar, 2003; Massis et al. 2016). Knowledge pertaining to the firm's history, its tradition, is in fact recognized as an imperative, powerful and inimitable innovation parameter (Messeni Petruzzelli and Albino, 2014). Tradition may be defined as the knowledge, signs, values, beliefs, competencies, materials and production processes pertaining to the past (Messini Petruzzzelli and Albino, 2012). In this study, we focus on the design side of tradition, more specifically the design reasoning. We build on and extend the recent studies on 'innovation through tradition', that calls for more knowledge on 'why the past can be valuable and how managers can leverage it to innovate." (Massis et. al. 2016, p 94).

Past research suggests two key activities or challenges for innovating through tradition, respectively the interiorsation and reinterpretation of tradition. Interriorsation refers to the sharing and assimilation of knowledge pertaining to the firm's tradition. Whereas reinterpretation focus on the selection and combination past knowledge with new technologies (Massis et. al. 2016, p 94). While recent research has provided an understanding of the overall process of innovating through tradition, we go more into depth with the activity of reinterpretating. As, we are interested in understanding how designers reinterpret tradition and use it to make sense of new technologies.

2.2 Reinterpretation and Framing

To study the reasoning level of designers' reinterpretation process, we draw on framing theory. The concept of framing has been discussed in various fields of research (Goffman, 1974; Schön and Rein, 1994; Kahneman and Tversky, 1984). Across the various disciplines, framing is commonly recognized as a cognitive and communicative interpretative device, which at its core concerns "separating that which deserves focus from that which does not". (Clegg, Kornberger, and Pitsis, 2015). It is a boundary-setting move, whereby decisions are made as to what makes sense. When people frame they "consciously or unconsciously structure a situation by selecting relevant features: what is important and what is less important" (Hey, Joyce, and Beckman, 2007). Framing both describes and perceptually transforms given situations. A psychology experiment, for example showed how, when

framed differently, essentially identical options lead to different evaluations, different interpretations, and in the end, different decisions (Kahneman and Tversky, 1984). Frames represent and reveal underlying structures of belief, perceptions and priorities (Schön and Rein, 1994). In their essence, frames allow us to see things through a certain lens, they allow us to reinterpret.

In the field of innovation and design, several contributions have rendered the interpretative attributes of framing more explicit. For instance, Hey, Joyce, and Beckman (2007) showed how frames can be operationalized with elements such as the desired goal, the prioritization of relevance, the boundaries, and the evaluation criteria. Dorst (2015) captured how designers reinterpret problem by framing. Schön (1983) proposed that generative metaphors were central in expressing frames, since it is not only physical attributes that are relevant, but also the interpretative pictures or images of what could be. As metaphors provide a richer understanding for an interpretation, that allows for communicating, reasoning, reflecting, and transforming (Simmons, 2006). A recent study by Haase and Laursen (2019) in fact showed how frames are indeed interpretative in the sense they convey, the inherent logic of a product. Building on Dorst (2015) they showed how frames in their essence, connects an *insight* (into the market, user technology) to an *aspiration or vision* (e.g., of what needs to be changed), as well as how such an aspiration can be achieved and made real through a number of *situated working principles* (Figure 1).

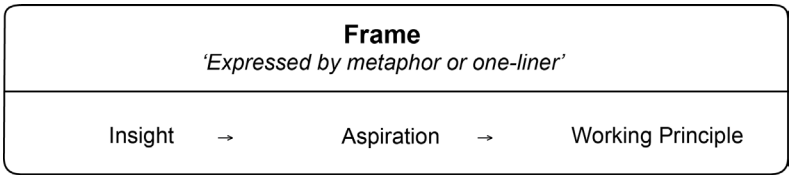

Figure 1 Frame: The connection between insights, aspirations, and working principles

2.3 Tradition: Framing the Design DNA

Research shows how frames are instrumental in the design process. While frames are often discussed as vaporizing entities, that is, devices used to attack a problem during the design or innovation process, studies suggest that every product, every firm, every design in fact, holds a number of inherent frames (Haase and Laursen, 2018). These are visible and inherent in the final concept, e.g. Steve Jobs' sunflower frame for the iMac or Motorola's pebble frame. These frames, that are embedded and evident in the final product design, we collectively label the design DNA.

The design DNA can be defined as a set of core frames that explicitly capture and reveal the focus and background of the design, serving as a guide for the visions and decisions embedded within the products (Haase and Laursen, 2019). The design DNA explicitly captures the conceptual structure of the product. It is the design DNA that makes a product *feel* and *appear* like a LEGO product, or an Apple product, or a BMW product. It explains the expression, experience, interaction, market positioning, and technology of the product. In

fact, the “underlying structures of belief, perception and appreciation” of a design represent the collection of frames that express the design DNA (Haase and Laursen, 2018). A recent study shows while the design DNA in new companies is created from scratch, in consolidated companies the development of the design DNA is based on a balance between renewing frames and re-applied frames from the companies’ tradition (Laursen and Haase, 2018).

Building on literature on framing and innovation through tradition, we make a model of the reinterpretation of the design DNA. We use frames as an analytical device to understand and make tacit interpretative elements of the design process explicit. We connect this to the recent studies, that suggests knowledge pertaining to a firm’s past, their tradition may be an important element for reinterpretation, which both includes tradition as well as new knowledge (Massis et. al. 2016, p 94). We gather these dimensions in a two-by-two matrix, which respectively move between how designers frame and reframe past knowledge from the firm’s tradition, as well as frame and reframe new knowledge of up-to-date technologies.

Table 1 Reinterpretation tradition and technologies

	Tradition	**New Technologies**
Framing	Core DNA	Aspirational DNA
	Framing the firm’s tradition in terms of the core design DNA	Framing new aspirational product designs (e.g. from digital products)
Reframing	Reinterpretation of Core DNA	Reinterpret Aspirational DNA
	Identifying and reframing outdated core DNA frames to match the territorial domain.	Reframing new aspirational design DNA to match to the updated core DNA.

3. Methodology

The in-depth case study was chosen to accommodate an audience of experienced researchers, experts and practitioners within design and innovation. Where beginners would benefit from a rule-based knowledge, an expert audience use cases as a central learning element (Flyvbjerg, 2001). In fact, experts and experienced practitioners operate on the basis of intimate knowledge of several thousand concrete cases (Flyvbjerg; 2006). Hence, the ambition of this article was to create an in-depth and contextually elaborate case study, which could be added to the expert audiences’ knowledge base.

3.1 Case selection

Then, in order to identify a case that would be appropriate for an expert knowledge base, a highly strategic case selection was applied. We selected both an atypical and to some extend extreme case in respect to innovation through tradition. We chose to do a case study at LEGO, which is one of Denmark’s oldest family-owned companies. To date, the company has sold over 400 billion LEGO bricks worldwide, most of them with a clear reference (and physical linking possibility) to the first plastic bricks that was created in the 1940s. Hence,

LEGO has a significant experience in innovating through tradition.

Another reason for selecting LEGO as a case company, is that they are in an industry, where the pressure from digitalization is particularly present. Like many other toy companies, LEGO are right now confronted with a growing competition from digital universes and devices, that consume larger and larger chunks of children's time. This means that LEGO must be able to compete with digital experiences, such as Minecraft, and Netflix, in the fight for children's attention. Therefore, the focus and urgency of embracing digitalization and innovating based on their traditions in LEGO is highly present.

Within LEGO we also selected a rather extreme case, when it comes to family involvement, which is highly relevant when studying tradition (Massis et al. 2016). We selected a project that was originated by head of the LEGO family and former chairman of the board, Keld Kirk Kristiansen. He had vision to create a brand and experience house, which was designed to reflect the "magic" of the LEGO universe. His vision turned into the LEGO House project and the family was highly involved all the way throughout its development. LEGO house is a brand and experience house, which is regarded by The LEGO Group itself as a prime example of how to integrate new technologies and digitalization while staying true to their traditions. The LEGO house was also an atypical case because it had a longer projected lifespan than most of LEGO's individual products and a different financial setup.

3.2 Research setup

The quality and depth of the collected data plays a significant role, when it comes to building a case-study that will be both relevant and useful to an expert audience. In this project there were a number of factors that secured this. First, the in-depth case-study of the LEGO house was an extension of a larger industry research project. This provided a significant contextual understanding of LEGO and helped in ensuring depth in the data collection for the case study. Furthermore, the research setup drove for intense and extensive interaction between the researchers and the informants, involving for instance bi-weekly, face-to-face meetings over a period of half a year, alongside formal presentations, email exchanges, dinners, etc. This resulted in an informal atmosphere, that was highly beneficial because this allowed a high level of detail and unfiltered discussions in regards to the LEGO house case. Finally, the informants included only long-term LEGO employees. This ensured deep knowledge of LEGO's traditions as well as hands on experience with conceptual development at LEGO. Two of the employees had been involved in conceptualizing and developing the LEGO House from its very beginning in 2013, where only a handful of employees were involved.

In order to provide sufficient concrete depth and detail, we chose to anchor this paper in one of the main experiences at the LEGO House called City Architects. City Architects is a platform located on a table, onto which children can place different buildings. The buildings are mainly created from white LEGO bricks combined with red, blue, yellow, or green bases to signify different kinds of functions (shopping, recreational, industrial, and domestic). On the platform, a digital projection adds small LEGO people who are running around the city,

looking for buildings that match their colour. When a child places his or her building onto the platform, a projection from above acknowledges the new building by issuing a “ta-da” sound, and new roads, parks, and trees are created around the building on a digital layer. If a child places a white house built on a blue base onto the platform, the small blue LEGO people will start running toward that house, and the child will soon realize what kinds of houses are missing from the city and, thus, what is needed next. This digital layer provides instant gratification and emphasizes the child’s experience of having created an expansion to the city. The child takes part in the creation of a shared and highly dynamic city with all the other children present.

3.3 Data collection

Whereas the industry project provided the contextual basis for the case-study, a number of research initiatives was taken to collect data directly for the case study. These activities included: interviews with key employees, presentations of the LEGO house development; a guided tour throughout LEGO House (before it was opened to the public), where key employees would explain their reasoning behind the different exhibitions; and access to materials and presentations from the LEGO House development process.

Moreover, the results from two workshops, where included as well. In the workshops employees from LEGO engaged in codifying the LEGO’s design DNA as well as LEGO Houses Design DNA, making the tradition explicit. The first workshop included research informants directly related to the research collaboration, the second workshop further included employees from the LEGO Brand Group and LEGO’s front-end function. After the workshops the definitions of the LEGO design DNA and the LEGO House design DNA were turned into presentations and informational texts. In order to ensure a high level of detail and accuracy, the documentation was then passed back and forth between the researchers and the LEGO employees in an effort define it as precise as possible. Finally, this material was presented to a group of company directors.

To secure a high quality and precision in detailing of the in-depth case study, the preliminary conclusions along with any inconsistencies with respect to the LEGO house, were further explored with LEGO employees, either individually or in group sessions. And as a last step in this process, the written material presented in this paper was send to approval to the LEGO employees to ensure the accuracy of the case-study.

4. Case analysis ‘City Architects’: Reframing LEGO

The focus in the analysis has been to identify the significant moves involved in selecting and combining past and new knowledge. In more detail, we have identified, how the LEGO employees have selected and combined their knowledge about the LEGO’s tradition and combined it with knowledge about digital technologies in design.

4.1 Framing tradition: The core DNA

The first step designers and developers applied in the creation of the exhibitions in LEGO house was to frame the core design DNA. This means that they would use prior product designs, and their in-depth understanding of these, as a way to create starting point or a direction for the new solution. For instance, in the case of City Architects the designers and developer had looked very close into the LEGO city products. The city theme is a classic LEGO theme, which can be traced back to the 1960s and the idea of LEGO as a "Systems of Play." As one of the designers explained, "City building in LEGO is big" [37] In the case of City Architects, the designers looked into the principles and background of LEGO City. One of the key principles in LEGO City is that "Imagination starts in reality." Children mirror what they experience in reality into their play. As cities are part of children's reality and children know what happens in cities, the city represents a great starting point for children's imagination. For this reason, LEGO City originally mirrored the classic city, with its small roads, houses, gas station, grocery store etc. The framing of this original thinking is illustrated in Figure 2.

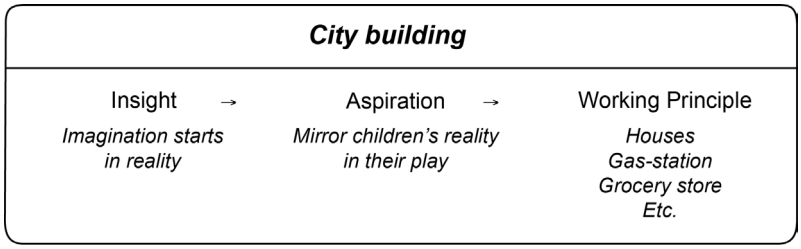

Figure 2 Frame: City building

The LEGO DNA of building cities, as well as the LEGO City products, were the starting points for exploring the possibilities that eventually became City Architects. The design DNA behind City Architects is fairly concrete, since it refers to a product category and to specific working principles.

4.2 Identifying and Reframing Tradition

The second step the designers focused on identify where the past/ present design DNA needed an update. More specifically the designers looked for working principles within core design DNA, which needed to be updated, in order to ensure that a future solution would be relevant to the users and competitive in the markets etc.

For instance, in the case of City Architects, the designers explored whether LEGO's "city experience" was still relevant. To qualify this they did some research into: how other successful products on the market present cities to children, for example, in movies, games, and toys. During this exploration, the designers identified a different city experience to the one typically presented in the original LEGO City products. In the digital domain in particular, children are presented with cities that are fast moving, high speed, and full of changes. Where the initial city-related products offered by LEGO mirrored a small town, the city experience in the digital domain mirrors big, dynamic cities. Such cities are constantly

changing, with each new building that emerges changing the rhythm of the city. The aspiration hence became to integrate this new dynamic city experience into the LEGO City experience.

4.3 Identification of inspirational products and the design DNA behind these

The third step the designers used during the process of creating the experiences within LEGO House involved identifying aspirational products. That is products that could provide some inspiration into how the Design DNA that needed an update could be changes. This means products, that are creating the new standards and expectations in the market, and essentially is the reason why there is a need for an update.

In the case of City Architects, the designers looked especially into inspirational products from the digital domain, which represented the "dynamic city." In particular, they looked at how games such as SimCity, which provide the "dynamic city" experience[38] With regard to SimCity in particular, the designers found it interesting that children were *building cities together*. They were also inspired by the continuous information on: *supply and demand of buildings* in the city, which triggered the children to continue to play. Finally, they found it intriguing that the children gained instant gratification from their actions.

As the example of the SIMcity shows the designer and developers at LEGO did not just find different solution elements, to copy, but they tried to identify the design DNA behind these, in order what kind of principles they are built on.

The working principles that were integrated into City Architects included for instance:

- Children building the city together on the platform (table).
- The dynamic city - in terms of the rapidly changing projection on the platform, which expands the city if a building is added and contracts the city if a building is removed.
- The instant feedback as to what is needed in the city in terms of the small LEGO people moving around on the platform. This is to inspire the children to create the next building in an effort to gain a reward, for instance, a concert at the stadium.
- Instant gratification obtained - in the form of a magic "ta-da" sound when the children place a building on the platform.

4.4 Development of new solutions that integrate past and new Design DNA.

The final step applied by the designers during the process of creating the experiences within LEGO House was to develop new solutions that reinterpreted new and past DNA.

When the designers updated the past design DNA they were respectful, in the sense they were very conscious of which working principles would fit the LEGO tradition. Every new solution principle was thoroughly evaluated and translated into the LEGO design DNA. For instance, in the case of City Architects, the pre-defined or pre-created houses from SimCity (and other digital games) did not fit with the LEGO design DNA. These 'readymade' and

fixed houses are very opposing to LEGO's tradition. Every LEGO brick represents different possibilities and essentially "endless" combinations. This offers the child the possibility to be creative and build whatever combination he or she finds interesting and intriguing. So in City Architects, children are encouraged to create whatever buildings they want, and they can explore how different ways of creating buildings work in the city context.

In the process of creating the City Architects, the updates also synthesized into new design DNA, that emerged out of the process. During the process, it became clear that the challenge in digital games and technology is that often absorb children's attention and thus leave no room for creating, playing, and building. The aspiration in city architects and Lego house, altogether therefore became to use technology to strengthen the experience when children are creating, playing, and learning. And a new design DNA slowly emerged, namely the idea of using: "a digital layer that keeps you in reality." (see Figure 3). Thus a new design DNA stringis added to the original design DNA.

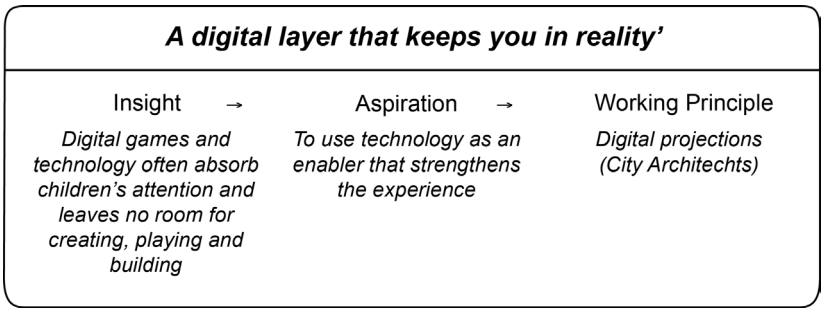

Figure 3 The new LEGO House DNA frame: A digital layer that keeps you in reality

5. Discussion

With the present paper, we have built on, and contributed to, two core discussions within the academic research, namely innovation through tradition and framing. This study extends these core discussions by linking them, and it supports the findings of a recent study suggesting that design may have the capacity to drive both relevance and consistency. We contribute to both research streams by identifying four modes of framing and reframing that designers apply to systematically frame and reframe new technologies in ways that make sense to the company they work for in order to balance the company's need for renewal (to keep up with new digital technologies and behaviours) with its need to ensure consistency (with the design DNA of the company).

When framing the core DNA, expert designers exhibit in-depth and sophisticated knowledge of the design DNA of the company they work for, as well as deep insight into the backgrounds of past products (for instance, the reasoning behind those products and how they were framed). They use this knowledge (more or less explicitly) to frame the design DNA of the company, and they then use this as the starting point for exploring new technologies. In this sense, the designers use the companies' core design DNA (for instance, DNA frames

that have been used in multiple products) to establish the foundation and direction for renewal.

When reframing core DNA, expert designers explore the extent to which the working principles inherent within the company's present products still resonate with users, the market etc. In particular, they do so by looking at the kinds of experiences and interactions offered by other technologies or digital products on the market. They do not begin by questioning the deeply rooted insights on which their products are based (i.e., in the case of LEGO, their insights on play), or their aspirations as a company, but rather they reflect upon whether the working principles are still appropriate to achieve this. They reflect on whether their design DNA still resonates, by identifying whether the solution principles still resonate.

When identifying inspirational DNA, expert designers explore other products that resonate with the market, with users etc. For instance, products that are successful, or the leading products in different markets (e.g., digital experiences or markets wherein technology is implemented in a sensemaking way). Having identified these inspirational products, the design team start to identify the working principles behind them that particularly resonate with the market, with users etc., as well as why this is the case.

When reframing aspirational DNA to secure a fit, expert designers carefully reflect on their implementation of new working principles. Even if they are highly inspired by a given product, they do not simply go ahead and implement all the working principles derived from that inspirational product. Instead, they consider each working principle with respect to the design DNA (which can be rather extensive) in order to ensure that the working principle is not contrary to any of the present design DNA, since this may challenge the consistency of the product with respect to previous products and the brand DNA. During the integration of new working principles, the expert design thinkers particularly look for working principles that may end up reinterpreting the design DNA.

This study provides practitioners with hands-on strategies for systematically making sense and integrating new technologies into a company. Furthermore, it provides important insights into how to use the concept of design DNA in order to comprehend and address the challenges associated with ensuring both renewal, in light of new technologies, and consistency with tradition.

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About the Authors:

Linda Nhu Laursen is an assistant professor at Aalborg University, Denmark. Her research interests cover the interrelation between design and innovation. Her current research is published and publically available in international journals such as Design Issues (MIT press).

Louise Møller Haase is head of the design research group at Aalborg University. Her research is concerned with how master creators renew companies through their Design DNA. Louise has been a visiting researcher at Stanford University's Centre for Design Research

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Mapping the Organisational Landscape of the UK FMCG Industry: A Review of Packaging Design & Development Professionals

Nicholas Samuel JOHNSON[a]*, Awais Hameed KHAN[b], Abbie LAWRENCE[c], George Edward TORRENS[a], Ian STORER[a]

[a] Loughborough University, United Kingdom
[b] The University of Queensland, Australia
[c] Cardiff Metropolitan University, United Kingdom
*Corresponding author e-mail: n.s.johnson@lboro.ac.uk
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Abstract: Packaging design can be acknowledged as a significant strategic avenue within New Product Development (NPD) for Fast-Moving Consumer Goods (FMCG). Packaging can have direct impact on sales conversions, consumer visual and brand perception. However, packaging design and development (PD&D) remains underutilised in organizations, viewed as a risky activity and unnecessary additional cost. Limited research has been conducted to address how PD&D activities are managed. This study expands our current understanding of the PD&D landscape through content analysis and frequency of occurrence measures, of a sample of LinkedIn profiles (n=200) to begin to identify and categorise professionals involved in PD&D for the FMCG sector through their own perception of self. The contribution of the study is to assist in understanding the synergy of key decision-makers and influencers in the industry landscape, expanding on existing design management literature to provide an expanded comprehension and more strategic outlook of characteristics and capabilities of those involved.

Keywords: design management; new product development; packaging; fmcg; linkedin

1. Introduction

Fast-Moving Consumer Goods (FMCG) are low involvement, inexpensive everyday use teams such as food, beverage or personal care products (Clement et al., 2015). The FMCG sector accounts for the UK's largest manufacturing sector (approx. 14%), worth over £125 billion in consumer spending, 8% of the country's GDP (Francis et al., 2008; The Stearling Choice, 2019). Research and Development (R&D) is of fundamental strategic value to FMCGs, for the development of new products to remain competitive in global markets and sustain organisational financial growth (Costa & Jongen, 2006). UK retailer portfolios stock over

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40,000 different product lines, requiring large quantities of New Product Development (NPD) projects. This demands extensive design function resource and support (Nancarrow et al., 1998; Vazquez et al., 2003).When implemented correctly, design can add significant value and be utilised as a strategic tool for product distinction in their competitive landscapes (Rundh, 2009; Vazquez et al., 2003). FMCGs are generally low-cost, low involvement products, with a high propensity to be commoditised, i.e. faceless, brandless products; thus, packaging holds significant value in product differentiation, through the manipulation of product appearance and asset communication (Clement et al., 2015). However, from a traditional organisational perspective these design activities are often considered as 'nice-to-have'; peripheral and non-core contributors to mainstream business performance (Bruce & Daly, 2007). The development of new customer-facing packaging formats and design are often viewed as risky; with apprehensions associated with potential sales losses, reduced brand recognition, and high switch-over production costs resulting in minor, incremental or no changes to package design (Simms & Trott, 2014b, 2014a). Yet, 73% to 85% of purchase decisions are made at the point-of-purchase (Clement et al., 2015; Connolly & Davison, 1996); thus can be seen as a missed opportunity given packaging designs role at the point-of-sale.

Existing research presents models promoting the value and impact of various visual and tactile manipulation techniques of packaging design, such as the strategic use of visual elements, structural design and informational cues (Ampuero & Vila, 2006; Piqueras-Fiszman & Spence, 2012; Silayoi & Speece, 2007; Spence, 2016a). Application of these lessons, could in turn, influence consumer in-store behaviour and increase product saliency, perceived value and desirability during buying decisions (Clement et al., 2015; Clement et al., 2013; Rundh, 2013). Although the rules surrounding good packaging design are well known there is very little room to apply these practices due to risk-averse mindsets and practical concerns of packaging professionals. Managers within packaging design and development (PD&D) have been criticised for having a "…myopic and skewed views of packaging" emphasizing cost-driven solutions (Simms & Trott, 2014a p.2017) and reduced investment and R&D resource allocation (Costa & Jongen, 2006; Ryynänen & Hakatie, 2014). Due to the low-level regard of its value contribution, companies do not appear to consider design or the innovation of packaging until later NPD stages (Francis et al., 2008; Simms & Trott, 2014b); diminishing its potential strategic value.

At current, both industry and academia does not appear to consider PD&D as a holistic professional activity causing more isolated research and practice (Timney & Chamberlain, 2017). Azzi et al. (2012), Mumani & Stone (2018) and Johnson et al. (2019a) provide more rigorous and contextual understandings of the factors influencing PD&D; for example wider design considerations, organisational influences, logistics and supply chain impact and sustainability credentials through cohesive efforts of existing literature analysis. Specifically, design management within the FMCG industry remains under researched and PD&D has been described within a UK context as dysfunctional (Simms & Trott, 2014b).

The research presented here aims to extend exploration in this space by providing FMCG

and NPD professionals with: 1) awareness of the different disciplines involved in PD&D within the FMCG industry; 2) the distribution of different professionals within a conventional organisational structure; 3) the role of these professionals within a conventional FMCG NPD process; and, 4) profiling the knowledge, skills and capabilities of the range of professionals involved.

2. Literature Review

2.1 The Role of Design in Cross-Functional New Product Development

Design functions often sit within R&D remits in the distribution of NPD teams (Ateş et al., 2015; Urban & Hauser, 1993). Over time, design has moved from being a sub-process within NPD, becoming more integrated into business strategy (Braga, 2016; Brown & Katz, 2011; D'Ippolito, 2014; Dell'era & Verganti, 2009; Heskett, 2008; Johansson-Sköldberg et al., 2013; Verganti, 2008; Walsh, 1992; Walsh et al., 1988); as designers move into leadership roles; supporting the whole NPD process as facilitators requiring skills beyond the traditional design skill-set (Perks et al., 2005). Although design functions can exist internally in R&D territories, there is increased outsourcing of external services and design resource to gain specialized knowledge (Ateş et al., 2015; Le Dain et al., 2010; Perks et al., 2005). This has potential benefits such as improved output quality, reduced overheads and project time. However, there is a fear of lost control when outsourcing these services due to design's intangibility, uncertainty and concerns over intellectual property (Ateş et al., 2015; Twigg, 1998). Thus, a key issue within NPD is understanding who and when should be involved in decision-making for design and what is internalised or outsourced (Le Dain et al., 2010).

The impact product appearance has on consumer decision-making is clear and well documented (Bloch, 1995; Crilly et al., 2004). UK retailers employ and dedicate substantial design function resource to PD&D and in-store promotional material (Clement, 2007). The exploitation of design and visual elements of packaging to improve differentiation and communication remains a valuable product marketing strategy for FMCGs (Underwood & Klein, 2002; Young, 2004); yet, underutilised and not considered until later NPD stages (Francis et al., 2008). Visual design and subsequently design resource investment for PD&D can be considered crucial for product market success (Spence, 2016b). In organisational resource distribution, packaging is often considered an unnecessary cost (Chan, Chan, & Choy, 2006; Ryynänen & Hakatie, 2013). As a method to keep R&D costs low and reduce technological risks, incremental innovation strategies allow for increased product launches. However, it is estimated 70% to 95% of product launches fail at market each year (Costa & Jongen, 2006; Spence, 2016b); with some failures being accredited to poor packaging decision-making during NPD (Rudder et al., 2001). Thus, design can be considered one of the most crucial factors contributing to product success rates (Spence, 2016b). Therefore, studying how the industry landscape is composed becomes increasingly important to understand where these value tensions arise from and how they can be addressed.

2.2 Managing Design in FMCG Packaging Development

Packaging research has received extensive attention both theoretically and practically (Azzi et al., 2012). Various frameworks attempt to comprehend the functions packaging serves. At its most basic level of understanding, packaging is a logistical and marketing tool, protecting and preserving products through the supply chain and promote the product to the end consumer (Prendergast & Pitt, 1996). Various frameworks constructed help to understand the principles applicable to packaging design practice. However, these models do not appear to take into consideration broader contextual influences. Much of the existing literature also fails to provide insight into management of PD&D beyond artwork and graphic design (Simms & Trott, 2014a). However, efforts have been made to develop more industry specific models to help recognise stages and factors for FMCG design management in NPD (Bruce & Daly, 2007; Simms & Trott, 2010, 2014a; Vazquez et al., 2003). Vazquez and Bruce (2002) and Vazquez et al. (2003) provide insight into various stages of design management processes initially highlighting key procedural protocol to begin to identify some of the individuals and NPD stage-gates. Simms and Trott (2014) present a 'Grounded Framework for Packaging Management in New Product Development'. Their research highlights internal roles such as "packaging champions" and "packaging buyers" influencing internal organisational activities and external perspectives including retailer involvement, influence and collaboration of suppliers, agencies and technical experts. They emphasise many organisations primarily addressing 'skin deep' or 'body modification' adjustments and, overlooking technological and format changes. This could be associated with the "risk-averse and ad-hoc" attitudes with PD&D and has been accredited to packaging decision-making being implemented by non-packaging specialists (Simms & Trott, 2014 p.2020).

Johnson et al. (2019b) observed packaging design practice, highlighting that multiple stakeholders, from both internal and external organisations influenced conceptual design activities in PD&D. This affected practitioner design activities through factors such as: ineffective design brief management and communication, time compression of design practice activities and, the generation of frustration and tensions in communication between clients and functional disciplines. However, research exploring packaging management and the role of the design function as a core part of the FMCG NPD process still remains under-studied (Simms & Trott, 2010, 2014b). Thus, the understanding of a wider context of professionals involved in PD&D could be useful in considering the challenges associated with cross-functional NPD work for FMCGs and look towards improving design practice. Current research has explored organisational structure and management, but does not engage in depth with the roles, functions, capabilities and synergy of professionals. This research aims to more effectively profile the roles of the 'packaging designer' and other FMCG packaging professionals involved in PD&D, extending existing research frameworks developed within a UK context. This paper provides researchers, designers, design managers and other FMCG NPD professionals with an expanded understanding and clear mapping of the wider context of individuals, developing a typology of role archetypes involved in PD&D.

3. Method

This study looks to categorise professionals within a UK FMCG packaging context; and, to begin to define their capabilities, knowledge and skills. The following study was constructed within the procedures of Loughborough University Ethics Committee following its data protection guidelines and necessary approval processes (Loughborough University, 2019). The study presents a review and detailed analysis of PD&D professionals from the professional networking site LinkedIn. This research method proposed allows for the collection of a large set of self-report data about the professional remit, develop knowledge and understandings about different characteristics of these professionals.

3.1 Profiling Professionals in FMCG Packaging Design & Development

LinkedIn is the world's biggest network site of professionals with approximately 610 million users across 200 countries (27 million UK users) allowing professionals to collaborate and share information through user-generated content (Avocado Social, 2019; LinkedIn, 2019). This tool allows for profile creation including: a professional photo, self-reported profile summary, education and qualifications lists; career history; professional connections; and, key skills, knowledge and expertise lists (Case et al., 2013; Ecleo & Galido, 2017). LinkedIn has been used in various academic and industry contexts, by researchers, recruiters and hiring managers as a tool, for data collection of profile information, analysis of profile contents and employment drives (Case et al., 2013; Ecleo & Galido, 2017; Roulin & Levashina, 2019). More recently, academic research has begun to utilise LinkedIn as a valuable information repository for data collection in aid of understanding and profiling a population of professionals (Bastin, 2012; Case et al., 2013; Ecleo & Galido, 2017; Li et al., 2016; Pisano et al., 2017; Roulin & Levashina, 2019; Zide et al., 2014). For this study, an adapted method (Figure 1) from Ecleo and Galido (2017) to profile and analyse a set of industry professionals was chosen.

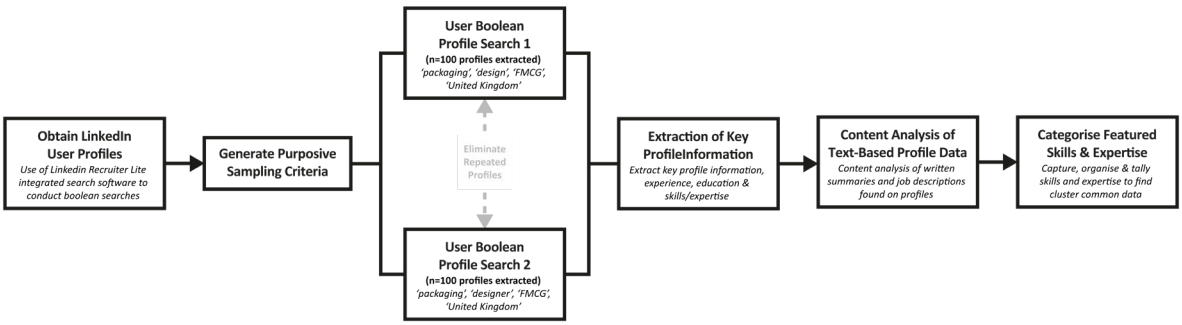

Figure 1 Adapted Flow Diagram for LinkedIn Profile Data Collection and Analysis.

3.2 Procurement & Selection of LinkedIn Profiles

Data was collected from LinkedIn profiles in two Boolean searches labelled S1 and S2 over a 3-week period in June 2019. For each search a reference code was given to each participant

profile (e.g. S1:07), to assist with tracking and referencing when undertaking profile comparison and narrative reflection. Reference codes will be used to indicate profile data sets, referencing to the search (e.g. S1 or S2) and the participant number (e.g. 23). Data was collected and archived in a meta-data repository (Figure 2) in MS Excel only accessible to the researchers to maintain protection of data and anonymity of profiles.

Code	Assumed Gender	Current Job Role	Industry	Location	Previous Role(s)	Education & Qualifications	Summary Biography	Skills & Expertise	Additional Notes

Figure 2 Spreadsheet Matrix Design for Profile Data Collection

Boolean searches were conducted using the LinkedIn Recruiter Lite function to avoid just searching members displayed around the researcher's personal network. This allowed to control key search terms and locations. The overall quality of the data input on the profiles was crucial for effective and valuable data to be successfully gathered and interpreted.
To ensure this a purposive sampling criterion was established for the selection of profiles during data collection. Purposive sampling was chosen over other non-probability or non-random sampling techniques such as convenience sampling to ensure that a logically assumed representation of a population can be chosen and allow for the deliberate choice of participants due to certain qualities they may possess, in this case professionals within FMCG PD&D and assessment of profile quality. Although both can be applicable to qualitative data collection, purposive sampling is generally more suited. For the case of this study the participants profiles need to be information-rich to ensure valuable data can be extracted (Etikan, 2016; Lavrakas, 2008). Expert sampling, a form of purposive sampling, was employed using the criteria established and displayed in Table 1 to focus on the collection of specialised and/or difficult to reach participants which demonstrate experience and expertise within a specific domain (Etikan, 2016 p.3). This sampling method is utilised in other qualitative studies examining UK FMCG PD&D populations (Simms & Trott, 2014b).

Table 1 Purposive Sampling Criteria

Sampling Criteria Point (CP)		**Description**
CP1	FMCG Professional	The profiles must demonstrate their current involvement in a role involving the design and development of packaging within the FMCG industry.
CP2	Experience Identified	Where applicable, previous experience should be identified on the profiles.
CP3	Education Identified	Where applicable, the profiles should identify their level of qualification.
CP4	Key Skills Identified	The participant profiles must include a key skills section in the profile layout.
CP5	Overall Profile Quality	The profiles must be completed with detail to provide clarity on their current role, previous role(s), education level(s) and an indication of their key skills.

Although gender and location were collected, these were omitted for analysis as focus was primarily on professional features and to protect the anonymity of profiles. Each profile had to satisfy all criteria points to be included in the final data repository. An example of a high-quality LinkedIn profile meeting the criteria is displayed in Figure 3.

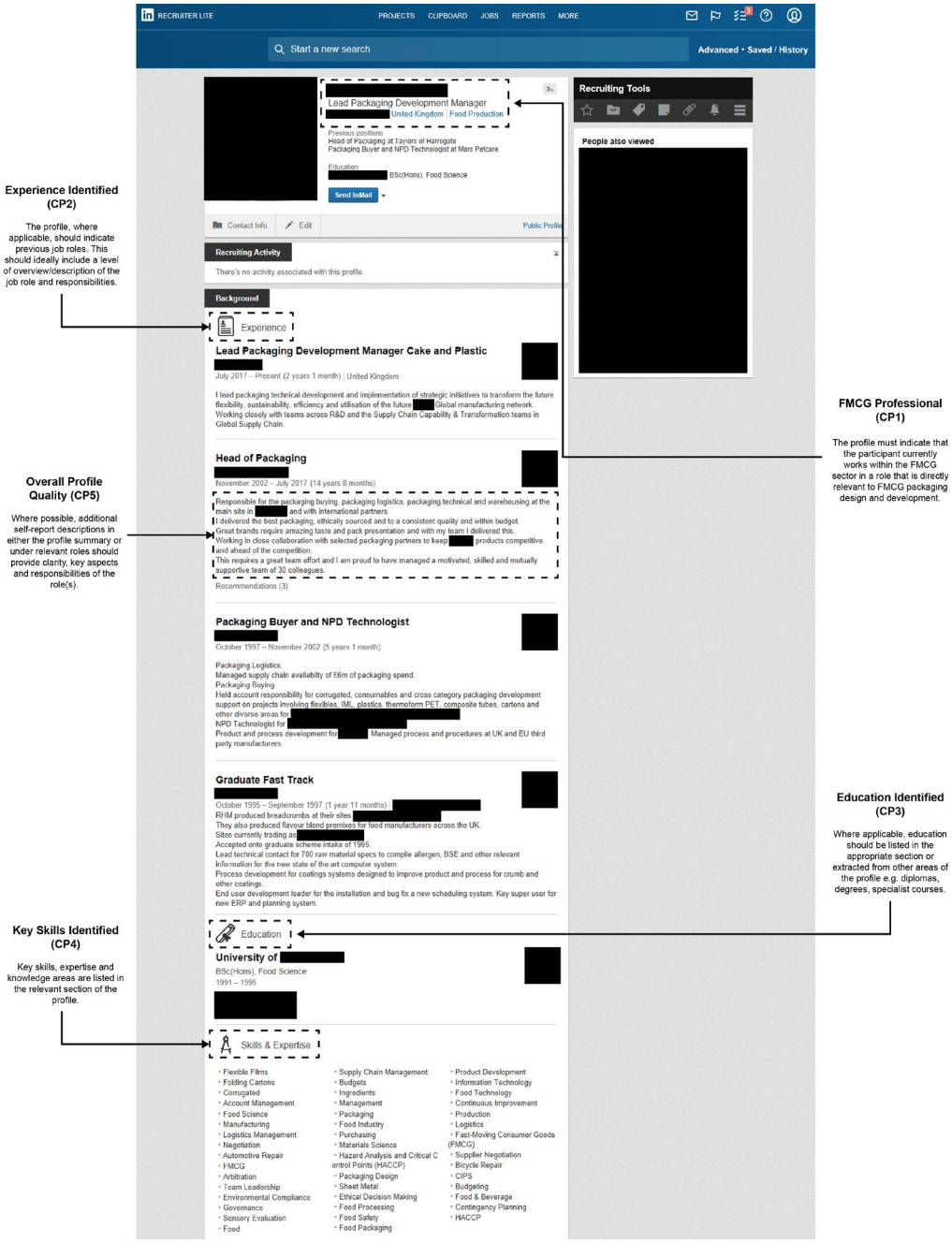

Figure 3 An example of a High-Quality LinkedIn Profile (S1:23)

To avoid bias on inclusion, profiles were extracted on quality of completion based on the purposive criteria with no content analysis performed at this stage to remain objective in the approach to profile selection. A summary of the profile search terms and results can be found in Table 2.

Table 2 Boolean LinkedIn Search Terms and Results from June, 2019

Boolean LinkedIn Search	Search Terms & Phrases	Search Results
S1 (n=100)	'Packaging', 'Design', 'FMCG', 'United Kingdom'	10, 671 profiles
S2 (n=100)	'Packaging', 'Designer', 'FMCG', 'United Kingdom'	2, 079 profiles

In the previous research used as a frame for the study, one-hundred profile samples have been used per occupation. Ecleo & Galido (2017 p.56) use one-hundred profiles over one occupation; and, Zide et al. (2014 p.592) use three-hundred over three occupations. As two searches were being conducted, two-hundred profiles (n=200) were collected, one-hundred from each search. To reduce the risk of documenting a profile more than once and allow for profile data to be re-checked, profile hyperlinks were generated to be able to track and reference each profile collected.

4. Data Analysis

A twofold approach to analysis including inductive content analysis and frequency of occurrence measures as primary interpretation techniques were used. Data extracted from the profiles (n=200) included the profile qualitative descriptive summaries and self-reported job role descriptions, previous experience, education/qualifications and skills/knowledge lists. The analysis of the profiles was then sectioned into three stages: 1) Categorisation of profile architypes; 2) Qualitative content analysis of self-report profiles; 3) Clustering and categorisation of professional skills based on semantic relatedness and similarity.

4.1 Stage 1: Initial Interpretation & Categorisation of Profiles

To begin to explore and understand the types and synergy of the profiles gathered, a conventional content analysis process was performed to begin to interpret and cluster the profiles (Elo & Kyngäs, 2008; Hsieh & Shannon, 2005). Initially, the lead researcher performed the inductive content analysis to formulate initial general categories of the PD&D professionals based on the purposive criterium points CP1, CP2 and CP3. Two additional doctoral researchers knowledgeable in FMCG PD&D were then recruited and provided the data to perform additional content analysis to aid in consensus seeking. The categories: (1) Design-Orientated Practitioners, (2) Design-Affinity Directors, Managers, Technologists & Developers, and (3) Product & Technical Orientated Technologists, Developers & Managers were established, taking into consideration the analysis performed by all researchers. Once the final categories (Table 3) were developed, these were then redistributed to the research team to gain full consensus. Descriptive summaries of the categories were then established to assist in further clustering and interpretation during continued analysis of the professional profiles.

Table 3 Categorisation of Packaging Design & Development Professionals

Category Established	Category Descriptive Summary	Profile Quantity
Design-Orientated Practitioners (D)	The professional is an active design practitioner or participates in design-based functions and activities as part of their day-to-day job role.	n=77
Design-Affinity Directors, Managers, Technologists & Developers (M)	The professional is not in an exclusive design practitioner role but assumes managerial responsibilities, has experience in past design roles or has a background in design related education.	n=64
Product & Technical Orientated Technologists, Developers & Managers (T)	The professional is not a design practitioner, has not held previous design roles or a design-based education but supports the packaging design & development process from a product and/or technical perspective.	n=59

4.2 Stage 2: Qualitative Content Analysis of Self-Report Summaries

To provide additional context, inductive content analysis was further employed on self-reported descriptive individual profile summaries at the start of the profiles and distributed throughout sections (*CP2* & *CP5*). These summaries were text based, that often outlined the professional activities, job role(s), key skills/knowledge and further insights into the tasks and summative day-to-day activities. This was utilised as supplementary data to aid in profile categorisation and further interpreting the organisational landscape and synergy of professionals involved in FMCG PD&D. If there was any uncertainty, further understandings of professional domains were also undertaken through the examination of organisational websites to provide greater context to job roles and activities through understanding organisational capabilities, products produced, and FMCG sectors engaged with.

4.3 Stage 3: Preliminary Categorisation of Key Skills

All Data, including skills, was extracted and recorded verbatim directly into the meta-data repository from profiles. As self-reporting is prone to human error (e.g. spelling mistakes and term repetition) the raw data was *'cleaned up'* (Osborne, 2008; Salkind, 2010); to enhance quality and accuracy of the data for analysis. In some cases, Americanisms and acronyms were use which had to be interpreted. These were matched with their appropriate associated phrases and terms. No clustering of semantically similar terms to create larger term categories was conducted at this point to provide an as accurate as possible representation of the data directly self-reported in the profiles.

4.4 Stage 4: Semantic Similarity & Relatedness of Key Skills

For this stage of data analysis, a conventional approach to content analysis was undertaken again on the terms extracted from the LinkedIn profiles to logically combine and organise

larger sub-categories into a smaller, more easily manageable number (Hsieh and Shannon, 2005 p.1279). To improve validity; and, not to be the sole opinion of a single researcher, the categories were presented to the two additional doctoral researchers to moderate the activity. They were asked to analyse and critique the term clusters based on semantic similarity and their semantic relatedness personal to each of the researcher's professional interpretation, experience and industry-related knowledge.

5. Findings

This section introduces preliminary findings from qualitative content analysis of profiles and a narrative of key findings. This can act as a starting point to improve current insight and understanding into the synergy of roles and professionals involved in PD&D, not only just including design-based practitioners such as graphic and structural design; but, wider design and development professionals involved in the holistic artefact creation needed for product realisation and commercialisation. Due to the mass of data collected, analysis and assessment of the frequency of occurrence of skills/knowledge, design tools and expertise of these professional groups is not presented. This paper aims to be an overview to explore and understand the wider, cross-functional body of PD&D professionals. However, highlights of this preliminary analysis are discussed throughout the narrative. The study forms part of a wider PhD research project in which further investigation will be undertaken into PD&D professionals within the UK FMCG industry.

Throughout the narrative of findings, participant profiles references are presented to support the statements which are made using the coding system highlighted in Section 3.2. This meta-data repository can be requested and will be made available to view providing greater insight into the profiles documented. Figure 4 summarises the key categories of domains of industry in which PD&D occurs and, but not limited to, what these domains can offer. This was disseminated from the profiles to provide further context to the narrative of findings. Research presented here expands on existing research by Simms & Trott (2014a) investigating FMCG packaging design management on a more granular level paying attention to the characterisation and synergy of professional roles and archetypes that contribute to PD&D in more detail to expand the existing understandings and frameworks within academic literature (Francis et al., 2008; Simms & Trott, 2014a; Vazquez et al., 2003).

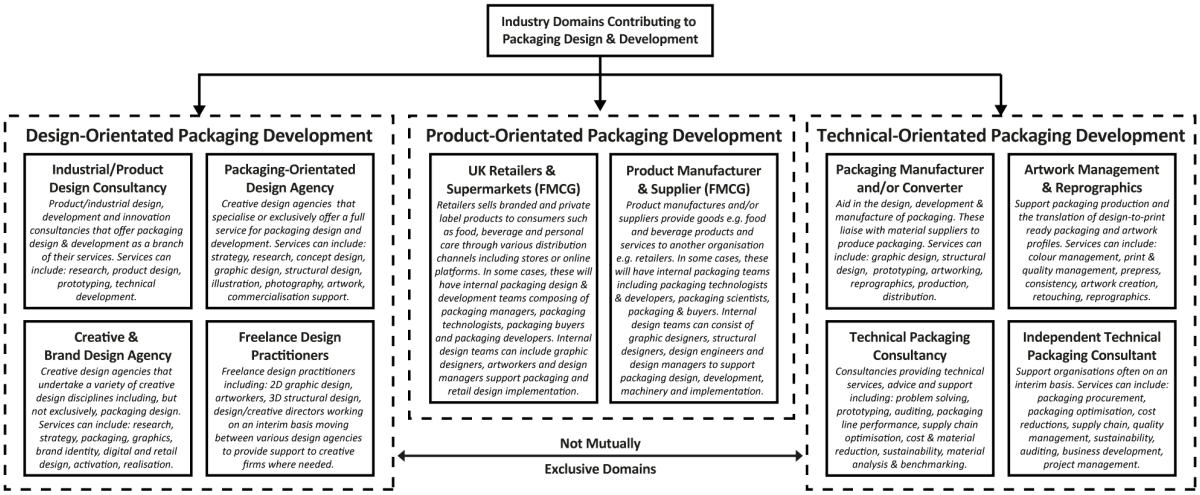

Figure 4 Summary of Industry Domains Contributing to Packaging Design & Development

5.1 Design-Orientated Practitioners

There are many roles and remits in which the general title *'packaging designer'* resides within organisations and functions. We propose three major subcategories that they could be distilled into displayed in Table 3.

Table 3 Design-Orientated Practitioners Summary

Sub-Categories	Summary Description	Example Role(s)
Graphic & Brand Designers (D1)	Orientated towards the 2D aspects of packaging design. For example, an emphasis on graphic/artwork design, brand & Identity, logo design, photography and art direction.	Brand & Packaging Designer, Creative Designer, Graphic Designer, Graphic Packaging Designer, Packaging Artworker, Packaging Designer
Structural & 3D Designers (D2)	Orientated towards the development of 3D structural design. For example, with emphasis on 3D modelling, CAD, design for manufacture and industrial design.	3D Designer, CAD Designer, Design Engineer, Packaging Designer, Packaging Engineer, Structural Designer, Technical Designer
Holistic Packaging Designers (D3)	Orientated towards the consideration and inclusion of both graphic and structural design during packaging design & development.	Creative Designer, Creative Lead, Designer, Packaging Designer

Graphic & Brand Designers (D1)

Brand and Packaging designer (S2:21,52) roles orientated towards graphic design and 2D visual packaging elements appeared frequently with reported skills and knowledge such as branding and identity design, brand development, typography, logo design, photography and creative direction. Many of these professionals would often be in brand and design

agency-based positions; or, within freelance roles moving between agencies. However, this does not mean that graphic design capability is mutually exclusive to agency-based remits. Graphic design skill and knowledge was also representative internally within organisations such as product manufacturers and suppliers (S2:18,36,39). Some packaging manufacturers/converters also held these capabilities although tended to be orientated towards creative artworking. Other roles included '*Packaging Artworker'* which appeared to be more concerned with technical application of graphic elements, artwork management, retouching, legal compliance, print management and reprographics knowledge as examples. Artworkers often sat internally within a manufacturer or supplier of products (S1:28, S2:35); or, within packaging manufacturers/converters and artwork management houses (S2:37,70,84). Some artworkers also appeared to work within the remits of design agencies in both permanent and freelance roles (S1:04) suggesting design agencies utilise this resource as part of their services.

Structural & 3D Designers (D2)

Practitioners focusing on structural and 3D aspects of PD&D featured commonly. *'Packaging Design Engineer'* (S1:91; S2:09), *'CAD Designer'* (S2:26) or *'Technical Designer'* (S2:75,76) were also terms used to describe similar roles. Structural Designers often sat in both agency (S1:22,37; S2:26,53) and packaging manufacturer/converter-based remits (S2:10,50). Structural designers within packaging converters were often material specific practitioners for example cartonboard, corrugate or plastic. This could infer a greater knowledge or ability to design for manufacture with that specific material as they have greater familiarity of material properties and, manufacturing processes and constraints. Some structural designers within packaging converters had experience with secondary pacakging, shelf-ready packaging, and point-of-sale design, not exclusively primary package design (S1:37) as this was an extension of company expertise and services. In the case of agency-based structural designers (S1:22,31; S2:53) these individuals appeared to focus on 3D brand design development and their associated visual guidelines often with backgrounds and qualifications in industrial/product design. Although organisations such as external design agencies hold structural design abilities, some product manufacturers also had these competences. *'Packaging Design Engineers'* were evident within the remit of R&D functions for structural innovation projects within internal teams to develop visualisations, prototypes and tolerance considered CAD models that were translatable into tooling from pilot through to production ready tools (S1:91; S2:06,15,32,64). Often these encompassed technical knowledge and understandings of utilising multiple packaging materials relevant to their organisation's products and brands.

Holistic Packaging Designers (D3)

Thirdly, an emerging category of design-orientated practitioners are what we will term *'Holistic Packaging Designers'* who presented themselves as professionals implementing skills, knowledge and practice of a hybrid between structural and graphic design into their day-to-day design practice (S1:90; S2:01,19,24,28,52,62). These practitioners appeared to sit

within internal design teams for product and/or packaging manufacturers (S2:19,46,52). A clear example is S2:47 who had a background in packaging structural design and packaging artworking to prepare print-ready artworks before moving into structural packaging design and commercial support. Other titles such as creative lead or innovation lead also appeared within packaging and product manufacturers as a dedicated internal creative resource orientated towards a certain product or service. These could maybe be comparable to creative brand managers looking after a particular brand or product from a creative design perspective (S2:73,91). Some designers had additional supplementary roles including illustrator (S2:78); project, commercial and account management (S2:60,91); supporting brands through consulting (S2:61); research responsibilities as part of co-creation activities (S2:73) and next generation product development (S2:72).

5.2 Design-Affinity Directors, Managers, Technologists & Developers

There were a variety of professional individuals who had affinity, knowledge, education or experience as design practitioners but whom instead undertook roles that facilitated and managed design activity and development processes summarised in Table 4.

Table 4 Design-Affinity Packaging Professionals Summary

Sub-Categories	Summary Description	Example Role(s)
Design Managers (M1)	Oversee and manage design-related tasks and employees. May require technical knowledge of processes and undertake supplementary design work activities.	Creative Design Manager, Design Manager, Packaging Design Manager, Technical Design Manager, R&D Packaging Manager
Design & Creative Directors (M2)	Supervise design projects and manage creative teams. Supplementary design work activities may be required to be undertaken as part of the role.	Art Director, Creative Director, Design Director
Design-Affinity Technologists & Development Managers (M3)	Ensuring specification and requirements are met, performance quality and trailing, supplier liaison, packaging procurement and development from a technical perspective.	Packaging Developer, Packaging Development Manager, Packaging Innovation Technologist, Packaging Technologist

Design Managers (M1)

Design managers within the remit of packaging design appeared to lead day-to-day operations of design teams, creative direction and delivery of PD&D within an organisation. Although they appeared to undertake project and people managerial responsibilities work as a primary function (S1:07,49), it appeared this role would require experience as a practitioner and a degree in a design domain such as industrial/product design. Packaging design managers were not exclusive to but were found more commonly within the realm of technical packaging manufacturers, product manufacturers and retailers. Design managers

within retailer's, product manufacturers and suppliers (S1:20,49,55,71,98; S2:03,27) were portrayed as both an internal and external facing role working with commercial teams, internal and external design resource and suppliers to ensure process quality and efficiency. Within packaging manufacturers, design managers were often orientated towards structural or technical design capability management (S1:76;S2:08,22,41,42,43,44,51,83,90,99). Often experienced structural/technical designers, these individuals reported that they were client-facing aiding in design brief formulation, design work to meet client and business goals as well as workload and workflow management.

Design & Creative Directors (M2)

Apposed to design managers, design and creative directors were often associated in external design agency-based companies such as product design, brand and packaging design agencies (S1:02,26,40,50,52,54,79,97; S2:04,69,98). These individuals appeared to be responsible as the head of creative teams in more supervisory, project and account/client management driven roles to facilitate the design process. These were also responsible for creating, realising and communicating creative 2D and 3D design briefs to a design team and aiding in design rationale, client presentations as well as day-to-day design work. They appeared to hold previous experience as design practitioners (*Section 5.1*) up to senior designers. These individuals also existed as freelancers moving between agency-based environments contributing to senior design activities and design/art director responsibilities (S1:61; S2:14,30).

Design-Affinity Technologists & Development Managers (M3)

Packaging technologists & development managers with design-affinity were another evident category (S1:01,03,06,41; S2:79). These individuals appeared to work within packaging development ensuring specifications and requirements are met, performance quality and trialling, supplier relationship development and liaison, packaging procurement and development from a more technical perspective but appeared to hold some form of empathy or understanding towards design through a design-based education or prior experience in design practitioner-based roles. Other roles such as packaging development managers held key responsibilities in packaging innovation opportunities, R&D and procurement strategies for companies to facilitate business customer relationships and project management between internal and external teams, brand/category management and business growth. These individuals held key skills typically used by design-orientated practitioners with an additional set of skills towards technical packaging development gained from either Diplomas in Packaging Technology (The Institute of Materials, Minerals and Mining, 2019) or from knowledge gained through career development. In some cases, additional management and problem-solving based qualifications were evident such as the Chartered Management Institute (CMI), PRINCE2 and TRIZ training (S1:03,39,52,92; S2:34,72).

5.3 Product & Technical Orientated Technologists, Developers & Managers

Finally, the last set of profiles categorised identified individuals with no apparent design-

affinity and appeared to focus on product and technical-driven outcomes in PD&D echoing some of the findings by Simms & Trott (2014a p.2020) regarding NPD and R&D members with focus on core product and technical related issues. These individuals reported to have no design-affinity in terms of education or previous job roles but worked in roles within or managing PD&D. These are summarised in Table 5.

Table 5 Product & Technical Orientated Packaging Professionals Summary

Sub-Categories	Summary Description	Example Role(s)
Product-Orientated Packaging Technologists, Developers & Managers (T1)	Ensuring specification and requirements are met, performance quality and trialling, supplier liaison, packaging procurement, development and implementations from a product and technical perspective.	Packaging Developer, Packaging Development Manager, Packaging Development Technologist, Packaging Technologist
Technical-Orientated Technologists, Developers & Consultants (T2)	Overseeing the technical-orientated development and management of packaging advising on supply chain, manufacturing, packaging machinery, procurement, material choice, value engineering and cost reductions in packaging development and implementation.	Packaging Consultant, Packaging Coordinator, Packaging Development Manager, Packaging Director, Packaging Engineer, Packaging Innovation Manager, Packaging Scientist, Packaging Technologist, Technical Packaging Specialist

Product-Orientated Packaging Technologists, Developers & Managers (T1)

These individuals appeared to have a rapport towards the product contained within the packaging and product-technical concerns based on their education and professional backgrounds. Holding similar roles to professionals identified in S*ection 5.2.3 including 'Packaging Technologists'* (S1:35;S2:09) *and 'Packaging Development Managers'* (S1:23,35) working internally in product manufacturers; they did not appear to have design-affinity and in many cases had worked previously in product development roles such as formulation chemists or food and beverage product developers before moving into packaging development roles. In turn, this often meant that these individuals were trained within degree-based courses including food science and technology, agricultural science and chemistry (S1:45,62,96; S2:09). They would often have skills and knowledge including food processing, food safety, factory trials, quality assurance (QA), lean manufacturing, ingredients, distillation, formulation and fragrance knowledge as examples extracted. For their career transition into PD&D roles, additional diplomas in packaging technology were often attained appearing in cases to provide supplementary packaging specific knowledge. A clear empathy and understanding towards the product contained within a package was evident but as 'packaging champions' within a company have no evident experience or expertise in design-aspects of packaging. With this said, this cannot be a generalisation or something attainable interacting or relying on the engagement with design-orientated

professionals (*D1, D2, D3*) gaining knowledge through experience. This suggests product manufacturers internally hold such expertise and further echo discoveries made by Simms and Trott (2014), in where this could potentially affect an organisations level of packaging absorptive capacity via the knowledge and abilities these individuals acquire, potentially affecting or hindering design and technical development of packaging.

TECHNICAL-ORIENTATED TECHNOLOGISTS, DEVELOPERS & CONSULTANTS (T2)
Finally, professionals who could be classified as more 'technically-orientated' in their approach to PD&D included roles such as *'Packaging Technologists' (S1:05,12,13,15) 'Packaging Scientists'* (S1:17,65,73) and '*Packaging Engineers'* (S1:08,21,43,81,83,95) sharing similar roles and responsibilities to other design-affinity practitioners (M3) and product-orientated packaging technologists (T1). In this case, these individuals did not appear to hold an affinity towards design but a focus on technical packaging project management including the consideration of supply chain, packaging commercialisation and industrialisation. These included emphasis on specific areas such as product lifecycle analysis, optimisation, QA, packaging substrate choice, packaging machinery selection and approval and good manufacturing practices. Although in this case, they did not appear to have any design affinity and tended to be more concerned with technical packaging artefact development as part of internal product manufacturer R&D teams, this does not mean the role could not be adopted by someone with a design related degree or background and be representative of *M3* professionals as identified in *Section 5.2.3.*

Other roles identified included technical leaders, directors and other senior leadership positions. These professionals would often sit internally as part of a product retailer (S1:36,69), product manufacturer or supplier (S1:46,63,78,80); or, be incorporated into a technical-specific packaging consultancy (S1:09,10,53), or interim consulting role (S1:30,33,57) focusing fundamentally on packaging supply chain optimisation, value engineering of packaging artefacts and material/cost reduction. These appeared to have no affinity, experience or background with or within a design-based perspective and appear across multiple domains of PD&D and to be highly engaged with retail and product manufacturing during the decision-making and implementation of new packaging formats.

6. Discussion

This paper unpacks the current state of FMCG PD&D professionals using: 1) a bottom-up approach; drawing upon self-curated and self-reported, naturalistic data (Silverman, 2015); and, 2) mapping the current actors and power structures, to extend the framework developed by Simms and Trott (2014a). This approach differs from current approaches of understanding industry dynamics in both industry and academic literature i.e. meta-level indicators (Design Council, 2007, 2018; Moultrie & Livesey, 2009; PricewaterhouseCoopers, 2017) and post-hoc accounts (Khan & Matthews, 2019). This study presents a more thorough treatment of different archetypes of practitioners, studies the synergy between their roles within the overall landscape, and relations between groups. This interpretation of LinkedIn

profiles, through our content analysis, gives us a better understanding of the various PD&D professionals that affect design practice, design process and decision-making during FMCG PD&D.

By adding to Simms and Trott's (2014a) very comprehensive framework with the practitioner's own perception of 'self' we aim to get a more holistic industry view. This allows us to carve off specific parts of the value-chain, where focused efforts and interventions can be made to apply the surfeit of unrealized lessons from packaging design research. More thoughtful, considered and targeted efforts can be made to address some of the challenges currently being faced by the industry today at a more granular level. Present provocations apparent in existing literature such as, 'why is the focus on innovation in packaging design still seen as a nice-to-have, not core to business?' (Bruce & Daly, 2007) or 'why are the business case arguments related to packaging design always geared towards cost-savings in materials and infrastructure (Simms & Trott, 2014b, 2014a)2005; Silayoi & Speece, 2004 and not potential lost in increased sales at point-of-sale conversion value?' (Clement et al., 2015; Connolly & Davison, 1996) can begin to be seen in a new light. When we map out the actual role archetypes that are the constituents of the industry itself, we can begin to fracture the over-generalised perception of faceless, ambiguous descriptions of PD&D professionals to begin to answer some of these questions in the future.

If we take on one of the aforementioned questions – the organisational aversion to include packaging design as a core business component, and try to apply lessons from our study – exploring the breadth of the practitioners who fall under the management decision-making positions within a specific organisation could help us distil decision-making to Design-Affinity Managers (M) and Product/Technical-Orientated professionals (T) categories. Within these categories we can further identify specific role distributions mapped to M1, M2, M3, T1, and T2 all of which have degrees of influence in management decisions beyond those tied to craft-based specialist roles such as D1, D2 and D3. In doing so from a skill-building, human capital development perspective, when applied to a specific organisation we can create specific strategies to tackle the organisational culture and mind-sets of the archetypes of the different sub-categories. Again, considering the other provocations raised of design side-lined with focus being on cost saving and value engineering initiatives on packaging artefacts within NPD projects; by using the knowledge generated in this study through understanding PD&D on this more granular level we could potentially begin to unpack reasoning and rationale behind these issues within organisations through studying who makes decisions on an organisational level? What is designs prevalence in product development processes? What are the roles, characteristics, knowledge and skills of the professionals chosen to be involved? For example, if the makeup of an organisation focuses primarily on the inclusion of T1 and T2 professionals in PD&D decision-making we can begin to understand why this provocation may be true in some cases. By equipping organisations with the knowledge provided here we can hope to educate and allow them to navigate the breadth of professional architypes that can or should be involved in PD&D allowing self-reflection on current practices internally to look to balance or provide knowledge, understand the value

to invest in certain architypes and dedicate organisational resource in design-based activity internally or to outsource externally.

Our research adopts a lot of the preliminary research conducted on packaging management, however we challenge points regarding the lack or absence of technical expertise of packaging NPD *'champions'*, originally termed by Markham & Griffin (1998), often associated with the fundamental success of packaging activities within FMCG firms (Simms & Trott, 2014a p.2020). Our data evidences these individuals are widely implemented across the FMCG sector in the form of M3, T1 and T2 professionals that fall within the working remits of internal teams of retailers and product manufacturers whose role are to *'champion'* the implementation of PD&D within their respective organisations. We argue their prevalence could be influenced by the size of the organisation which could impact buy-in power to invest in these professional architypes. Thus, we argue it is not only the absence, but the individuals design-affinity and technical packaging knowledge as part of their overall skillset as internal packaging *'champions'* chosen which could affect the lack of the active pursuit in new opportunities for packaging design and innovation.

We are cognizant that using the categories as a framing device we can fall under the peril of over-simplification, detaching the roles from the intricate complexities of the organisational hierarchy they are situated in and what these professionals bring to an organisation on an individual level. However, this hopes to allow for us to get more granular in identifying these almost 'persona'-like roles within an organisation and explore avenues of how to best provide specific support for bringing packaging design to the core of business decision-making, through each role and its influence. We hope this work helps other researchers understand the complexity of this industry; and, to take into consideration industry-based design and development practice approached to packaging research beyond more siloed, top-down views that currently exists. Figure 5 presents an accessible expansion of the framework by Simms & Trott (2014a) to communicate the archetypes and the influences of various PD&D professionals on packaging activities in NPD. We have mapped onto the existing framework expansions of professional architypes to provide greater context of their industry domains and increase the understandings when conceptualising design management of packaging within the FMCG sector. It must be noted that this mapping is non-exhaustive, and we urge other researchers to continue use, modify and expand this to continue to give us a better understanding of the entire scope of the industry.

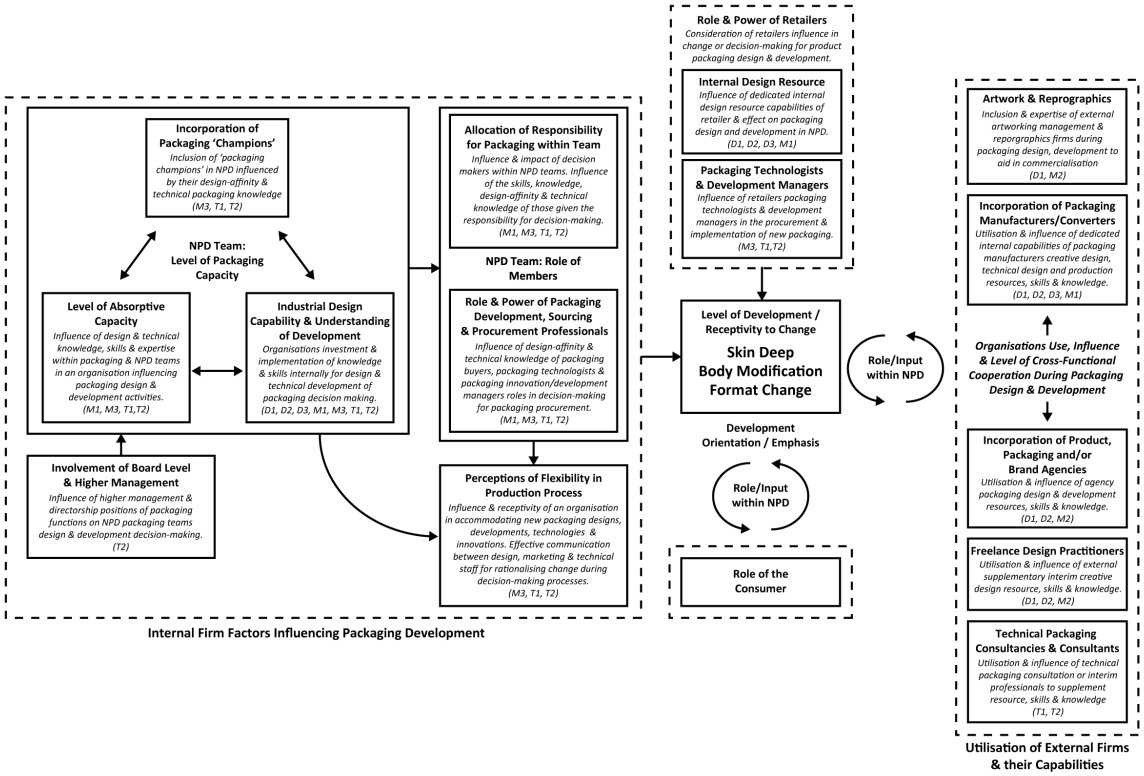

Figure 5 Adapted Framework of Influences Impacting the Management of FMCG Packaging Design & Development in NPD

7. Limitations and Future Work

Current results are concluded via qualitative interpretation by three researchers. Although knowledgeable within the research domain, this is an interpretation of self-reported data to establish preliminary categories. Further analysis of the dataset should be undertaken and displayed alongside these findings through in-depth research into these professional's education, skills and the context of organisational structures is encouraged. The technique used, although can be drawn comparable to that of explicit self-report survey methods, only allows the collection of data presented in this online profile format. Although providing rich insight into day-to-day activities, key skills, expertise and experiences; there are possibilities that the data may include superficial depictions or fabricated explanations of one's self-representation, job role(s) and skills. Additionally, not all professionals will use the LinkedIn service or fail to update the profile throughout career development. Furthermore, the profiles may not contain a full report of the capabilities as this is fully dependant on individuals completing all relevant sections or be allowed to disclose certain information onto their profiles.

Future research should also look to further explore PD&D management and process within the FMCG sector. Additional methods such as interviews with UK packaging professionals in the domains identified should be undertaken to confirm results or provide greater insight

moving forward. This includes other cross-functional R&D professionals e.g brand managers, marketing managers and key account managers that may be involved in influencing the decision-making and supporting PD&D. The use of other explicit self-report platforms such as *'Instagram'*, '*Pinterest'*, '*Behance'* or '*Dribbble'* from a practitioner evaluation perspective may also be beneficial as mediums for driving exposure and viewing traffic for designers. LinkedIn was chosen as a platform for this study due to the large amount and variety of professionals using the platform, depth of information that could be attained and existing methods that have been used to collect and analyse data.

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About the Authors:

Nicholas Samuel Johnson is a doctoral researcher and design insights researcher specialising in design and innovation management. His current research interests are in FMCG packaging design and approaches to improve design management and integration into cross-functional NPD within the UK FMCG industry.

Awais Hameed Khan is a doctoral researcher. His research explores how to make participatory design, tools methods, and practices more accessible to non-designers. He has industry experience in brand management and service design in FMCG & Telecommunications sectors.

Abbie Lawrence is a doctoral researcher and consumer insights specialist at the ZERO2FIVE Welsh Food Industry Centre focusing on packaging design for FMCGs for UK SMEs. She helps lead research utilising the Perceptual Experience Lab at Cardiff Metropolitan University.

Dr George Edward Torrens is a Senior Lecturer in Industrial Design. He has thirty years' experience of working in the field of assistive product and inclusive design. He has developed best practice for the design of assistive products in collaboration with charitable groups and manufacturing industry in the UK and Internationally; and, has over one hundred publications.

Ian Storer is an experienced multidisciplinary designer and academic. Current research interests are the understanding of product semantics/ semiotics and the efficient communication of design intent and outcomes.

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Multidisciplinary design collaboration in the lenses of CSCW and current technology enablement

Mimi NGUYEN[a]*, Céline MOUGENOT[a]

[a] Imperial College London, United Kingdom
*Corresponding author e-mail: m.nguyen@imperial.ac.uk
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Abstract: This paper aims to better understand team dynamic aspects in multidisciplinary design collaboration in reference to the CSCW discourse. We present an exploratory literature review and co-occurrence analysis of emerged themes from the studies. Then, we juxtapose the findings with technology-enabled tools suggested for CSCW. Finally, we review the industry relevance of the proposed tools. To illustrate our recommendation for future research, we discuss and suggest a matrix evaluating existing collaborative systems based on the identified team dynamics aspects. We identified two critical aspects, that are vulnerable in the digital channels: shared understanding and trust. The results allow us to discuss future direction, how CSCW and digital tools can aim at improving trust and shared understanding and to define the gap in the design research in reference to the real-world context, future of work and technology enablement.

Keywords: multidisciplinary collaboration; design communication; cscw

1. Introduction

Design tasks are described as those solving complex (wicked) problems (Akin & Hopelain, 1986; Buchanan, 1992; Goel, 1995), and since creativity is argued to be a prerequisite for invention and innovation, it is considered to lead to the increase of market growth (Hewlett, Marshall, & Sherbin, 2013). It has been suggested in the report by McKinsey & Co (Sheppard, Kouyoumjian, Sarrazin, & Dore, 2018) that there is a strong correlation between employing design practices - MDI McKinsey Design Index scores - and high business performance. The study shows that companies in the top-quartile scores have managed to increase their revenues by 32 per cent over the five years comparing to their competitors. In the case of the total returns to shareholders, this growth has reached 56 per cent. This phenomenon appeared true in all three studied industries - medical technology, consumer goods, and retail banking. Following such findings, it has been underlined by the authors that design practices are applicable, and yet even beneficial for the development of physical

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goods, digital products and services, or a combination of these. Moreover, multidisciplinary collaboration is found to influence group performance and increase the number of potentially useful ideas (Milliken & Martins, 1996).

The ground-breaking report from Guinney et al. (2017) refers to the global competition for cancer survival rates prediction, that took place entirely virtually via a crowdsourcing platform. In the light of such event, there is now concern about how online presence is influencing the way we work and collaborate? We will thus review the key themes from the research on multidisciplinary collaboration with respect to virtual communication tools suggested in the discourse of Computer Supported Co-operative Work (CSCW). By mapping the current communication systems with the identified themes in our suggested matrix, we aim to identify vulnerable areas and discuss the industrial relevance of suggested tools. This will enable us to determine the direction of required future work.

In addition to design practices, leaders from most innovative companies from the BCG 2019 report (Ringel, 2019), have extensively referred to the importance of team collaboration in the innovation design processes. Microsoft co-founder Bill Gates describes:

> "Communication skills and the ability to work well with different types of people are very important. (…) Software innovation, like almost every other kind of innovation, requires the ability to collaborate and share ideas with other people." (BBC, 2007)

Team collaboration discourse is undergoing a remarkable revolution as its virtual factor has become a widespread common practice in companies of all industries. At Alphabet\ Google, another company from the top 5 most innovative ones, 100 000 employees are spread out over 150 cities from more than 50 countries. A company report (Gilrane, 2019) highlights that nearly half (48%) of meetings in Google involves employees working from different buildings, and 4 out of 10 meetings involve different cities. In order to specify recommendations for future work of distributed teams, it is critical to understand the social structures and systems in the team dynamics (Giddens, 1991).

2. Methodology

Design studies, and especially design thinking in previous research used to mean something different than nowadays, as Goldschmidt mentions:

> "It was not meant to be a methodology (...) it was just a way of talking about how designers in different disciplines think." (Christensen, Ball, & Halskov, 2017)

As a result, the theme has evolved in the last decades from the study of design practices to wide-ranging research of co-creation across various disciplines, including team communication and cross-cultural collaboration. An extensive literature body highlights the benefits of these, especially in terms of multidisciplinary collaboration (De Luca & Atuahene-Gima, 2007; Troy, Hirunyawipada, & Paswan, 2008). However, there has not been conducted a comparative review of such studies. To address that, we investigate research articles from a meta-synthesis perspective (Robson & McCartan, 2016) using qualitative content analysis

and co-occurrence analysis to identify key themes in the literature, while acknowledging the diversity of the findings. We include all three multidisciplinary, interdisciplinary and cross-functional in order to retrieve studies on collaboration that include participants from differing disciplines at every knowledge synthesis level. The selected research articles include a subset of 17 core literature studies from the period of 22 years (1996-2018), that has been chosen from the body of over 200 articles identified within the design context. This commended an exploratory literature review. Our selection focuses only on investigations, that employ a sample of multidisciplinary teams performing design tasks and those, that provide an overview of the empirical research within meso-scale team collaboration level (Cash, Škec, & Štorga, 2019). Where the research paper refers to more than one experiment, only the studies within the scope of multidisciplinary collaboration are considered for this review.

2.1 Definition of multidisciplinary collaboration

Disciplinary background, in the discourse of design studies and the related fixation issue (Vasconcelos & Crilly, 2016), influences the design processes. As an example, industrial engineers, for their nature of thinking more outside-the-box, might be more capable of overcoming design fixation. Whereas, engineers, as they are more focused on idea feasibility and solution details, would create less variety of solutions when compared to industrial engineers. Companies have been creating cross-functional teams in order to get the best out of all the skills and experiences. It is, thus, worth investigating team characteristics such as disciplinary background or level of experience of the participants. Sonnenwald (1996) gives an example, where, many engineering firms integrate engineering, manufacturing, marketing, distribution and end-user knowledge. For Kleinsmann and Valkenburg (2008), the process of designing a new product involving actors from different disciplines is called co-design. However, the terms multidisciplinary and interdisciplinary appear to be more popular among researchers, when defining this type of the group-work environment. First, it is essential to define the scope of such approach in terms of the disciplinary partnership. There is a division in the literature body of the meanings of multidisciplinary versus interdisciplinary versus transdisciplinary. All three levels of the disciplinary integration are defined by Adams, Mann, Jordan and Daly (2009) under one term of cross-disciplinary a practice, that includes:

- multidisciplinary - joining together of disciplines to work on common problems and split apart when work is done,
- interdisciplinary - joining together of disciplines to work or identify common problems and interaction may form new knowledge,
- transdisciplinary - beyond interdisciplinary combinations to a new understanding of relationships between science and society.

They should, however, not be used interchangeably, as they describe different involvement degree of multiple disciplines in studied projects (Choi & Pak, 2006). Nonetheless, the terms multidisciplinary and interdisciplinary have been used interchangeably by Kasali and Nersessian (2015) in their study abstract. This shows how, in reality, the barriers between

such practices are being blurred in academic research. Adams et al. (2009) describe the term cross-disciplinary as a practice, where transgression into and across other disciplines takes place. However, few studies refer to this term as a separate level or practice in the disciplinary integration differentiation (Miller & Miller, 1982; Porter, Roessner, Cohen, & Perreault, 2006; Stember, 1991). For them, cross-disciplinary is viewing a problem from the perspective of another discipline. Therefore, for the purpose of this review and to understand best practices for design collaboration, we cannot limit the review to only one of the layers of such collaboration. While solving complex problems, team participants do cross their knowledge boundaries and synthesise practices from one another disciplines (Kleinsmann, Deken, Dong, & Lauche, 2012). Therefore, we will embrace both multidisciplinary and interdisciplinary terms together with cross-disciplinary collaboration in the review, in reference to complex problem-solving practices, employing many disciplines together, at all involvement level, defining the scope with an umbrella term. Throughout the review, we will use the term multidisciplinary to refer to this umbrella term. The next sections seek to methodologically analyse previous investigations and discuss findings from the research articles addressing this matter.

2.3 Variables manipulated in the studies

The past two decades witnessed a considerable rise of interest within the collaborative design paradigm. We present in the following summary table (see Table 1), methodological details of these research articles, with each row corresponding to one publication.

Table 1 List of the core literature

First author, year	**Experiment setting**		**Industry**			
	natural	laboratory	construction	manufacturing	healthcare	software
Adams et al. (2009)	X		X			
Awomolo, Jabbariarfaei, Singh, & Akin (2017)		X	X			
D'Souza & Reza (2017)		X	X			
Feast (2012)		X	X			
Haines-Gadd et al. (2015)		X			X	
Hu, Li, & Du (2017)		X	?	?	?	
Jutraz and Zupancic (2017)		X	X			

Kasali and Nersessian (2015)		X	X			X		
Kleinsmann and Lugt (2007)		X	X					
Kleinsmann and Valkenburg (2008)	X		X					
Kokotovich and Dorst (2016)		X		X				
Mcdonnell (2009)		X	X					
D'souza and Dastmalchi (2016)		X		X				
Sonnenwald (1996)	X		X				X	
Steele, Macmillan, Kirby, & Spence (2001)		X	X					
Wang, Roy, Barry, Chang, & Bhatt (2018)		X		X	X		X	
Zolin, Hinds, Fruchter, & Levitt (2004)		X	X					

3. Emerged themes

We collected the bibliometric data with abstract content of the core literature to construct and visualise the co-occurrence network of emerged themes. To perform the text mining functionality and create the term map (see Figure 1), we used VOSViewer (Van Eck & Waltman, 2011) that employs natural language processing algorithms to identify relevant terms. The co-occurrence network has been created following the steps (Van Eck & Waltman, 2011):

1. part-of-speech tagging through the Apache OpenNLP toolkit,
2. linguistic filter to identify noun phrases, with conversion of plural noun phrases into singular ones,
3. selection of most relevant noun phrases, through determination of the distribution of (second-order) co-occurrences over all noun phrases, where the larger the difference between the two distributions (measured using the Kullback-Leibler distance), the higher the relevance of a noun phrase,
4. grouping of co-occurrence network noun phrases with a high relevance into clusters (themes).

For each theme, the size of the label circle and its font size mirror the importance of such theme, and the varying colours represent classification clusters. These clusters lead to four identified themes that we will analyse in reference to the current research in CSCW.

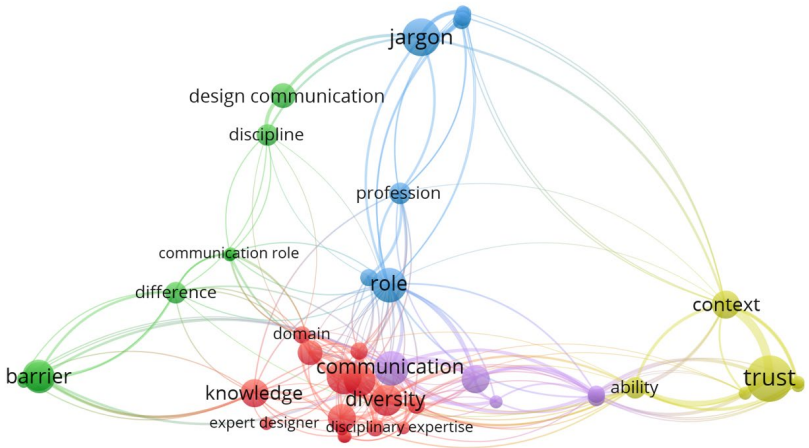

Figure 1 The co-occurrence map of emerged themes

In the following subsections, we present and discuss the emerged themes from the research on multidisciplinary collaboration in design studies with the corresponding tools from the on research (see Table 2).

Table 2 Mapping of emerged themes from design studies with CSCW tools

Design studies	**CSCW**
Knowledge diversity	Visual representation
Trust	Spatial faithful video conference
Barrier	Role detection
Jargon and communication	Content analysis

3.1 Knowledge diversity

An emerged aspect for bridging knowledge diversity in multidisciplinary collaboration is knowledge convergence that enables mutual agreements between participants to take place and create shared understanding (Feast, 2012). This has also been emphasised in the study of Hu et al. (2017), who suggest that more frequent knowledge sharing behaviour together with the complex sharing network lead to faster mindset shifting from one discipline to another. Mcdonnell (2009) defines shared understanding to be created through conversation during the design negotiations. Such exchange allows experts to express their non-expert knowledge, which in turn invites the end user to draw on their expert knowledge and thus gain a better understanding of the design context. Moreover, Kleinsmann and Valkenburg (2008) find that shared understanding requires face-to-face team communication, project

management and project organisation. However, comparative investigations of design meetings suggest that face-to-face communication results in higher perceived effectiveness than speech-only communication (e.g. telephone communication). Additionally, speech-only communication produces higher perceived effectiveness than text-only communication (Ostergaard, Wetmore, Divekar, Vitali, & Summers, 2005). We can thus, highlight inevitable challenges for CSCW and virtual teamwork in terms of the lack of shared understanding and lower effectiveness due to the nature of collaborative systems. Saad and Maher (1996) suggest employing shared databases integrating various media and information into a shared workspace to allow shared understanding development.

In our core literature, visual representations emerge as both facilitating and bridging medium between disciplinary boundaries. Adams et al. (2009) state that non-verbal activities, including gestures and drawings, act as communication aid between the group members, supporting multidisciplinary collaboration. Consistent with this, Kasali and Nersessian (2015) suggest that design drawings are critical in developing cross-domain expertise. Such drawings are thus defined as a synthesis of multidisciplinary knowledge. They suggest that beyond the verbal interaction, these visual representations act as a key role in translating and blending differing professional expertise. Mcdonnell (2009) highlights that the visual representations play an important role in defining the routine for internal interactions, helping to organise the discussions' themes. However, quick sketches in order to act as a bridging medium, require already established shared understanding in the collaboration (Feast, 2012). Similarly, a study from Kleinsmann and Valkenburg (2008) supports this finding, when an electrical engineer created an explanatory drawing for the ergonomist. However, they were still not able to productively negotiate with one another a solution to the problem. Kleinsmann and Lugt (2007) in a different study, suggest that the correct perception of the sketches requires knowledge of the jargon and an understanding of the context. In the discourse of CSCW, Gül and Maher (2009) in their comparative study between face-to-face and remote collaboration meetings with sketches, find that in remote sketching, teams dedicated more time on creating and deleting; whereas in the co-located meetings more time was spent on writing. Similarly to this finding, Garner (2001) shows that remote teams spent 51% more time on creating visual representation. Interestingly, albeit more time was spent on making the sketches, the number of drawings produced significantly decreases (by 30%) in computer-mediated, remote meetings. The author suggests such trend as a possible result of the unfamiliarity of the participants with the computer-based sketching tools. When implementing approaches from design studies to other industries, such as software engineering, medical and professional services, this unfamiliarity with virtual sketching will become an obstacle in CSCW.

3.2 Trust

A study of Haines-Gadd et al. (2015) highlights the importance of trust in multidisciplinary collaboration. Similarly, from the investigation of Zolin et al. (2004), trust is found to be a critical component in cross-functional teamwork. Apart from varying domain-related

perspectives and regional/ national cultures, geographical distribution (and resulting lack of face-to-face interaction) plays a great role in decreasing the level of trustworthiness between participants. In terms of disciplinary background, respondents from their research, claim that they would trust professionals from the same domain more than from other professions. Consistent with this, broader literature body supports such finding that direct, in-person meetings increase the trust between participating members, which results in higher creativity and quality of the work (Gloor et al., 2012). Even without the respect of disciplinary background, Feast (2012) reveals that bringing an outsider to an existing group, where participants' roles have been established, creates distrust and further misunderstanding of the group's motivations. Summing up, in order to efficiently collaborate with team members from the different disciplinary background, a high level of trustworthiness is required. Over the last decades, trust has become a core concern for CSCW studies due to the increased number of technologies supporting distributed teams (Riegelsberger, Sasse, & McCarthy, 2005). The research suggests audio and video exchange systems are potentially as effective as face-to-face meetings (Bos, Olson, Gergle, Olson, & Wright, 2002). However, they highlight the evidence of delayed trust, which is slower progress to full collaboration and fragile trust, which characterises the vulnerability to opportunistic behaviour. However, Nguyen and Canny (2007) argue that video conferencing can significantly affect trust formation in multiple-participant systems. They suggest using a spatially faithful video conferencing – MultiView – simultaneously displaying different video streams to different participants based on their viewing position. In their study, teams collaborating with the faithful spatial video cooperated more than teams using standard video conferencing systems.

3.3 Barrier

According to Kokotovich and Dorst (2016), novices cannot cross domains nor develop new higher levels of abstractions. Their sample of the least experienced participants was represented by students from the undergraduate academic level. In 56% of the observed instances, the team was not operating on the competent level (Dreyfus, 2004), where problem-solving is accompanied by high design situation involvement, emotional involvement, learning and reflection. Contrary to this, D'souza and Dastmalchi (2016) find that undergraduate juniors still make a significant impact on the design process. However, in the study of Kokotovich and Dorst (2016), the novice team did not use any methodologies or tools, and thus did no enrich the solutions space. Lower experience level, in the research of Haines-Gadd et al. (2015), led to inefficient use of time and resources. In the majority of studies, teams are being formed in a laboratory experimental way with students from the same academic year. Notwithstanding, in a real-world situation, there will be a diversity of experience level across the project team, ranging from 0 to over 30 years.

An interesting perspective is presented by Sonnenwald (1996), where she suggests that the number of years of professional experience reflects the participant's role within the group. She presents the communication roles that emerged during the design process and enabled the team to collectively integrate multidisciplinary knowledge and form boundary-spanning

activities. For example, participants with minimal professional experience can take on the roles of facilitation interaction between members within the project. Participants managing cross-organisational information require more than 8 years of professional experience, with these coordinating activities with more than 14 years. It is worth highlighting that the interdisciplinary star who integrates knowledge from different disciplines and domains has a minimum of 10 years of professional experience. García, Maria Balmaceda, Schiaffino and Amandi (2013), propose an approach for automatic detection of team roles in a CSCW system. This would apply Artificial Intelligence (AI) to garner the team role that best suits the characteristics and behaviours of a user through performing classification algorithms.

3.4 Jargon and communication

As design is defined as a social process (Bucciarelli & Bucciarelli, 1994), it is crucial to make efforts investigating the communication within it. This has been quantified by Steele et al. (2001), who observe that social interaction is a critical component and accounts for 21% of the conceptual design activity time. They also notice that social interaction is neglected in the used framework model. Additionally, renegotiation of the earlier defined roles of the team members emerges as a feature of social integration during the design talks (Mcdonnell, 2009). Sonnenwald (1996) suggests that any interpersonal talks, e.g. about weather, families or hobbies facilitate the discovery of other participants perspectives and language, which can lead to establishing personal bonds. Kleinsmann and Valkenburg (2008) suggest that on the team communication level, the difficulties emerge due to differences of jargon used by the participants, different design representations and responsibilities. Similarly, the importance of understanding the communication and design jargon issues was advocated by D'Souza and Reza (2017). Hu et al. (2017) define different jargon as unique, specialised work languages together with different past experiences, work patterns, quality and success perception, organisational priorities, and technical constraints. High constructive interactions foster productive creation of good ideas, promote idea integration and co-building. One person contributes from his/her discipline expertise, inviting the other to respond and supply information with the provoked expert response (Mcdonnell, 2009). This, however, requires the recognition of others expertise and appropriately timed assertion of such expertise in order to reach consensus. To solve jargon related issues within CSCW, Yasuoka (2010) presents The Language Grid Toolbox, which extends machine translation functionality with a local dictionary. It facilitates multi-lingual collaboration, where users can create, develop and maintain a dictionary for local jargon iteratively.

Jutraz and Zupancic (2017) observe national-specific characteristics as other communication obstacles. Participants from Asia are described as quiet, polite and less impulsive than those coming from Europe. This leads to different communication styles between these cultures, as the Asians would not express their opinion and mainly listen to others. At the beginning of the meeting, discussions would only take place among the European participants. As a result, respondents from the study, point out that it is not the work with different professions, but working with different cultures and characters is more challenging for them. Zolin et al.

(2004) find that such cultural differences result in varying expectations, lower predictability, and following the decrease of the trust level. They suggest that the underlying rationale for this can be cultural misunderstandings instead of potential prejudices. In a similar study of meetings, including Asian - European collaboration, D'Souza and Reza (2017) take on the investigation of language within the cross-cultural design process. Their analysis of jargon/ slangs used by Eastern and Western participants reveals the different characteristics between these two groups, in terms of their individual vs collective and expressive vs restrained perspectives. They also point out the presence of cultural brokers in the sample and raises a question on how the design process can overcome barriers from cross-cultural jargon in the absence of such translators. In CSCW, automatic translation is suggested to promise to bridge the linguistic gap (Kamel & Davison, 1998). However, there are still asymmetries (e.g. translation of "dance" into "jump") and inconsistencies caused by machine translations that need to be resolved.

4. Limitations

Research efforts to date provide many lessons on multidisciplinary collaboration in design engineering activities. Albeit the studies have been performed comparably, there are limitations in differences in findings among variables related to the experiments.

4.1 Disciplinary homogeneity

In all studies, authors define studied teams as multidisciplinary or interdisciplinary. However, one could notice that many of them were homogeneously creative-industry characterised; for example, they were arranged with designers or design-related professionals. Albeit, Awomolo et al. (2017) highlights that having multiple functional groups reduces the impact of roles and positions on decisions (leading to a more interactive and democratic approach). In their sample from the DTRS11, 5 out of 8 team members belong to the Design Team, and the other 3 External Consultants (Market researcher, Design researcher and Design Thinking expert). This leads to the conclusion that almost all, but one, participants have a similar background under the design umbrella. Kokotovich and Dorst (2016) notice that design teams consisting solely of designers, in general, have very similar perspectives and heuristics. Therefore, their sample consisting of a group of designers and non-designers is supposed to tackle this homogeneity. Unfortunately, when investigating specialisations of each team member, we can enlist art drawing, painting, architecture, storytelling, art photography, journalism, graphic design or psychology. According to the definition from the American National Endowment for the Arts – the arts term includes:

> "music (instrumental and vocal), dance, drama, folk art, creative writing, architecture and allied fields, painting, sculpture, photography, graphic and craft arts, industrial design, costume and fashion design, motion pictures, television, radio, film, video, tape and sound recording,.." (U.S. Congress, 1988)

Similarly, the team of participants coming from art, architecture, psychology, journalism

and English in the research of D'souza and Dastmalchi (2016) described by the authors as a multidisciplinary team, is de facto homogeneous, as all disciplines are already requiring a high level of creativity or strongly related to creativity study. Another study (Kleinsmann & Lugt, 2007) is designed with the simulation of chosen skill sets. Notwithstanding, all participants have been recruited from design bachelor and master students and professionals with design experience. The laboratory study, albeit with simulated multidisciplinary role-playing, would still be heavily biased due to homogeneous designers' perspectives of all team members. Similarly, the sample from the study of Hu et al. (2017) employ graduate students from Industrial Design, Visual Communication Design, Furniture Design and Mechanical Design, Automation - the majority of which is still within the design discipline.

4.2 Experiment setting

With an increasing need for domain-crossing collaboration, the issue of multidisciplinary teamwork has generated appeal among academic work. Out of the 17 core research articles, 8 studies were collected employing samples of university students. Albeit, the scientific community draws into attention extra caution with experiments on student samples, half of the investigated papers in this review are studies within the university context. Additionally, many of the industrial-based studies are laboratory experiments, where the authors have manipulated variables. This can become a limitation for validating the emerged findings. In the research world, experts do acknowledge this limitation and explain the choice of laboratory student teams plausible for the sake of methodological strictness (Stempfle & Badke-schaub, 2002). They suggest that laboratory experiments can provide some insight into basic thinking processes and also, not being contaminated by unpredictable factors, which are prone to take place in research with an industrial context. Kasali and Nersessian (2015) notice, there has been little research into how interdisciplinary teams operate in the real world and how the multitude of professionals communicate and integrate their expertise. Only 3 studies in the core literature, were carried out in a natural setting, conducted in a non-experimental nature (see Table 1). Over 80% of the research articles involves experiments in a laboratory setting, highly correlated with the employment of student participants (60% of them with university context). A fundamental problem with studies created in such nature is that any generalisations to a broader population are considered hazardous (Robson & McCartan, 2016).

4.3 Industry bias

Multidisciplinary collaboration has gained popularity in the research society among all industries. The majority of studies in the core literature have been performed within the construction industry (see Table 1). We classify under this industry conjointly architecture, construction and engineering, and studies within such efforts engage over 70% of the analysed literature body. Most of the research papers, since they refer to design practices, focuses on architectural practices (Adams et al., 2009; D'souza & Dastmalchi, 2016; Feast, 2012; Jutraz & Zupancic, 2017; Kasali & Nersessian, 2015; Mcdonnell, 2009; Sonnenwald,

1996; Steele et al., 2001; Zolin et al., 2004). Healthcare and manufacturing constitute 17% each of the literature body, suggesting why design practices and multidisciplinary collaboration can find their application in other industries, where creativity is in need. Similarly, only two studies include experiments that included software development (Sonnenwald, 1996; Wang et al., 2018). Overall, the studies indicate the increasing need to employ design practices into industries, previously considered as non-design practices. As mentioned, applying lessons from design result in monetary value to the business. In the last decades, the economy has extensively switched to serviced industries and even companies producing hardware products, are alongside developing the most innovative digital applications to incorporate with their offering. According to literature, participants from the software department or any mechanical-oriented divisions create barriers in the multidisciplinary collaboration as they employ different development processes while using different jargon and different representations of the design (Kleinsmann & Valkenburg, 2008). On the contrary, architects can draw on their experiences from design nature, and act as enablers for efficient collaboration, setting out the right processes (Mcdonnell, 2009) and mediators between varying professionals (Jutraz & Zupancic, 2017). As a result, the disciplinary background of participants seems to directly impact the results of the experiments and research has been equivocal in terms of generalisation of findings on multidisciplinary collaboration.

5. Conclusions

The identified themes from the literature review, highlight two critical, socio-cognitive team dynamics aspects: shared understanding and trust. In the attempt to determine the direction for future work, we plot the collaborative systems defined by Saad and Maher (1996) versus the two criteria in the proposed matrix (see Figure 2), where:

1. High trust / High shared understanding – characterised in face-to-face meetings.
2. Low trust / High shared understanding – found in Asynchronous Interaction, including shared databases and thus current file management systems such as Google Drive (Saad & Maher, 1996).
3. High trust / Low shared understanding – found in Synchronous Distributed systems, including video conferencing (Bos et al., 2002; Nguyen & Canny, 2007).
4. Low trust / Low shared understanding – found in Asynchronous Distributed, defined as different time / different space (Saad & Maher, 1996), to which we categorised email and communication chat apps.

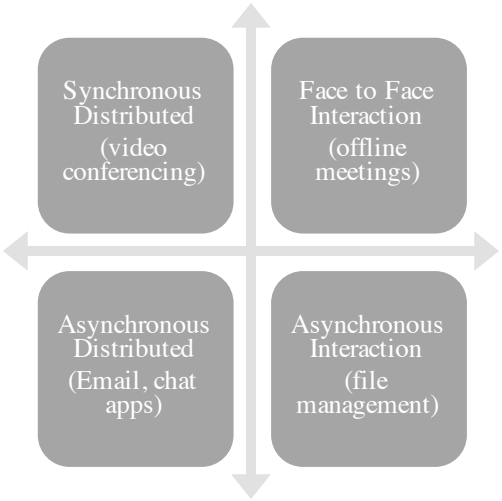

Figure 2 Mapping of collaborative systems (based on the systems from Saad and Maher (1996)) with the emerged themes of trust and shared understanding

We suggest that the most vulnerable system is the asynchronous distributed one, including email and communication chat apps; and this should be the direction for future research on facilitating team dynamics aspects in multidisciplinary collaboration. Moreover, they both are speech-only communication channels, defined by Ostergaard et al. (2005) to be correlating with the lowest perceived effectiveness of teamwork.

Interestingly, the two most vulnerable communication channels identified in the previous section – with the lowest indicator of trust and shared understanding – represent the top two collaboration tools used in the industry (Spiceworks, 2017b, 2017a): Email (98%) and Collaborative chat apps (44%). To illustrate the industrial relevance, we map the functionalities offered from vendors against the tools from CSCW research in Table 3.

Table 3 Analysis of current communication tools

CSCW	**Role detection**	**Video conference**		**Sketching**	**Communication**	
		Traditional	Spatial faithful		Jargon translator	Auto translator
Email						
Skype for Business		X				
Google Hangouts		X				
Slack						
Microsoft Teams		X		X		
Atlassian HipChat						
Workplace by Facebook		X				X

As shown in Table 3, the majority of suggested tools from CSCW studies are not available in the leading communication channels used in the industry. Only traditional video conferencing systems, sketching and auto-translation are present in the vendors offer. However, it is worth noticing that the two latter ones have been available for commercial use since Q2 2019. This brings the promise of potential implementation for state-of-the-art tools recommended from academia into employment in the real-world context.

Research in other areas can bring good inspiration for future studies on applying such approaches in multidisciplinary collaboration on a broader scale. An attempt in the analysis of speech-only communication meetings by Wasiak et al. (2010) refers to the use of content analysis of participants' email conversations. We can also identify one of the methodologies, already used in (homogeneous) design collaboration research – latent semantic analysis – of intra-group communication proposed by Dong (2005). Another promising approach involves NLP. The most recent research effort from Yang et al. (2019) present attempts to create a rapid, NLP-powered tool to enhance writing experience during design activities. They present yet challenges that still need to be addressed in further investigations and raise questions on how their findings can be generalised to other design situations. Due to variation in variables used by the experiments' authors, findings include both common similarities and contradictions in some aspects. Reviewing current literature body on multidisciplinary collaboration with a critical review in respect to the CSCW discourse is an important starting point in defining how to examine teamwork and develop tools for collaboration in the realms of the future innovation-led economy.

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About the Authors:

Mimi Quynh Trang Nguyen is a PhD candidate at the Dyson School of Design Engineering, leveraging creativity and innovation with multidisciplinary collaborations and an Associate Lecturer of Innovation Management at Central Saint Martins UAL. Background: tech consulting (Accenture and BCG), fintech startup and gaming.

Céline Mougenot is Senior Lecturer (Associate Professor) Design Engineering, Dyson School of Design Engineering Imperial College London, researching Design Cognition and Collaborative Design. Interests: socio-cognitive aspects of innovation processes, conditions favouring multidisciplinary and multicultural collaborations, development of tools for user-centered innovation.

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Swipe, Scroll, Add-To-Cart: a case study of e-commerce gallery designs for small screen devices

Nicholas VANDERSCHANTZ[a]*, Nicole SIJNJA[a]

[a] University of Waikato, New Zealand
*Corresponding author e-mail: vtwoz@waikato.ac.nz
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Abstract: With significant increase in mobile online shopping the design of user experiences that promote purchaser decisions and increase sales is highly desirable to retailers and their marketing and digital production companies. Surprisingly little investigation into the usability of product galleries is available to guide the design of product listing pages for e-commerce websites, especially those websites viewed on small screen devices. Our research takes a synergistic view of the design and usability literature and provides a visually guided case study of e-commerce websites on mobile devices. We offer initial guidance to designers based on the insights from a heuristic analysis of current design trends of e-commerce websites viewed on a mobile device.

Keywords: e-commerce; mobile web; product display; gallery design

1. Introduction

It has long been known that presentation of information and products for users will influence purchasing behaviour in both digital (Blanco, Sarasa, & Sanclemente, 2010; Liao, To, Wong, Palvia, & Kakhki, 2016) and non-digital contexts (Ares et al., 2013; Childers & Houston, 1984; Percy & Rossiter, 1983). With the increase in mobile shopping ("Shopify Announces First-Quarter 2018 Financial Results," n.d.) the design of quality usable product presentations in e-commerce features of digital libraries as well as websites is critical. One such opportunity to present products is the gallery of an e-commerce website which often functions as the showroom or product catalogue of the digital age. Exploration of the existing body of work highlights the lack of guidance in the visual structuring of e-commerce galleries.

Presentation of information (Kim & Sundar, 2016; Vanderschantz, Timpany, & Hinze, 2015) and interaction with that content (Vanderschantz, Timpany, & Feng, 2018a, 2018b; Wei, Chang, & Cheng, 2015) on small screens is problematic in a number of contexts and is a common feature of the HCI and digital library literature. The presentation of interactive

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visual information that we describe in this paper provides insights for designers of websites, mobile apps, and digital libraries that contain e-commerce and non-e-commerce gallery presentations of products.

This study focuses on the presentation of fashionwear in website galleries on mobile devices because e-commerce is an often-reported pain point in the fashion industry (Møller Jensen & Hansen, 2009; Parker & Wang, 2016; Rodgers & Harris, 2003). Clothing items are often considered a difficult product to sell online due to consumers perceptions of risk and inconvenience (Dittmar, Long, & Meek, 2004; Møller Jensen & Hansen, 2009; Rodgers & Harris, 2003). Consumers reported risk and inconvenience are due to the inability to try clothing items on coupled with the lack of personal advice while shopping online. We hypothesize that designers need to find methods of displaying products and communicating product information in order to bridge this gap between purchasers and e-commerce providers (Dittmar et al., 2004; Ulbrich, Christensen, & Stankus, 2011). We identify four common interface design metaphors and give recommendations for the design and further testing of e-commerce galleries on mobile devices.

2. Related Work

While there has been a plethora of studies that have looked at various aspects of e-commerce design, there has tended to be a focus on the overall aesthetic design, home page design, or product detail page design, rather than research regarding e-commerce gallery design. Our research is concerned with the product listing pages of e-commerce websites, that is to say, web pages that provide a list or gallery of available products. We distinguish product listing pages from other pages in e-commerce websites, such as home pages and product detail pages. Home pages are well established as the storefront of an e-commerce website and typically provide brand and service information for a store. Product detail pages are the pages a user is presented when they select an item from a gallery or list provided on a product listing page. These product detail pages provide garment specific information about the product to assist with purchasing decisions.

We will discuss the related work on e-commerce web page design and highlight the areas of research needed with specific reference to product listing pages. We will focus our reporting to related work that considered visual design and usability design of e-commerce web pages and their impact on purchaser behaviour.

2.1 Product Listing Page design

Of the study's conducted on product listing pages, most only look at the differences between a list design verses a matrix grid style (Flavián, Gurrea, & Orús, 2009; Hong, Thong, & Tam, 2004b; Schmutz, Roth, Seckler, & Opwis, 2010). Lal (2013) suggests either style should be used while keeping a vertical scroll format as best practice in e-commerce. Both Hong et al. (2004b) and Schmutz et al. (2010) suggest that the list format is better for comparison tasks because products are presented close together. Lists also reduce the information and

product search time while aiding information recall on desktop devices (Hong, Thong, & Tam, 2004a; Hong et al., 2004b). However, the vertical stacking of lists on restricted screen sizes results in the consumer needing to scroll and can diminish ease of comparison and increase browsing time (Flavián et al., 2009; Hong et al., 2004b).

When a consumer is browsing the matrix format can create more effective information search and product recall. This is likely because images increase the speed with which a consumer can locate a product in a list when they already know what the product looks like (Hong et al., 2004a). However, images in a list can be too small for fashion items to help purchasing decisions (Tupikovskaja-Omovie, Tyler, Dhanapala, & Hayes, 2015). Images should be big enough to see important details but not impact download time (Nielsen, Snyder, Molich, & Farrell, 2001).

Hong et al. (2004b) suggest detecting the type of task the user is trying to fulfil in order to determine if a list or matrix format should be shown. However, (Schmutz et al., 2010) cautions against this technique as the method of detecting a user's intended task is difficult to achieve and may not be accurate. An alternative would be to provide the consumers the ability to switch between the two formats through a button.

Spacing of products require attention. Where product images are visually close together, consumers will be less successful at keeping their attention on the focal product (Juanéda, Sénécal, & Léger, 2018). However, where distractor items and the focal product are similar, there is a positive impact on accuracy during decision tasks and could explain why consumers can have a positive attitude towards websites when a list layout is used (Hong et al., 2004b). An interesting investigation by Fu et al. (2018) discovered that designers tended to prefer interfaces with low density spacing of products, while consumers preferred high density interfaces with tightly spaced product images or lists.

The number of products included in a store can have a large effect on cognitive load, where the catalogue of products is small, the layout has little effect as there is usually less scroll required to view and compare products. Flavián et al. (2009) suggest that in large product catalogues consumers struggle with comparison tasks and tend to prefer a matrix layout as it makes processing information and comparing products easier. Contradicting this (Hong et al., 2004b; Schmutz et al., 2010) suggests that the list format facilitates the comparison task more so than the matrix layout.

Further research that has considered the design of the product listing page has included the prototype design of one-page visual catalogue based on information visualization techniques (Lee, Lee, & Wang, 2004) while Zhang et al. (2017) tested different ways of arranging product information in list view designs. Other studies that focused on this page looked at the effect of the order of products listed (Cai & Xu, 2008; Y. Xu, Cai, & Kim, 2013; Yan-Kwang, Chiu, & Yang, 2014).

Even given the work we highlight here; few studies have made clear recommendations for the visual or usability design of product listing pages. Especially lacking are recommendations for small screen product listing page designs.

2.2 Product Detail Page Design

There is a large focus in the literature on the product detail page, with guidelines on how to design various aspects of that page. While our study does not focus on the design of product detail pages the findings of this work are applicable. One widely accepted design guideline for product detail pages is the inclusion of a product image. Images provide visual as well as textual information, both of which are thought to be critical to assist decision making (Blanco et al., 2010; Hong et al., 2004b; Liao et al., 2016). Where high information load occurs, visual based product presentation modes are recommended when presenting product information to consumers (Li, Wei, Tayi, & Tan, 2016). Hong et al. (2004b) showed that use of a product image beside a brand name or brand mark assists with memorability and product name recall. Video formats have also been suggested to be more effective where products are deemed experiential goods, such as clothing (P. Xu, Chen, & Santhanam, 2015).

2.3 Design & Usability Evaluation

Research into design, human-computer-interaction, and usability have often been co-located in inter-related or semi-autonomous research spheres. While at times the individual literatures can be found using similar jargon in different contexts, in the design of digital technologies the observations from each field must be acknowledged and drawn from.

Design and usability research providing guidance for the development of product listing pages on small screen devices is missing from the literature to date, however, general design guidelines for small screens include:

- Keep the design simple (Lobo, Kaskaloglu, Kim, & Herbert, 2011; Shitkova, Holler, Heide, Clever, & Becker, 2015)
- Simplify user input (Lobo et al., 2011)
- Keep to vertical scrolling (Evelhoch, 2016; Lobo et al., 2011; Shitkova et al., 2015; Yu & Kong, 2016)
- Use multiple versions of the website (Cazañas & Parra, 2016; Lobo et al., 2011) via responsive/breakpoints or separate mobile sites
- Choose between native apps or mobile web apps (Lobo et al., 2011)
- Optimise navigation for mobile usage (Garcia-Lopez, Garcia-Cabot, Manresa-Yee, de-Marcos, & Pages-Arevalo, 2017; Lobo et al., 2011; Shitkova et al., 2015, Vanderschantz & Yang, 2019)

Commonly both the design and usability evaluation literature refer to a set of general design guidelines and usability heuristics, usually the heuristics outlined by Nielsen (1994). As the adoption of mobile devices increases, so has the research on adapting common usability heuristics, such as Nielsen's to fit with the usability needs of smaller screen devices (i.e. Inostroza, Rusu, Roncagliolo, Rusu, & Collazos, 2016; Thitichaimongkhol & Senivongse, 2016; Yáñez Gómez, Cascado Caballero, & Sevillano, 2014). Updates to Nielsen's original heuristics have been proposed by Thitichaimongkhol & Senivongse (2016) and Yáñez Gómez et al. (2014) who proposed inclusion of *privacy* heuristics as well as interactions that are

pleasurable and *respectful*. These proposed privacy heuristics consider data and information security while pleasurable and respectful heuristics consider typographic presentation and ease of form filling on mobile devices. Additionally, Yáñez Gómez et al. (2014) proposed the *skills* heuristic which is equivalent to Nielsen's (1994) guidelines regarding *flexibility* and *efficiency*. While Nielsen's heuristics (1994) were designed with software in mind, these guidelines are applicable to website design on mobile devices to this day.

3. Method

We conducted a case study that was used to analyse the current designs of fashion-oriented e-commerce websites on a small screen device. Due to consumers perceptions of risk and inconvenience related to online fashionwear shopping (Dittmar et al., 2004; Møller Jensen & Hansen, 2009; Rodgers & Harris, 2003) this case study focuses on the product listing pages to determine how they are designed for mobile devices and what pain points for users may exist. Our review of the related work (see Section 2.1) has shown that few studies have made recommendations for the design of product listing pages, especially in the context of small screen devices. Therefore, our case study was designed to fill this gap in the literature and in so doing reveal insight into present design conventions and usability issues related to the presentation of e-commerce gallery's on mobile devices. We argue that before adapting or developing suitable layouts for testing it was important to first provide evidence of current practice to guide future development. Given the findings of this case study designers and researchers will be equipped to develop suitable e-commerce galleries and new design solutions based on evidence of current practice which is not currently available.

3.1 Sampling Procedure

Following the advice of Fu et al. (2018) on the 6th of November 2018 we conducted an internet search with the following five search queries; *best fashion websites 2018, best fashion eCommerce website 2018, Popular fashion eCommerce, best design fashion website* and *best online shopping sites for women's clothing*. At the time of this study Google had a 90% market share of search engine use (*Search engine market share worldwide 2019*, 2020) and thus we conducted our searches using only the Google search engine. We used the results of this web search to identify 10 online lists of fashion websites that appeared across all five of those search queries. From these 10 lists we selected, documented, and reviewed 12 websites that were common across those 10 lists. All reviewed websites appeared at least three times across the lists.

3.2 Heuristic Evaluation Tool

Our review of the related work (see Section 2.3) has shown that numerous researchers have proposed guidelines for the development of small screen interfaces that build on Nielsen's work, however, Nielsen's (1994) heuristics remain most suitable for the evaluation of website features even on small screen devices. When conducting the test with each website of

browsing the ‘dresses’ category and adding a summer dress to the cart we used each of Nielsen’s usability heuristics (see Table 1) to evaluate each website. Our analysis and heuristic evaluation reported here applies only to the product listing page.

Table 1 Heuristic evaluation criteria

Heuristic	**Evaluation topics**
User control	Consumers ability to organize and filter products
	Layout impedes/enhances completing shopping tasks
Flexibility	Consumers have multiple ways to complete shopping tasks
Minimal Design	A Minimal design was used
	Small screen devices were considered
	Layout impedes/enhances completing shopping tasks
Feedback	Feedback indicating actions were completed
Error Recovery	Consumers can recover form accidental actions
	Layout impedes/enhances error recovery
Error Prevention	Website prevents errors happening
	Layout impedes/enhances error recovery
Users’ Language	Language used matches consumers language
Consistency	Consistency within and across websites
	Layout impedes/enhances consistency
Recognition	Layout impedes/enhances recognition
Providing Help	Help features are provided
	Location of help features

3.3 Study Procedure

The study was planned and developed by two researchers who both have a background in the design, development, and evaluation of user interfaces. The two researchers agreed upon the search method and evaluation process. An initial evaluation of a website not included in the study was undertaken by both researchers to ensure agreement with the process and evaluation criteria. A single researcher undertook the sampling procedure (see Section 3.1) and the study walk-through (see Section 3.2). Early in the analysis phase, confirmation of mutual agreement was achieved through the discussion of a sample of the websites identified to ensure agreement was achieved regarding the classifications of the websites and usability issues encountered.

3.4 Apparatus

All websites were viewed in the Chrome web browser on a Xiaomi Mi A1 running Android 8.1.0. This device has a screen size of 5.5 inches and was set to full HD (1080P) resolution. We tested each website with the task of browsing through the ‘dresses’ category on the website to find and add a summer dress to the cart. During this process, screenshots of the

homepage and the product listing page of each website were taken to allow for additional evaluation of the designs on a desktop computer using Preview (an image viewer by Apple Inc.). These screenshots provided records of the design should changes have occurred on the websites after the analysis was undertaken. Additional analysis of the websites through screenshots allowed us to see what was visible at given points along the process of browsing and purchasing of items. Screenshots were also used to determine any additional usability issues with the interface that may have been missed in the initial evaluation walkthrough.

4. Results

We detail the results of our case study analysis. This section encompasses the visual design of product listing pages for fashion websites as well as a heuristic analysis of the usability of these webpages on a mobile device.

We identified four methods for presenting product galleries. We have called these: Symmetrical Matrix (see Figure 1 A), Asymmetrical Matrix (see Figure 1 B), Large Product (see Figure 1 C), and Swipe and Scroll (see Figure 1 D). We found no websites that presented a product list view. Table 2 provides an overview of the sizes of the product catalogues that we studied and the design metaphors that were implemented.

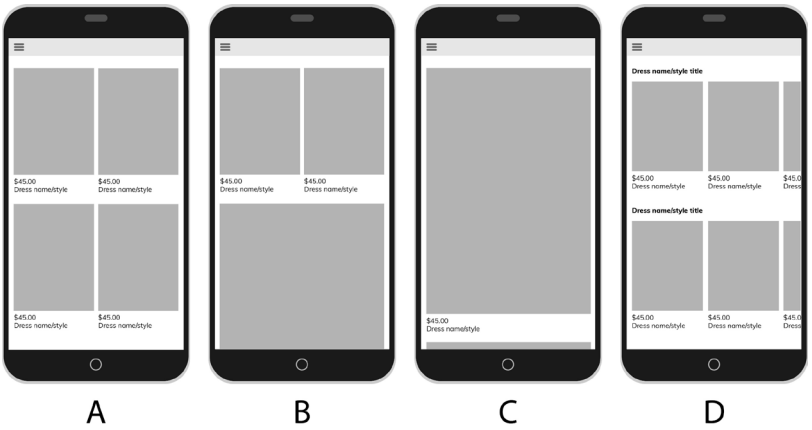

Figure 1 *Four metaphors of gallery interface design, (A) Symmetrical Matrix, (B) Asymmetrical Matrix, (C) Large Product, (D) Swipe and Scroll*

Table 2 *Product Catalogue Sizes of Websites Analysed*
*(*Table 2 records results for 13 websites instead of 12 because one website allowed the user to switch between Symmetrical Matrix presentation and Large Product presentation)*

Layout Metaphor	0-5k	5k-10k	10k-15k	15k-20k	20k-25k	25k-30k	30k +
Symmetrical Matrix	2	3	-	3*	-	-	2
Asymmetrical Matrix	1	-	-	-	-	-	-
Large Product	-	-	-	1*	-	-	-
Swipe & Scroll	1	-	-	-	-	-	-

The Symmetrical Matrix (see Figure 1 A) is a traditional layout commonly seen within e-commerce where products were organized in a grid, usually containing two columns. Ten of the websites analysed utilized the Symmetrical Matrix layout. It can be seen in Table 2 that two of these websites that used Symmetrical Matrix designs had catalogues of less than 5,000 products, three websites had catalogues with 5,000 to 10,000 products, with another three websites with 15,000 to 20,000 products, while two websites that used Symmetrical Matrix's had product catalogues of more than 30,000 products. One website broke the two-column mould by utilizing a three-wide grid. Websites using this metaphor had catalogues ranging from very small (83) to very large (70K +).

The Asymmetrical Matrix (Figure 1 B) layout used a similar two column grid to the Symmetrical Matrix with featured product images that were scaled to fit the full width of the screen. Only one website analysed used this gallery metaphor and had a smaller catalogue size of less than 5,000 products (see Table 2).

One website used the Large Product (see Figure 1 C) layout which consisted of products which were displayed the full width of the screen. Each product was listed one after the other. This same website offered the user the option to switch between the Large Product metaphor and the Symmetrical Matrix metaphor using a menu item towards the top of the page. This was the only website that offered multiple methods to interact with the product listing page and had a large product catalogue of 15,000 to 20,000 products (see Table 2).

Finally, one website used the Swipe and Scroll (Figure 1 D) metaphor where the variations of a product style (such as The Cashmere V neck sweater) were grouped together in a container that could be scrolled sideways. The website utilizing this style had a small catalogue size of less than 5,000 products (see Table 2).

4.1 Usability

Eleven of the websites had designs which appeared to be designed with a mobile screen in mind. These appeared to either use responsive layouts or media queries to create designs suitable for where there is less screen real estate available. One of the Symmetrical Matrix websites had a layout that was not optimised for a smaller screen (see Figure 2). This design was very hard to use as navigation, filter, and menu items were smaller than the user's finger; leading to interaction errors.

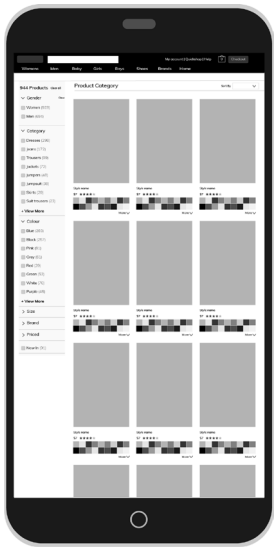

Figure 2 A Symmetrical Matrix layout that was not optimized for small screen devices

Techniques used to maximise the screen space included having filter menus appear when needed and menu bars shrinking to the top of the screen or off the screen completely (see Figure 3 B & C). Both techniques allow larger thumbnail images. Where menus moved above the screen, initial confusion may occur, however, the learning curve is likely short. Scrolling up slightly results in the menu appearing again.

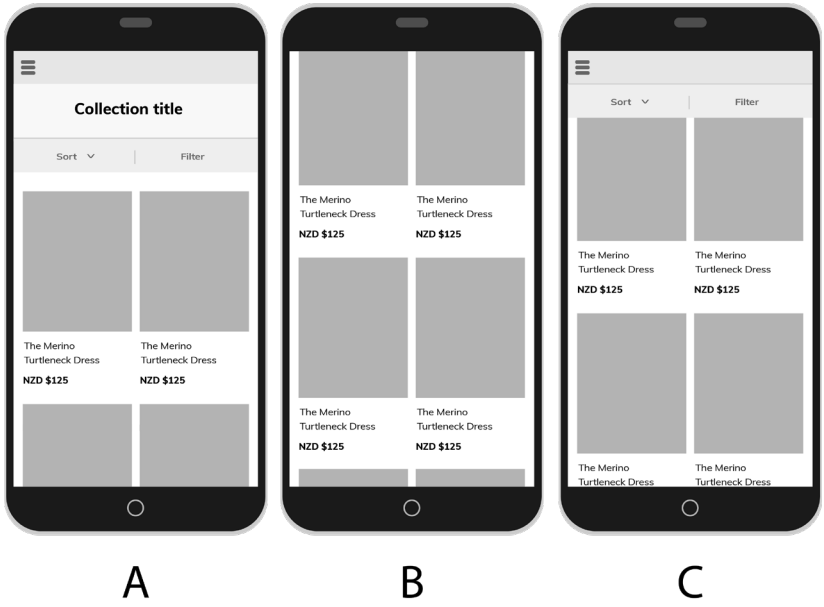

Figure 3 Header menu behaviour before scrolling down (A), off screen due to scrolling (B), minimized due to scrolling (C)

Frustration levels of consumers is of concern for website development. Ten of the twelve websites would be likely to cause little frustration, presenting little to no issues. The few identifiable usability issues were; no back to top when scrolling through items or having to

figure out how to access the menu bar. Those types of issues were small and could be easily worked around. Only five websites included a back to top button when browsing through the items in the company's product catalogue. Of the remaining seven websites, five had a large product catalogues (15,000 products or more) and required significant scrolling.

Usability Heuristics

For the most part, the websites we analysed were designed in line with the guidelines set out by Nielsen (1994). Where websites failed a guideline, these tended to fall into the User control, Error prevention, Flexibility and Minimal design heuristics. All websites did well in the aspects of Feedback, User's language, Consistency, Recognition, Error Recovery and Providing Help.

User control

The websites that failed the user control guideline tended to be due to a lack of search or filtering options. Two of the Symmetrical Matrix and one of the Asymmetrical Matrix failed the user control guideline. For large catalogues the issue is more severe making it harder to narrow products down. However, the lack of filtering in a category had less impact on the consumers where a smaller number of items appeared in a catalogue. User control was impeded on the Large Product metaphor due to the nature of large scrolling required to complete shopping tasks. This would make comparison tasks harder for consumers to complete.

Flexibility

All websites provided multiple ways to interact with items or complete tasks. Shortcuts provided were generally global search of products (10/12) and filtering (11/12) of items. Websites which did not have these features (2/12) forced consumers to interact how the website wanted, instead of the consumers preferred way. The one website that provided both a Symmetrical Matrix and Large Product layout allowed consumers to browse products in their preferred layout.

Minimal Design

Minimal design was a guideline that only one Symmetrical Matrix website failed to meet. As seen in Figure 2, by displaying all elements of the website such as filtering on the screen constantly, the interface appeared cluttered and reduced the overall physical size of the elements on the screen. It appeared that little consideration was given to maximising the available screen real-estate. While the Large Product metaphor website had a very minimal design consumers were required to scroll significantly to view all products.

Feedback, Error prevention and recovery

Feedback was commonly given when a consumer added an item to their cart or wish list. A small number indicator was placed within the cart icon (see Figure 4 B) and occasionally beside the icon (Figure 4 A) to indicate the action had completed successfully on all the websites reviewed. When adding items to a wish list the icon usually swaps from an outlined

to filled icon, often with a micro animation to draw attention (Figure 5).

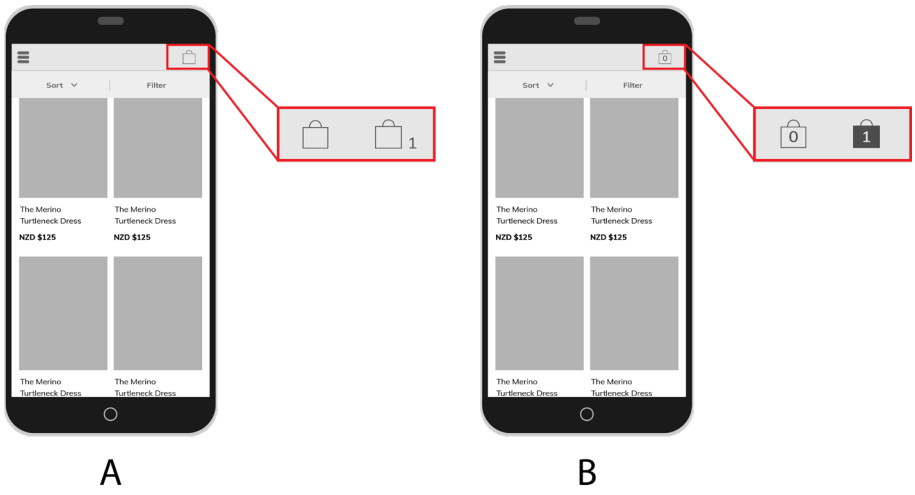

Figure 4 *Indicator of items in the cart: Number indicator next to icon (A), Number indicator within icon (B)*

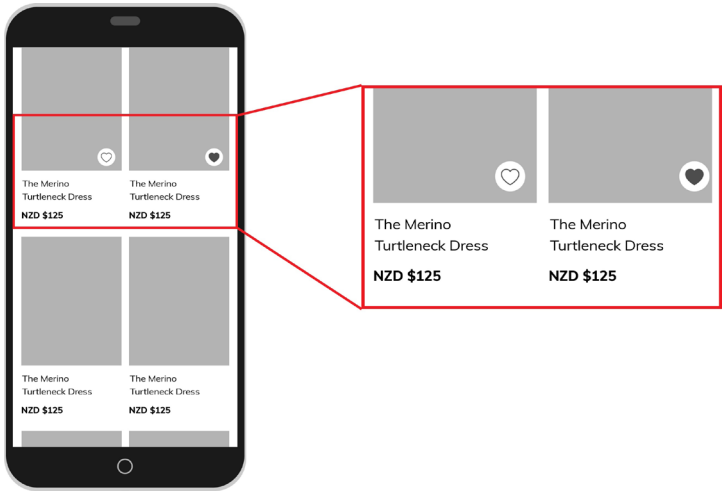

Figure 5 *Favourites icon before and after adding item to the wish list*

Textboxes would have validation to confirm the correct input type was used. This validation was completed as a consumer typed, allowing the consumer to quickly fix errors, which ensured speed of error correction. Websites would occasionally also force a numerical keyboard where a numerical value was required. The Swipe and Scroll layout was most likely for consumers to make the error of missing products. To minimize this, a large portion of the partially visible item was shown to prompt horizontal swiping (see Figure 6).

Figure 6 *Partially visible product indicating side scrolling functionality*

Users Language

The language used across the websites included common terms used by fashion consumers. Terms varied slightly between brands, alternate terms were similar and ensure that consumers could quickly determine what a term meant (see Table 3).

Table 3 *Examples of similar terms used across websites*

Term	Terms used
Product Range	Collection, Product Category
Clothing shape	Style, Shape
Curated collections	Shop the Edits, Shop by Trend, Trends

Consistency and Recognition

Standard conventions of the information provided to a consumer of e-commerce product catalogues was identified. Typical information included a product image, title or short description and price. As noted in Section 4.1 the websites all used a familiar matrix grid design, along with a standardised mobile layout. The use of consistent design conventions within the layout and catalogue design will also aid ease of use for consumers and ensure low learning curves from one website to another. The Swipe and Scroll layout was the only design for which a learning curve would occur.

Providing Help

While the websites provided help features within their pages, this was not seen within the product gallery pages. These were usually found in the sitewide footer menu or located on the individual product listing pages. The most common forms of providing help was providing frequently asked questions (FAQs) and providing sizing chart information.

5. Discussion

Our analysis of 12 highly rated e-commerce websites has identified four different gallery metaphors. The symmetrical matrix was the most implemented product listing page design in 10 out of 12 of the analysed websites. We hypothesize that this may be due to the prevalence of e-commerce platforms (such as Shopify) providing free templates that typically come with the symmetrical matrix design as a default. Equally, as this format is a common feature of wider web-design visual language this metaphor may be expected by consumers and thought by developers to provide consistency and recognizability. The research shows that a matrix is better suited for most situations (Flavián et al., 2009; Hong et al., 2004b) and is particularly suited for small screens as more products can be seen at once compared to list views (Hong et al., 2004b).

We suspect that large products in the Asymmetrical Matrix and the Large Product may become a frustration point for consumers. Large product images are a useful visual feature in galleries because consumers can see the clothing items in more detail at larger sizes, but this comes at a cost of a longer scroll to view more products. Coupled with a lack of filtering or return to top functionality in large catalogues this usability hinderance may impact sales.

The Swipe and Scroll was a unique method to display multiple variants of a product. The nature of grouping them together in the horizontal scrolling container meant that consumers could see the available colourways of items or could continue to scroll vertically if uninterested. This may reduce the number of products a consumer is required to scroll vertically passed when browsing a product because repetition of products in different colours is not necessary. The unfamiliarity of two-dimensional scrolling, which goes against the advice of using pages that scroll vertically (Lal, 2013), may lead consumers to miss products they may have easily seen in other layouts.

The Large Product layout would appear to work well for smaller product catalogues rather than large product lines. This suggests that the size of a brands product catalogue may dictate the style of gallery they should use to be most effective. This may be one reason that the Symmetrical Matrix was so prevalent amongst the websites analysed.

We did not identify a List metaphor used for product listing pages by any of the websites we reviewed. We would have considered a product listing page to be using a List metaphor if it presented results using only text in a formatted list presentation (see Figure 7 A) or text accompanied by a small graphic in a formatted single column presentation (see Figure 7 B).

Figure 7 *Two metaphors of List View gallery interface designs, (A) Text-only, (B) List with thumbnail*

This preference for a gallery metaphor for product listing pages by fashion retailers is not surprising given that numerous researchers (i.e. Blanco et al., 2010; Hong et al., 2004b; Liao et al., 2016) report the importance of images in e-commerce websites. The gallery metaphor use that we identify in our case study is in line with recommendations by Hong et al. (2004) who suggested that galleries are superior to lists for browsing by users because galleries improve information search and product recall. This use of galleries over lists also reinforces Tupikovskaja-Omovie et al.'s (2015) findings that purchasing decisions regarding fashion items requires larger images than List views typically provide.

5.1 Recommendations

We provide the following recommendations for the design of e-commerce galleries in either websites or digital libraries based on our findings from the related work and our heuristic analysis.

Familiarity: If a very familiar layout is desired for an e-commerce store, the Symmetrical Matrix design is likely to be common across websites that consumers visit. The Symmetrical Matrix will have a low learning curve for users and can facilitate a wide range of catalogue sizes.

Catalogue Size: The number of items in a company's product catalogue compounded the noted screen real-estate issues on mobile devices. This suggests that the size of a brands product catalogue may dictate the style of gallery that will be most appropriate. We would caution against the use of the Large Product metaphor as the primary gallery design for a large catalogue. For a smaller catalogue the Large Product metaphor might provide the illusion of a more sizable catalogue due to the increased need for scrolling to view products.

Vertical and Horizontal: Horizontally scrollable containers of products are not a new concept. Horizontal scroll may offer potential benefits of reducing choice overload and shopping

efficiency through a reduced number of products shown to the consumer overall. This may also serve to offer colourway, or product variation choices to consumers quickly and efficiently. The concern with this technique is that learnability may be an issue and there is a chance that consumers may miss products if they are not familiar with this interaction design.

Back to top: For all gallery sizes we would recommend a suitably implemented Back to top button. This device was found to be critical on galleries with large product catalogues and especially for galleries that implemented the Large Product metaphor.

5.2 Future work

Our work here nor the related work has yet fully assessed implications of user preference and user success with product galleries on e-commerce websites. Further work regarding user preference, user success, and purchaser behaviour using mobile e-commerce galleries is required. Specifically, for galleries, the minimum size of product images for both usefulness when identifying a product and usability during touch interaction requires investigation across all of the gallery metaphors that we have identified. Importantly, investigation of the implications and effects of gallery metaphor on purchaser behaviour is required. We recommend user observation studies that test both the gallery metaphors that we have identified as well as novel user metaphors developed for e-commerce.

6. Conclusion

Facilitating ease of swipe, scroll, add-to-cart e-commerce anywhere and anytime is a primary goal for retailers across many industries today. We focus our investigation here on the fashion industry with a heuristic case study of e-commerce product listing page designs for small screen devices. Our inter-disciplinary review of the related work identified surprisingly little advice for the successful user experience design of website, digital library, or mobile app galleries to guide the design of product listing pages for e-commerce. A significant feature of our case-study is that we have identified, classified, and labelled four design metaphors for mobile gallery designs. All e-commerce fashion websites reviewed used a gallery metaphor, with no list designs used for this genre of e-commerce website. Further, we have used a usability heuristic evaluation to offer initial guidance to designers to implement *Symmetrical Matrix* interfaces which will align with the common visual language of e-commerce websites today. Finally, we identify specific investigation needs for designers and developers to better understand user preference and user success with e-commerce galleries.

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About the Authors:

Nicholas Vanderschantz is a Senior Lecturer at the University of Waikato investigating the design of user-centred solutions to information seeking and use problems. Nicholas' research focuses on the presentation and visualisation of information in a range of contexts, with an emphasis on mobile and on the go situations.

Nicole Sijnja is a Master of Computer Graphic Design graduate from the University of Waikato. Nicole's master's research investigated user preferences and user experience design practises for mobile e-commerce interfaces. Her central research focuses on the presentation of and user interaction with information in varied applications.

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Exploring wearable technology for supporting couples in long-distance relationships

Hong LI[a]*, Pradthana JARUSRIBOONCHAI[a], Jonna HÄKKILÄ[a]

[a] University of Lapland, Finland
*Corresponding author e-mail: holi@ulapland.fi
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Abstract: In this paper, we explore the possibilities of wearable technology in supporting couples in long-distance relationships (LDRs) to achieve better insights on how wearables could be designed to fit the real needs of this user group. We approach the topic with a hands-on design workshop, where twelve participants living in an LDR created concepts and low-fidelity physical prototypes of wearables, and presented the video-recorded concepts to their remote partners to get their feedback. We thoroughly documented and analysed the workshop, and, based on the findings, we propose design considerations for designing wearable communication devices to support LDRs, including supporting secret communication modes, effortless awareness, and asynchronous lifestyle of the couples. It is also important that technology, particularly wearables, is designed so that it can be seamlessly integrated as part of everyday life and fits to different contexts.

Keywords: co-design; participatory workshop; wearable technology; long-distance relationships

1. Introduction

Fulfilling one of the most crucial human needs – relatedness – is regarded primarily as a positive experience that technology can create to make a relationship flourish (Hassenzahl, Heidecker, Eckoldt, Diefenbach, & Hillmann, 2012). There are increasingly many couples in long-distance relationships (LDRs) who cannot interact physically or talk to each other face-to-face on a daily basis. Their interaction and communication depends on different computer-mediated communication (CMC) tools, such as phone, email, instant messaging and video chat (Neustaedter & Greenberg, 2012), to mediate intimacy at a distance (Jiang & Hancock, 2013). Despite that CMC tools provide a wide variety of communication channels, evidence suggests that the current mainstream technologies are unable to support the full spectrum of communication needed in intimate relationships (Hassenzahl et al., 2012). Commonly used CMC tools, e.g. text messaging and email, are not designed to support

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sharing activities together (Pan, Neustaedter, Antle, & Matkin, 2017) or to provide a sense of remote presence (Tollmar & Persson, 2002), and they are unable to fulfil the need of relatedness (Sahlstein, 2004; Hassenzahl et al., 2012).

Recently, LDRs have become more common than ever and the number continues to increase due to various reasons such as the growing acceptance of international education and overseas employment (Stafford, 2004). This drives a need to create new communication technologies that can better support the needs for connectedness and communication of couples in LDRs. Wearable technology has been shown to have potential to change the way people interact with one another. Wearable devices can be embedded in clothing, worn close to the body as accessories, implanted in the body, or even as temporary tattoos on the skin (Liu, Vega, Maes, & Paradiso, 2016). A growing body of research has set out to explore the use of wearable technology in enriching communication over distance. However, there is still less understanding from the users' perspectives in terms of the content and interaction that should be communicated or mediated through wearable technology. In this paper, we further explore the communication needs of couples in LDRs through a co-design and low-fi prototyping methodology. This paper contributes to better understanding of the communication needs of couples in LDRs, and provides design considerations that support researchers, designers, and developers working on the topic.

2. Related work

In addition to the conventional communication tools, a variety of novel solutions have been designed to connect couples at a distance (Li, Häkkilä & Väänänen, 2018). For example, MyEyes (Pan et al., 2017) allows LDR couples to see through the eyes of a distant loved one to share daily activities and experiences together. Also, numerous embodied and tangible interfaces have been developed. For instance, Cubble (Kowalski, Loehmann, & Hausen, 2013) is a hybrid communication concept that consists of a cube-like object and a mobile application. A couple could remotely share their digital presence through the change of colour of the cube augmented with haptic tap patterns and thermal feedback to imply emotions and simulate the feeling of holding hands.

Wearable devices, different from most computing form factors, are typically worn directly on the body. This allows the technology to always be with the user. Being close to the body also offers an intimate communication channel which is more challenging for other forms of technology. This has made wearable technology a highly potential candidate for facilitating communication between remote couples, and prior art has presented examples such as HugShirt (CuteCircuit, 2002), ComSlipper (Chen, Forlizzi, & Jennings, 2006), and United-pulse ring (Werner, Wettach, & Hornecker, 2008).

A recent systematic literature review on 52 communication systems for LDRs shows that the majority of previous research in this area has focused on presenting novel concepts to mediate LDRs, addressing a single idea at a time and creating proof-of-concept level prototypes (Li, et al., 2018). Most of the recruited participants in the reviewed lab studies

were not remote couples in real life, but instead used substitute participants (Li, et al., 2018). Although a number of studies have involved remote couples in the design process (e.g., Kaye & Goulding, 2004), the subjects have been mostly involved in evaluating the proposed systems (e.g., Saadatian et al., 2014; Silina & Haddadi, 2015). It has been pointed out that there is a gap between understanding the needs of LDR couples in research and designing technologies for them in practice (Li, 2018). Remote couples who have sustained a long-term commitment in their relationships are experts by virtue of their personal experiences (Visser, Stappers, Lugt, & Sanders, 2005). In our study, we listened to LDR couples by engaging them in a number of co-design workshop sessions to create desired communication devices that could better support their relationship.

3. The wearable co-design workshop sessions

Co-design workshops (Sanders & Stappers, 2008) have been found to provide rich insight into an exploratory research topic in the design aspects of HCI (Devendorf et al., 2016; Pakanen, Lappalainen, Roinesalo, & Häkkilä, 2016). We organised three co-design workshop sessions (see Figure 1) with potential users of wearable technology aiming to support LDRs. We were particularly interested in getting insights about the design decisions and how they were justified, as well as the types of messages and forms of communication that remote couples wish to communicate with their significant other. We divided the workshop into three sessions (with four, three, and five participants) so they would fit into the time slots that were convenient for the participants. The activities and given tasks were the same in each session.

Figure 1 Participants making wearable prototypes in the co-design workshop sessions.

3.1 Participants

We recruited twelve participants (3 males, 9 females), with the age of 19-45 (mean 29) years, with different backgrounds at the University of Lapland, Finland, from the university's emailing list. All participants had been in a stable LDR, see Table 1. Participants described their own LDR stages as "*married*", "*engaged*", or "*dating*" according to their marital status. One of the participants was involved in a same-sex relationship while the rest of the participants were involved in opposite-sex relationships. All participants had experience

of using wearable devices, e.g., Apple Watch. Each participant received two movie tickets (worth of appr. 20 euros) as gratitude for their participation.

Table 1 Summary of the workshop participants and their remote partner.

	Gender	Age	Partner's gender	Partner's age	Partner's location	Length (years)	Stage	Duration of separation (months)
P1	F	38	M	38	UK	14	Married	7
P2	F	19	F	18	China	3	Dating	7
P3	M	40	F	33	Estonia	10	Married	48
P4	F	26	M	29	Belgium	1	Engaged	12
P5	F	20	M	22	Netherlands	4.5	Dating	48
P6	F	21	M	21	France	5	Dating	8
P7	M	23	F	23	Japan	3	Engaged	12
P8	M	45	F	52	Germany	12	Married	108
P9	F	24	M	23	Finland	3.5	Dating	24
P10	F	25	M	21	Russia	3	Married	6
P11	F	26	M	41	Russia	7	Married	24
P12	F	35	M	57	Chile	9	Dating	24

3.2 Set-up, Procedure and Data Analysis

Each co-design workshop session took approximately 2.5 hours. In the beginning, we explained the nature of research activities and filled in the consent forms with the participants. All the sessions started with the participants reflecting on the problems they were facing in existing communication channels and ideal communication that supported their LDRs. Then, the participants designed their ideal form of wearable device and desired input and output modalities. During the design activity, we provided the participants with a deck of design cards which includes essential aspects needed to be taken into account when designing communication devices to mediate LDRs. The design cards were created based on two systematic literature reviews of communication devices for mediating intimate relationships at a distance (Hassenzahl et al., 2012; Li et al., 2018), and a framework for designing emotional communication systems for LDRs (Li, Häkkilä, & Väänänen., 2019). We introduced the design cards to the participants as a design tool to help them develop ideas. We also provided the participants with different materials and tools, e.g., white fabrics, coloured ribbons, yarns, to build low fidelity prototypes to communicate their design idea. After that, they reflected on how their design could work as a medium for their long-distance communication through an individual semi-structured interview and an open-ended questionnaire. The interview questions and the questionnaire focused on the participants' reasons for choosing a certain form factor and input and output modalities for their wearable design and the target experience they intended to create using the design. After the co-design workshop sessions, we invited the participants' remote partners to take part in the

study as remote participants, as explained later.

Data was collected during the workshop sessions through questionnaires, photographs, videos and audio recordings. We transcribed the audio recordings in verbatim. The data analysis followed general qualitative coding principles (Saldaña, 2015). The data was collaboratively analysed by two researchers so as to form a common understanding of the findings as well as commonly agreed categories. A number of themes were identified, and similar codes were emerged into categories.

4. Co-creation workshop outcomes

Each participant created different designs that they believed would help address the challenges they were facing in their own LDR. Figure 2 shows the outcomes of the co-design workshop sessions, with a detailed description in Table 2.

Table 2 Details of the design outcomes.

	Functionality	**Form factor**
P1	Simulating an embrace of a distant loved one.	Wearable blanket
P2	Live streaming of a remote partner via hologram during a video call.	Wristwatch
P3	Sharing intimate voice messages between a remote couple.	Multi-wear pin
P4	Changing its colour to create a sense of remote presence.	Attachable multi-wear accessory
P5	Sharing agendas or making plans together with a remote partner.	Attachable notebook
P6	Changing its colour to cheer up the remote partner.	Bracelet
P7	Using eye-movements to generate visuals visible only to the remote partner.	Augmented glasses
P8	Thermal and haptic feedback to generate awareness and simulate hand-holding.	T-shirt and pendant compass
P9	Simulating head massage given by a remote partner.	Gloves and headset
P10	Playing music in real-time and sharing audio messages between the LDR couple.	Headband
P11	Sharing personal audio messages between the LDR couple.	Attachable stuffed toy
P12	Changing its colour to evoke a feeling of relatedness.	Bracelet

Figure 2 The design outcomes made by the workshop participants.

5. Findings

5.1 Designing for Inner Relationship Experience

The participants designed their wearable devices considering inner experience and feeling of being connected with their love one through the devices. Particularly, the participants' designs attempted to create and imitate experiences of themselves being more involved in each other's lives at a distance. The design concepts sought for warmth, caring and intimacy, and form factors that supported them. For example, P1 created a blanket and indicated that "it is comforting and warm like a loved one's embrace". Several participants design their devices with the intention to be "always connected". P6 chose to design a bracelet because it would always be with her and her partner, and P4, P6, and P12 explained that their designs were meant to deliver a message saying, "I am thinking of you" or "I am always with you", to their partner.

> "If I am doing something and go like 'oh, I miss my partner', and I can kind of like fiddle with [my design], then, it would change the colour at my partner's end [...] Maybe he's also busy doing something, but it's kind of like 'Aww, she is thinking about me'." (P4)

The purpose of the messages, or the meanings encoded in them, could be clustered to the following categories:

- Enabling remote touch
- Expressing emotions
- Providing mental support
- Reliving shared memories

Haptic feedback was largely presented in the participants' designs. Haptic feedback was considered as a way to mimic natural touch experience, like "a warm hug" (P1) or "holding hands" (P8). The feeling of holding a distant loved one's hand was commented to be a way to comfort each other in difficult times, and the design could be used to "show support to the partner when it is a difficult time" (P6).

> "If you are lost, you would like crumble the sleeve [of the T-shirt], something that you press out of despair basically, and then the partner could, for example, put the hand on the truck, basically on the heart, and send you some reassuring, maybe vibration or some thermal stimulus." (P8)

Some participants designed their device with the intention to mediate a feeling of physical intimacy. "It's already easy with today's technology to share images, video, call, and keep in touch. But it's not possible to feel physically close or being touched by the love one" (P1).

A number of designs were made to express affection and personal feelings and to show mental support in various ways. For example, emoji were used in highly personalised and purposefully secretive ways in P7's wearable design to convey intimate and personal sentiments, i.e., inside jokes, between him and the partner. P3, P10, and P11 designed wearable devices that allow them to express intimacy by sharing audio messages. The voice of a loved one was said to be "unique" (P3), "reassuring" (P10) and "intimate" (P11). P11 found listening to her partner saying romantic words was more intimate than looking at those words typed on a screen. "We would [use the stuffed toy design concept to] send each other sweet messages to express our romantic feelings or our favourite music to remind us of some moments we shared together, or to just cheer each other up" (P11).

Another theme present in the designs was the idea of reliving shared memories through tokens that could evoke them. As P3 commented: "Memory is everything, either good or bad, they are usually cherished". P8 designed a shape-changing T-shirt to relive shared memories and shared experiences with his remote partner in a playful way:

> "Both of us like to travel a lot and we collect memories together in that way... If I'm thinking of a past trip, I could show my wife the gathered experiences by having some gears added to the top of the truck [of the T-shirt], and when she touches that, it starts an app on the screen of her phone and generates some photo slide shows or texts that we wrote down back then." (P8)

5.2 Ambient Design and Openness for Interpretation

Several participants designed their devices to send messages that are ambiguous and open for interpretation. Ambiguous messages are usually non-verbal, such as haptic, temperature, colour, light, shape-changing, or music. This was considered to be a way for the participants to maintain intimacy over a distance without other people being aware. Furthermore, ambiguous messages were believed to add tones and emotion such as playfulness or a hug and warmth to their communication, which could not be easily done through verbal communication. The ambiguous form of messages was a way to maintain privacy when exposed to others. The participants believed that light, colours, or other forms of visuals in wearable devices would be considered as part of their outfit. P6 highlighted that ambiguous messages could help fill a communication gap: "sometimes it feels difficult to find the words to express a feeling of attachment to support the other". Ambient designs could be used at work or during studying via subtle implicit messages without disturbing the other end, as P5 stated: "When he's busy and can't text or call me, he would still feel good to receive a

message from me and know that I'm thinking of him" (P5).

When choosing a form factor for their design, the participants considered also the appearance of the wearable device when used or worn in public. It was important to the participants that their design could function as an everyday object, e.g. to blend in well with any outfit, and be suitable to wear in everyday life. For example, P10 designed her wearable concept in the form of a headband because they both were usually wearing one on a daily basis. For example,

> "At first I thought I'd make a scarf or something like that, but then I thought if it's summer or depending on the weather I might not wear it [...] It has to be something that I'd like to wear all the time, so I decided to make something that can be attached to anything or can be worn in many ways, then I can just attach it to my handbag or wear it in whatever way I want." (P4)

5.3 Messaging the Partner

Despite that the participants regarded their devices as a channel to send a message to their partner, a reply from the partner to acknowledge the message was not necessarily expected, as P12 stated: "I don't need him to answer to the change of colour, just to let him know that I'm thinking of him". Most of the participants preferred that their devices did not require both themselves and their partner to be active at the same time, as they believed that asynchronous communication would perform better when dealing with diffident schedules at both ends. For instance, P1 considered different time zones and different schedules herself and her partner had. Asynchronous communication was described as "less time consuming" (P6), "less demanding" (P5), and "less stressful" (P4) as there is no need to "wait for an answer or reply immediately" (P7).

The ephemerality of the messages divided opinions. Five participants wished the messages to disappear by themselves, but on the other hand, many designed their device concepts so that the message should be acknowledged by their partner before it disappeared. The arguments for ephemerality were partly in the nature of the message, e.g., "Touch cannot be stored" (P1). Furthermore, ephemeral messages were believed to be more "stress-free" (P3) and "convenient" (P11). Also, the concern of making the partner worry over nothing was a factor to take into account, if one happened to send a negative message when temporarily feeling sad. "I mean, everything is just horrible and then five minutes later it's fine again, so you don't need to keep on that 'I am lost' message, because that may worry the partner." (P8)

5.4 Paired Designs and Customisation

The majority of the participants designed their wearable device to be the same for both themselves and their partners. This represented a feeling of being a couple. The participants also considered that this would support "a better feeling of reciprocation and mutuality" (P4) between them. The designs, however, were not necessarily identical, but the paired devices could be subtly different to match different genders, preferences, and styles, as, for instance,

a pair of bracelets with different colours (P12).

When the participants discussed the material qualities they preferred to use in realising their design, comfortable materials were common as their devices were expected "to be worn all the time" (P6). P6 further explained: "Soft materials should be used so that [the wearable device] would be nice to touch. I could even take it to bed with me". Organic and natural materials were the selected choices of many participants. They wished to create devices that looked like ordinary clothes and accessories, believing that such materials would make the devices "fit to many styles and occasions" (P4). However, P3 preferred "unique and rare" materials for his design, and would use "special wood that emits nice scents" in realising the multi-wear pin.

Customisation was seen as another relevant feature in the participants' designs. The participants wished the appearance of their wearable device, such as colour, to be customisable to match with different tastes. A few participants mentioned about fine-tuning interactions to their preference, e.g. "adjusting the level of vibration and light" (P7), so that the user experience could be enhanced according to the user's needs. The participants also mentioned that customisable appearance would allow the device to be used as different accessories, so it could be worn anywhere, attached to clothes, bags, or worn as a bracelet or in the hair (P4). Furthermore, customisation was regarded as an important aspect to enable meaningfulness of the design and to enrich shared memories.

6. Feedback from the remote partners

In this section, we report the feedback collected from the remote participants who commented on the concept designs created by their partner. We video recorded each local participant explaining their design, which was later sent to the remote participants for their feedback. We created an online questionnaire for the remote participants to give comments on the designs, and also to rate their partner's design on a five-point scale ranging from bad to excellent. The questionnaire was intended to understand the remote participants' perspectives on the design made by their partner, to investigate whether and how the design could support their own LDR, and to seek their suggestions for making improvements on the design.

Even though the design concepts created by the local participants were merely low-fidelity prototypes, they were still appreciated by the remote partners, and overall, received positive responses to their partner's design, rating *good* (1/12), *very good* (8/12), or *excellent* (3/12). The remote participants appreciated their partner's thoughtfulness towards their preferences. For example, P5 stated that, "I think he would like [the attachable notebook], he appreciates simplicity [...] The notebook idea is something simple yet practical because it doesn't attract the attention of others". P5's partner remarked that,

> "It is an idea I could have expected from my partner [...] A very simple yet useful design for people in LDRs. It is a nice additional way of communication, that does not take much time when time is scarce, but it does make people feel closer."

Furthermore, the remote participants considered the designs to be meaningful and well address problems they were facing in LDRs. For example, P1's partner appreciated the reminiscence of a meaningful experience when they were together:

> "I miss those moments like at the end of the day when we sit close to each other on the sofa sharing a blanket while watching TV [...] we can talk as often as we like via WhatsApp but we can't reach out and touch or hug as we sometimes would."

All the remote participants found the design made by their partner was able to support their own LDRs in a variety of ways. Mimicking physical touch was believed to (virtually) lessen the distance by making remote couples enjoy a physical sensation together while being apart, if it "felt dynamically authentic enough" (P9's partner). Asynchronous communication was seen to better support couples in LDRs since it was often challenging to agree on a suitable time for both to be active at the same time while being apart.

> "Sometimes it's quite annoying to wait for her reply because we have five hours' time differences between us [...] Knowing my partner's condition immediately can make me at ease, especially when she's too busy to inform me." (P2's partner).

The designs with unconventional form factors were deemed to "show support in a different way than typical communication means do" (P6's partner). The use of subtle cues, such as tactile, thermal, visuals, etc., to support non-verbal communication could enhance intimacy at a distance "by adding an extra dimension to the interaction" (P7's partner). The designs that enabled customisability were said to be meaningful, as it "builds a bond" and "creates a unique link" between couples.

There were suggestions given to adjust some details of the design so as to fit personal preferences, e.g., P4's partner suggested that: "A necklace or bracelet would be not as comfortable to wear as a man, a phone case or a phone accessory would be better". When asked about the potential ethical issues, P6's partner raised a concern about obtrusion with an illumination interference: "Having a bracelet emitting light in an important meeting or during class can be disturbing".

7. Discussion

In this section, we summarise and discuss the main findings and the design considerations derived from them.

7.1 Expressing the Emotions and Supporting Physical Connection

The design concepts and discussions in the study both emphasised, not surprisingly, the need for expressing emotions, creating awareness, and communicating the feeling of caring between the partners. The concepts were aimed for expressing affection rather than communicating more complex messages. Our study findings align with prior research, as awareness and expressivity have been found the most common relatedness strategies with emotional communication systems (Hassenzahl, et al., 2012; Li, et al., 2018). In general, the

designs were meant to serve as an additional interaction channel for mediating LDRs that add on to their existing communication channels, rather than replacing an existing one. The designers should thus consider how the unconventional communication device could support the idea of a physical connection and expressing emotions, and complement the conventional, explicit messaging channels. A wearable device could serve as a fast nudge that couples use to remind each other about their remote presence without using any explicit and verbal communication.

7.2 Supporting Secret Communication

The findings also emphasised that couples wished to share intimate messages, which no-one else was able to understand, and through which they could mediate a private and intimate message, e.g. a memory or a shared joke. This aligns, with Crystal & Hancock (2013), who have stated that intimacy is derived from transactions of self-disclosure. Some similar communication strategies, such as repurposing an emoji in a secretive manner has been reported before (Wiseman & Gould, 2018). As a design consideration, we recommend supporting an exchange of private, or secret, messages in a way which is meaningful for the couple but ambiguous to others. This could be done e.g. with an ambient colour change of an object, or by repurposing commonly used symbols, e.g. emojis. Differing from the current standardised communication channels, wearables offer customisation possibilities with materials, form factors, integrated colour and light elements, and shape-changing.

7.3 Coping with Asynchronised Lifestyles

The study highlighted that LDR couples often had different daily schedules, resulting from geographic separation, time zone differences, and diverging daily routines. Due to the asynchronised life between the remote partners, they often faced obstacles to calling and chatting due to their different rhythms for day/night and work/leisure. As a design consideration, unobtrusive and ambient designs for output technologies should be preferred. When integrating such features with wearable form factors, the designer needs to consider that the device is suitable for different use contexts, and how the communication is placed in the periphery of the user's attention.

7.4 Supporting Effortless Interaction

The feedback gained in our study often emphasised the wish to easily and effortlessly send and receive short, affective messages. With current communication means, the actions for taking up the device and composing a message, as well as to open it, was perceived to require extra effort. The designer should consider how to support effortless interaction. With wearables, this could mean integrating inputs and outputs into the everyday garments or accessories.

7.5 Entwining with Everyday Life

As the final design consideration, the designer should take into account how to entwine the communication tool with everyday life. The findings emphasised that the technical solutions, as well as the design, should blend in with daily lifestyle. Subtle output, ambient design, and secret message encoding support this goal. Unobtrusive information delivery and aesthetic ambient displays that can be integrated into everyday wearable form factors and accessories, and, for instance, designs that can be worn with several outfits could be beneficial. Considering long-term use is also important in order to support the couples over lengthy time periods and to create sustainable design solutions.

7.6 Methodological Notes

Taking a participatory approach, we delivered three workshop sessions where each of our participants was given a chance to design wearable devices to support their own LDRs. We encouraged the participants to feel that they were regarded as experts in LDR experiences (Visser et al., 2005). In doing so, they felt more confident to contribute their insights for designing new wearables, even if some of them did not come from a design background. Overall, the participants embraced the participatory making environment and showed a sense of accomplishment and joy when presenting their works. The design cards were found to be useful for providing participants (mostly with no background in technology) ideas of different possibilities with technology.

As known from the prior art, user studies on LDRs are challenging to organise due to the long distances, contributing to the low number of studies involving actual LDR couples (Li et al., 2018). Our approach of engaging the remote partners in giving comments and suggestions on designs online functioned as a good methodology to gain feedback from both partners. With this compromise, we managed to involve true LDR partners, even though only one of them participated in the co-design workshop sessions. Based on our experience, the method worked well and provided insights into how both partners perceived the proposed design concepts. Naturally, note should be taken for the possible (positive) bias in assessing their partner's design. However, for discussing the wider design considerations, as well as generally, our experiences with the method were positive.

We acknowledge that our study is limited by the small sample size with an unbalanced gender sample. However, we believe our work utilising our participants' empirical experiences in LDR contributes useful insights on how wearables could be designed to support LDRs, and can help the designers and engineers working on the topic.

8. Conclusion

We have taken a participatory design approach to investigate the design of wearable communication devices for supporting couples in a long-distance relationship. Based on the findings of the three co-design sessions, we have identified design consideration and possibilities of how wearable technology could better support couples in LDRs from

potential users' perspectives. Especially, awareness between partners, expression of emotions, strengthening the physicality of the communication, and enabling the delivery of secret messages should be taken into account in the design. Our findings also highlight the importance of practical aspects of how the concept should fit into the user's everyday life, and could be worn, or used, long-term. Our study methodology involving the remote LDR partners through videos can be used as an example of how to conduct a co-design workshop with people who are geographically divided. We believe the findings may be generalised to help develop wearable technology to support other types of LDRs and other types of couples. Future research could include involving both partners in co-designing a wearable communication device concept, and creating functional prototypes.

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About the Authors:

Hong Li is a doctoral researcher at the University of Lapland, Finland and a project manager in an EU Horizon 2020 project – SmartCulTour. Her research has been dedicated to applying design thinking to investigate how intensive technologies can be redesigned and humanised to support new and positive human experiences.

Pradthana Jarusriboonchai is a senior researcher with a computer engineering background. Her expertise in the field is computer-supported cooperative work, user experience, and interaction design. Her research interests are mobile computing, tangible interaction, and wearable & ubiquitous computing.

Jonna Häkkilä is professor for Industrial Design at the University of Lapland, Finland, and an adjunct professor for computer science at University of Oulu, Finland. She has published 150+ peer reviewed scientific papers on user centric design in ubiquitous and mobile computing, and led projects funded by EU Horizon 2020, Interreg, and Academy of Finland.

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Mapping Interactive Experience Over Time

Chung-Ching HUANG[a]*, Erik STOLTERMAN[b]

[a] National Cheng-Kung University, Taiwan
[b] Indiana University Bloomington, US
*Corresponding author e-mail: chungchinghuang@gs.ncku.edu.tw
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Abstract: This paper presents a method to explore user experiences over time. The authors propose a structured procedure, using timelines and annotations to facilitate storytelling and data analysis in a user study. It captures participants' storytelling of prolonged interactive experience. Through our research trial, we demonstrate the potentials to use the timeline's visual representation for analytical purposes as well as creating accumulative knowledge. The novel contribution of this proposal is a complementary research method to many well-established longitudinal research approaches. The timeline annotations feature like a map on collecting information about people's prior interactive experience with technologies. It also supports a holistic understanding of a target user group and their overall user experience with devices, functionalities, and services.

Keywords: user experience over time; mapping

1. Introduction

We all have prolonged engagement with various interactive devices and technologies. User experience over time might start from early products and services, assembled throughout similar product use and built upon related genres of the interactive experience. To study a changing user experience, the understanding of the product histories or users' possessed products (Odom et al. 2009; Odom, Blevis, and Stolterman 2008; Petroski 1992, 1994) might be a good starting point. More commonly, HCI investigates user experience **directly from the users**. With approaches such as interview or focus group, researchers ask our informants to tell their **stories of uses**. The retrospection can start right after a given lab task in a usability study, or a recall of the situated use episodes that happened hours, days, months or even years ago.

Some difficulties do exist such as how to reconstruct a prior scenario from a distant, fragmented memory. However, the storytelling might help research participants recall and reflect upon individual prior use. We believe storytelling might be an ideal resource

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in longitudinal user experience research. Design practice also collect and map stories (Patton and Economy 2014), which help envisioning future viable interactive products. The understanding of storytelling and its relationship to the changing user experience becomes a primary goal in our research. This paper aims at addressing those concerns:

- Can HCI retrospective studies address both historical and individual aspects of long-term experience?
- Can participants communicate, build a common ground (Clark and Brennan 1991) and achieve a holistic understanding of their user experience over time through storytelling?

This paper describes the development of our research method proposal. Stemmed from literature such as group storytelling (Kankainen et al. 2012), product history, and changes of user experience over time, we suggested using a critical analysis of user experience over time and convert it into a structured procedure in retrospective user research.

This paper also takes Digital Photography as a topic of research. For instance, some young users might take photos exclusively with their mobile devices, while other experienced users have taken pictures for years with both traditional film and digital cameras. Their preference for photography, such as how they shoot, archive and share photos with printed or digital copies, might be dramatically different. Recently, the software and hardware innovations have converted digital camera products into the embedded camera modules in everyday mobile devices, with enormous computing capabilities through mobile applications and cloud services. As a result, users now adopted to the new "computational photography (Davidson 2014)." Their intention of use, their expectation of function, and most importantly, the interactive experience is also changed accordingly. Digital photography can be one of the good examples of user experience over time. We review those camera products and software applications existed or used by users, for the purpose of historical and individual aspects of long-term experience.

It is important to address here that we pay special attention to **enrich longitudinal research methods in HCI**. We aimed at reflection and iteration for future method implement. On the other hand, the understanding of a carefully chosen interactive experience over time, through explorations in multiple retrospective studies, might also be a prominent research direction that is not in the current research scope.

This paper structures as follows. First, we reviewed retrospective research methods in HCI and research arguments for user experience over time. Second, we apply the timeline annotations originally introduced in a research paper as structured approaches in our retrospective workshop. Third, we describe the results and map the data in an enhanced visualization. The paper concludes with the reflection and our suggestion for future method iterations.

2. Retrospective research methods for user experience over time

HCI user studies had applied structured procedures analyzing users' response, such as diary (Czerwinski, Horvitz, and Wilhite 2004; Rieman 1993) experience sampling method (Hektner, Schmidt, and Csikszentmihalyi 2006) and talk aloud in protocol analysis (Ericsson and Simon 1984). However, using those methods in the middle of interactive use might lead to an interrupted experience. For example, asking the research participants to think-aloud their current use, prompting research participants to record ongoing experience, or keeping a daily diary might break the flow of interactive use (Nakamura and Csikszentmihalyi 2002). Besides, participants might change their behavior because the expected interaction happens in an unfamiliar context, such as user studies in a lab setting (the Hawthorne effect (Adair 1984).) As a result, an after retrospection for earlier use might be a preferred method, comparing to an immediate report in the middle of interaction (van Gog et al. 2005). Interview and focus group methods are applicable approaches collecting data from our informants after defined research task.

Cues for memory, such as the system log of software uses, can serve as hints in user's retrospection. For example, Russell and Oren developed Retrospective Cued Recall (RCR): a passively capturing of the computer desktop screen when users interact with the web browser (D.M. Russell and Oren 2009). The screenshots became the references in a delayed review, regarding the search engine user behaviors happened several weeks ago. One important goal using this method was enabling users to "tell their own story" and "understand how participants thought about and framed questions as they went through their research process over hours, days and week [emphasis added] (Daniel M. Russell and Chi 2014, 379)." The reason to use memory cues was "the accuracy of uncued memory rapidly deteriorates after one day, there is good reason to wonder about the accuracy of retrospective recall (Daniel M. Russell and Chi 2014, 376)." With their method, Russell and Oren suggested that user research could still collect accurate data of use even in a delayed retrospection.

In short, with suitable memory aids a delayed retrospection might be still helpful for collecting data of prior interactive experience. In the following paragraphs, we build on this viewpoint and challenge if the retrospection timespan is more than just days and weeks, and if the cues of use are not readily available for later user retrospection.

2.1 Recalling a Very Long-Term Interactive Experience

Regarding different temporal scales in retrospection, Russell and Chi categorized retrospective user research, with their definition, into Short-term, Intermediate-term, and Very Long-term studies. The research tasks can range from two hours to two days, and users' retrospection might start right after the research task or after one or two days (Daniel M. Russell and Chi 2014, 384). The reason for Russell and Chi to define those time spans was "retrospective memories (and the reflections elicited) vary so much by the amount of time from the original event…." In addition, they also suggest to "avoid values statement" or

"avoid asking for global affective response from experience in the past," which based on the argument of global hedonic experience discussed in (Schwarz et al. 2009). Russell and Chi suggested "emotional perception from the past cannot help but be influenced by subsequent events and especially the perception of the entire experience at the end [emphasis added] (Daniel M. Russell and Chi 2014, 389)."

We reflect and raise the following concerns. Can HCI retrospective studies still in a systematic way study a long-term interactive experience happened in months, years, or even from the beginning of using interactive products or services (i.e. an overall experience)? When a distant memory of prior interactive use is not accurate enough and mixed with others influencing factors are told stories of previous interactive use still valuable to HCI research?

We then briefly review the development of methods and theory toward a very long-term user experience. Peer tutoring (Höysniemi, Hämäläinen, and Turkki 2003) is a useful research tool revealing how users have learned and adopted their products use over time. Ask our informants to "teach me back" (Phillips et al. 2013) showcases their current uses and preference. Regarding a remembered experience from the purchase of an interactive product, Karapanos et al. proposed iScale, a survey tool that elicits both experience narrative and trend of use in a visual form (Karapanos et al. 2010). Some standard templet is also defined to keep track or reflect prior use, such as sketching UX curve (Kujala et al. 2011). Huang and Stolterman reviewed similar retrospective methods for long-term user experience, and many of those were structured procedures with visual aides such as (Huang and Stolterman 2013). Karapanos et al. proposed a framework of user experience based on mobile phone adoption (Karapanos et al. 2009). They defined the temporality of interactive experience with three stages, i.e. Orientation, Incorporation, and Identification. Even with this concise review, we saw many prior research initiatives and are confident that HCI might still be able to study a very long-term interactive experience with the aid of enhanced research methods.

2.2 Memory Cues for Distant Interactive Uses

Russell and Chi also suggested that proper memory cues can bring users' back to a recognizable prior context (Daniel M. Russell and Chi 2014). Besides the passive screen captures in their developed RCR method, contemporary information technologies such as mobile devices or web browsers can automatically record system activities. Many HCI research investigate user experiences based on system logs. The massive amount of activities data also helps to infer the user behaviours in various industrial software implications. However, system log might not be always available and, most importantly, suitable for the research purposes. Also, most of the everyday interactive products do not have automatically logging capabilities. Even when the system log is available, the researchers and the end users might encounter enormous difficulty to assess, understand, and use the data as memory cues for their prior interactive experience. We then raise another concern: when automatic system logging is not available or suitable for recalling a distant interactive experience, is it possible to find alternative and practical memory cues in a retrospective study?

We briefly mentioned in the introduction session, that the product histories and personal possessions could serve as references in user experience research. For example, Odam et al. interview users and find various personal possession, which trigger immediate and unique retrospection connected to user' memory and use history (Odom et al. 2009). Product reviews might provoke reflections among readers, such as the review of everyday products (Petroski 1992, 1994), the review of social construction in technology system (Bijker, Hughes, and Pinch 1989) or the essays of "Evocative Objects" (Turkle 2007). Buxton's famous chapter of his changing experience using juicers with supporting visual materials (Buxton 2005) is so vivid and fascinating. Norman and Verganti's analysis of product innovations articulated the change in video game consoles and Swiss watch industry development, which is an excellent example of analytical argument (Norman and Verganti 2013).Imagine we researchers can introduce those reviews and critiques in a group user research. Participants might resonate the interactive experience description with their own stories in prior use of the home appliances, the video game consoles, or their timepieces. We considered the academic research or critique of selected interactive products could be used as alternative memory cues in retrospective studies for similar interactive experiences. We planned to explore how to incorporate those research findings and critical argument into HCI retrospective user study.

3. Research Argument for user experience over time

Essays, critique, product reviews and publications in HCI are critical arguments and often about the changes in human-computer configurations. To better communicate their arguments, the authors described not only with text but also with other supporting materials such as pictures, engineering diagrams or design sketches. We have observed many creative uses of visual materials in various disciplines, in particular for the arguments of changes over time using diagrams, treemap or timelines. In the following paragraphs, we review selected analytical visual representation in HCI, which critically explore product history or interactive experiences. The review had led to our method proposal of using existing research and annotated timeline in a group retrospective study.

3.1 Analytical Visual Arguments

We can trace the use of visual representation to communicate concepts or archive knowledge back to the Porphyrian Tree. The tree representation "depict logical relationships, affiliations, genealogical descent, affinity, and historical relatedness between the elements portrayed on the tree" (Gontier 2011). A treemap is often used to describe changes within species, families, or a genre of artifacts, such as Darwin's diagram for the origin of species (Darwin 1859) (please see Figure 1.A.) We also reviewed selected analytical use of visual materials for argument and communication in our field. In the development of theoretical framework "trajectories" for the game and interactive performance experience, Benford et al. described the trajectories using lines and diagrams. The authors noted they "have taken inspiration from the anthropologist Tim Ingold who, in his recent history of lines, has

drawn on fields as diverse as geography, genealogy, music, drawing, calligraphy and weaving to argue for the benefits of thinking in terms of interwoven continuous lines rather than discrete networks" **[**emphasis added] (Benford et al. 2009). Their diagrams compared the story time and (ST) and clock time (CT), which can be used to demonstrate the authors' research arguments and showcase the changes in game experiences (please see figure 1.B. also (Benford n.d.).)

In Norman and Verganti's research for incremental and radical product innovation, they analyzed the meaning and technology changes in the industry development. For instance, they described several critical moments of Swiss watch industry, such as the manufacturing of mechanical watch as jewellery, the failing to use the electronic watch as jewellery, the facing of competition from Japanese electronic watch manufactures, the changing to electronic Swatch as fashion accessories, and the moving back finally to luxury mechanical watches as status symbols. They use a table and shift of meaning and technology positioning to foreground their arguments (please see Figure 1.C. also (Norman and Verganti 2013, 87).)

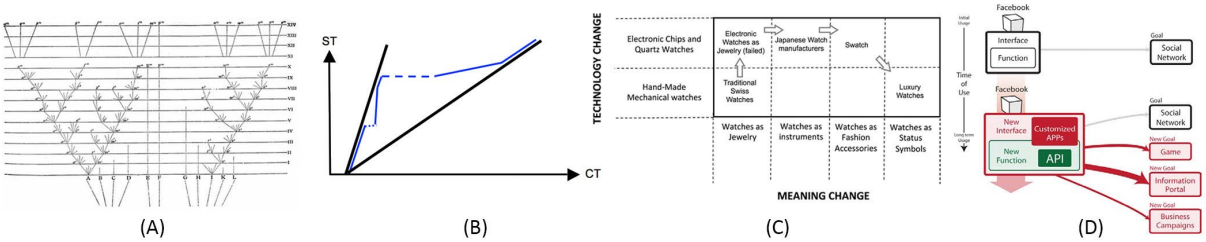

Figure 1 *Tree map for the origin of species (A) and other analytical visual representation in HCI and design Research (B, C and D).*

In Huang and Stolterman's analysis of how interactive artifacts changes over time, they follow the "artifact approaches" and illustrate changes in product interface, product function, and the goal of interactive use with visual annotations (Huang and Stolterman 2012, 460). For example, when Facebook opened application software interface (API) for third-party developer, the internal function has changed because of API, the user interface is changed because of the new third-party applications, and the goal of using Facebook also changes to games, information portal and other business purposes (please see Figure. 1.D also (Huang and Stolterman 2012, 460).) In addition, their research arranged multiple critical moments into a top-down timeline according to temporal order for an analytic purpose.

4. Our Proposal: conducting retrospective user study with existing research finding and its visual analysis

After the literature review, we are encouraged that visual representations do help communicate academic arguments. We then question if HCI researchers can use established academic findings and accompanied visual representations as supporting materials, memory cues, or even structured procedures in other studies for user experience, such as:

- When studying game experience, can we introduce the "Trajectory" dimension diagram by Benford et al.?
- When studying timepiece or game console interactive experience, can we demonstrate the "table of meaning and function changes" by Norman and Verganti?
- When exploring mobile photography usage, can we introduce the "timeline annotations" by Huang and Stolterman, which describes changes in internal function, external interface, and the use goals for mobile photography? How about conducting research again with the same topic, replicate the original critical analysis or process, and compare the result from another informant's retrospection?

As a result, we plan to develop our research methods with the following steps. First, we replicated a similar group storytelling setting proposed by Kankainen et al. (Kankainen et al. 2012), where the informants told personal stories that aligned to a interaction or service journey. Second, we adapted Huang and Stolterman's analysis (Huang and Stolterman 2012) illustrating the changes for an interactive product and use it as a reference in the group storytelling. Those two published research can be an ideal reference for exploring interactive experience over time, through describing the changes in a product or a service journey.

In particular, Huang and Stolterman's analysis of mobile photography experience provided a timeline representation with *five critical moments*, arranged in a top-down order (Huang and Stolterman 2012). This analysis captured a rapid software and hardware innovation in mobile photography, including smartphone, GPS, and mobile photo software applications. We planned to invite out research participants responding to this analysis, asking if they agree or would add extra moments according to unique personal experiences. We also planned to extend the discussion from the current use journey to a longer history of interactive use, such as in similar digital photography products.

We anticipate, through the group storytelling, participants and researchers can discover other important moments of interaction in a long product history. Also, Huang and Stolterman's analysis was not grounded with empirical evidence. We planned to invite our research participants to tell more their stories, which might help to validate the prior analysis for the goals of uses. In addition, we plan to observe if annotated timeline is an applicable research approach for group storytelling.

4.1 Method Trial Workshops

We recruited participants through faculties in U1 and U2 (pseudonym for anonymous peer review), email invitations, flyers and social network advertisements. Twelve graduate students and one professor joined the workshop in U1. Six graduate students, two Ph.D. students and one faculty joined the workshop in U2. All of them were current students or had prior education in design with a focus on ergonomics, interaction design and information system. After their consent, the workshop facilitators recorded the conversation and took

pictures for future anonymous analysis. The exploratory workshops had a controlled number of participants based on the typical focus group research setting. The workshop structured as follows:

INTRODUCTION

The research facilitators introduced Huang and Stolterman's timeline analysis of mobile photography to the workshop participants. The facilitator showed a printed timeline diagram and explained those five critical moments of the change in product function, interface, and use goals (20 minutes). The timeline diagram was available throughout the entire workshop.

RETROSPECTION

Participants were encouraged to add new moments to the existing timeline regarding their mobile photography experience (60 minutes). They could provide moments related to a particular model they have used, the experience of mobile photography they owned, or a historical event such as new generations of a product to the market. The facilitator also prompted the participants to:

- Discuss and arrange those moments in a proper temporal order (based on the shown initial timeline,)
- Contribute personal or known interactive use stories direct to those moments, and
- (Optional) Comment on the goals of use within those moments (designed goals or user's appropriate goals, according to (Huang and Stolterman 2012)).
- The participant's conversation was transcribed and analyzed after the exploratory workshops.

4.2 The workshop results

We have observed a vigorous discussion among our participants in the workshops. They had contributed an impressive amount of storytelling, which had formed new moments in timeline analysis. In particular, many use episodes were told and built upon other participants' storytelling, which directly related to their user experience in the past. To better explain our research result, we first categorized the discussion transcription into the following two genres:

- The participants described **moments** of changes in user experience happened in the past. The moments might relate to the changes of product function, software, or interface. Participants might also report changes from related interactive products.
- The Participants described **stories** from their unique prior interactive uses.

The data from the transcription was so rich and difficult to fully discuss in this paper. In the following paragraphs, we will only present the preliminary quantitative analysis, such as the number of the told moments and stories and selected qualitative analysis of participants'

storytelling.

Retrospection: Mobile Photography

We have identified a lot of moments (U1=46 and U2=25) discussed in the one-hour Retrospection session. Participants commented on the reference timeline by Huang and Stolterman and added new moments from their unique prior experience. The retrospection had converged nicely into discussion of product functions and use qualities, which were also similar between workshops in two universities. Recalled new moments had formed new timelines in the middle of retrospection; in additions, the workshop participants recalled not only their stories but also stories from friend or family, which is beyond our expectation of a user study. We also observe many turn-takings of storytelling throughout the whole retrospection session, which was a positive sign for a constructive user retrospection.

Moments of changes in mobile photography

Participants recalled moments especially for the following two kinds of changes in interactive experience:

- **Changes of functions** on the mobile phone, for example the camera module, physical button or mechanism to activate photo taking, shutter sound, storage.
- **Changes of use quality** such as how to transfer or share photos, the different resolution of photos, how to retouch or edit the photos.

Many described moments belonged to the same aspect of mobile photography experience; as a result, the facilitators prompted the participants to group and arrange those moments with a temporal order. Table 1 described representative timelines formed among workshop participants based on their retrospection and discussion.

Table 1 Representative timelines and moments.

Timelines	**Moments (arranged)**
Camera module / function	No camera / One rear camera / Timer shutter / Flash / One rear camera with selfie mirror / Pivot camera module / One front camera and one rear camera / Camera module cost down / Better resolution camera module / Accessories for rear camera / One front camera and two rear camera module / Remote camera module
Activate photo taking	Software menu / Dedicated physical button / Slide on mechanism / Earphone button as shutter button
Shutter sound	Default shutter sound / Customizable shutter sound / Turn off shutter sound / Forced-on shutter sound
Data transfer and storage	Special data cable / Infrared / MMS / Removable memory card / Bluetooth / Smartphone data service with mobile APPs / WIFI with mobile APPs / Automatic backup to the cloud / NFC
Resolution and quality	VGA / 2 million pixels / 4 million pixels / 8 million pixels / 40 million pixels

Timelines	Moments (arranged)
Photo retouching	Retouch after photo shooting in mobile APPs / Retouch embedded in the shooting

4.3 Stories in mobile photography

We also identified a lot of storytelling from Retrospection. Many of the stories were told right after the discussion of moments and arranged timeline. Here we summarized selected stories from participants that were particular interesting, with identified timelines and specific moments related to their unique use episodes.

Threshold of resolution for product adaption (Resolution): several participants complained the early mobile photo's resolution was not good enough that mobile devices can replace an ordinary camera. One participant in U1 talked about his decision making to purchase a particular mobile phone model because of the resolution had enhanced:

> I decided to purchase this Windows CE mobile phone because the photo resolution is two million pixels. I believe the resolution had passed the threshold of "usable photos" for my daily use, and now I could bring only this mobile phone. However, to use the photo function is extremely difficult, since I have to go through various levels of function menu. However, it has a dedicated shutter button that I liked a lot. Meanwhile, the quality of images was not satisfying enough, so I still bring my digital camera with me. (Participant in U2)

Easy to shoot a mobile photo (Dedicated button / Slide-on): one participant mentioned the reason he adopted mobile photography because it was very easy to shoot with a particular mobile phone:

> I started to take a lot of mobile photo because of this particular phone K750i. When you slide the front panel, the camera module is exposed and ready to take photo. It's so handy, and taking photos became the most frequently used function of this mobile device, not making a phone call. (Participant in U2)

Unlimited wireless data (Smartphone data / WIFI)**:** the wireless data plan for smartphone had changed the frequency of taking mobile photo for some workshop participants:

> I don't clean my photos in my phone anymore. All my photos are sync to the cloud. Also, sharing photo with friends had no extra cost. Many IM software and social network APP become now the major ways I share photos with friend. (Participant in U1)

Prank other people with random mobile photo (Bluetooth): there was a discussion thread about how to transfer and share photos from mobile phone in a nutty way. Here is a vivid and interesting use story:

> Many of us sat in a big auditorium for a boring lecture. We turned on the Bluetooth on our mobile phones and tried to pair with another Bluetooth device. If we find some weird Bluetooth ID, we will send the device some funny pictures. Just for fun and kill time. (Participant in U1)

Shopping for things for remote friends (Photo retouching after shooting): mobile photos

can be used as handy visual information, which could be exchanged immediately. For example:

> I stood in front of the shop window, taking a photo of all products with my phone, and send the photo immediately to my friend. My friend used a photo retouching software, marked those products she wanted me to purchase, and send the picture back to me on the fly. (Participant in U1)

5. Post Analysis: Presenting Research Finding with Timeline Map

Although we can only present selected moments and stories because of the limitation of paper format, we decided to map data from our trial workshop research in a visual representation. Figure 2 was our first attempt mapping storytelling. The map has a similar visual fashion with Huang and Stolterman's artifact center timeline annotations. Using similar visual elements, we added new annotations to the map according to informant' storytelling, formed new timelines, and try the analyze the goal of uses. The enhanced timeline visualization has the following three parts:

1. The **reference timeline** exemplifies Huang and Stolterman's original analysis of five critical moments in the history of mobile photography, anchoring their temporal positions.
2. The **timeline annotations** display new moments, stories, and timelines collected from our retrospective workshop.
3. The **extended analysis** illustrated the goal of use described by our informants in the group storytelling (using the timeline of camera module and function as an example).

The reference timeline helped us to align moments and told stories on the map. All the timelines, however, did not display with an accurate time scale. Instead, this map is used for an analytical purpose, and chronological order is the focal point. We anticipated the viewers could compare different moments and stories across the timelines and have a reference of temporal order.

Meanwhile, this map presented selected contents and was developed to fit a print media. The current visualization might not be ideal for every design or research implications, and we planned to develop other alternative formats to be used in HCI research or design practices.

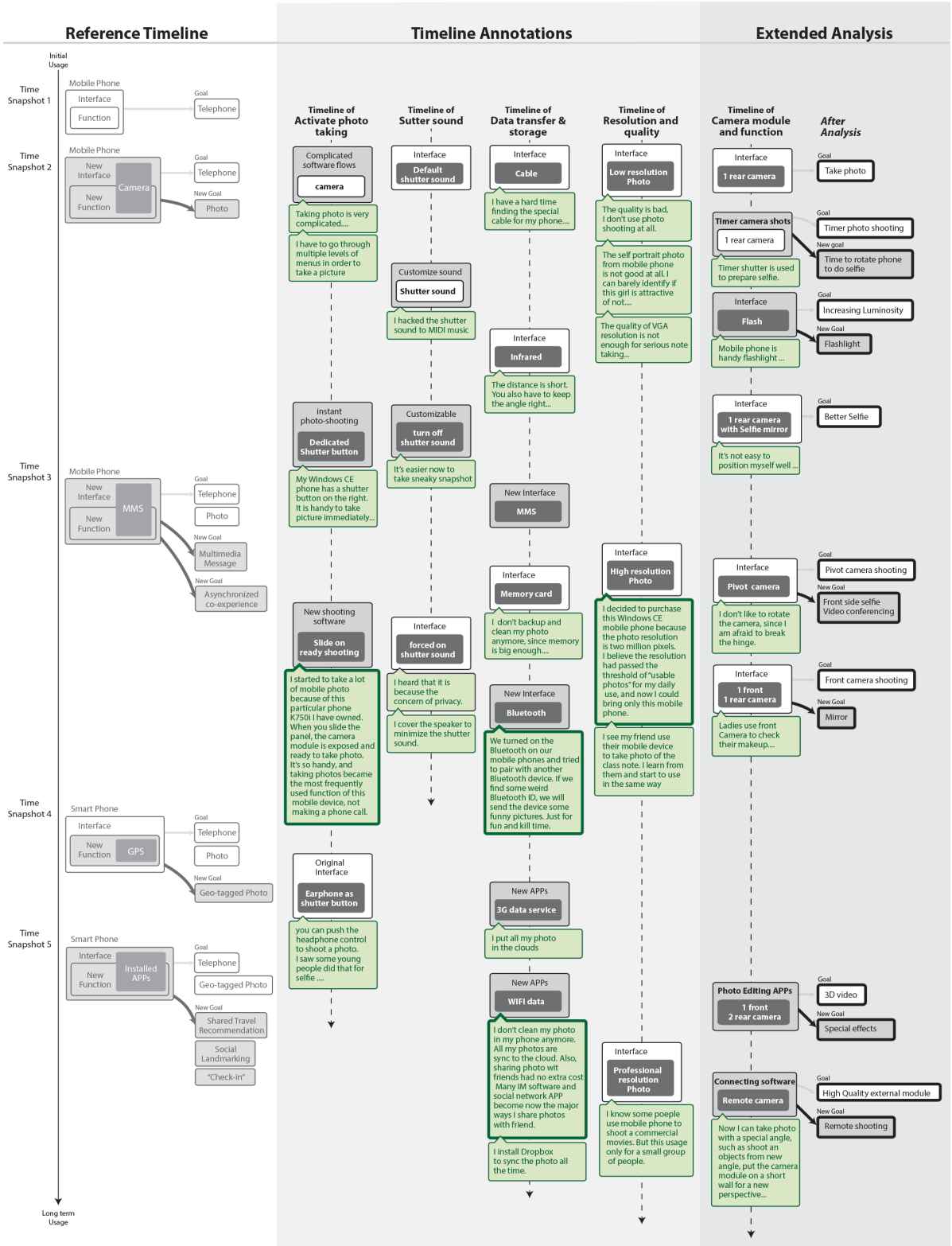

Figure 2 Example of the timeline annotation and extended analysis in mobile photography.

6. Discussion

We reflect upon our current research implementation and suggest for the next method iteration.

6.1 Reflection on Our Method Implement

Validation of method implication

We recognize that our research does not intend to validate the implications immediately in the current trial method implement. The workshops were an early exploration, and those collected data was rich but limited for hasty generalization. For example, the sample size was small, and the current participants from design school might have individual-level factors such as high technology literacies that might impact the result. We plan to test the method with other user groups in the next round and use the method in a design project.

Facilitation of storytelling

The length of told stories was often very short. An in-depth reflection from our informants upon a specific moment or use episode was somehow missing in the retrospection. One of the possible reasons was the tempo of the conversation. The turn taking went so fast that a focused discussion on particular moment or story was lacking. For future method implementation, we will be mindful that the facilitator must

In our workshop, the participants started with reflection upon an existing timeline. Our moderators encountered a new problem eliciting important stories and forming new timelines. They had tried doodling over whiteboard to capture most of the retrospection; unfortunately, it was not possible to take full annotations effectively. One major issue was that the participants recall too many moments and stories without a predefined temporal order. To arrange their retrospection into multiple timelines and annotations might need further confirmation with all the participants. It might be more complex than the single journey map in Kankainen et al.'s group storytelling.

In Kankainen et al.'s study of group storytelling, they suggest a moderator and additional creative secretory to help arranging five fictional stories into a service journey. After the initial steps, they added free personal reflection to the timeline. It would be ideal if we arrange extra moderator in future research, also use assistive tools to arrange the current annotations. Post-it or an interactive note taking software would be ideal for the group retrospection.

The initial timeline worked as a temporal reference in the retrospective workshop. However, the moderators and participants all found it difficult sometimes to decide temporal orders across different timelines, such as contrasting "Bluetooth for transfer photo" to "front camera module" across in different threads of storytelling. In future method implement, supported historical data, such as the temporal order in a family of similar products, might need to be provided to facilitate a structured retrospection.

Group dynamics in storytelling

Some researchers consider retrospective research producing a phenomenological understanding of "lived experiences that belong to a *single person (emphasis mine)* (Giorgi 1997)." In our group user research, the ongoing conversation seemed to shape a shared phenomenological understanding among participants. For example, one participant talks about his or her previous use, and the other follows the conversation since they might share a similar experience. It is less explored if the conversations continue when there is a commonality of experience. Meanwhile, the dynamics among participants, such as turn taking, was critical but not studied. It is a challenging topic; however, a further analysis was beyond the scope of current research plan. We will introduce suitable research analysis, such as thematic or interaction sequence analysis, in the next round.

6.2 Positive Findings After Our Trial Research

We discuss the positive findings after our method trial research with the following two perspectives.

Reconstructing a Remembered Experience

In many cases, our research informants started recalling the changes in products and continued with their unique use scenarios. We believe the inclination might be due to the reference timeline since product functions and interface were the primary visual elements and served as good memory cues in the discussion with other participants and research moderators.

Russell and Chi describe several important factors of HCI studies using human memory: 1. To reconstruct a memory of a prior event according to a widely held, prototypical pattern of this event category rather than by accurate recall of the actual events. 2. To follow the researcher's lead in answering questions about the event. 3. To make associations about events based on perceived similarities between the recalled event and other, similar experiences that influence memory of the event to be similar to those previous events [emphasis added] (Daniel M. Russell and Chi 2014)."

Based on Russell and Chi's arguments, we review our method proposal. First, by using a timeline annotation the participants had reconstructed a collective understanding of their interactive experiences. The retrospections followed a clear pattern: participants discuss the changes in design things first, and they tell the story of use accordingly. Second, the research facilitators led the retrospection simply by prompting the participants to follow the timeline annotations, which had formed a perceived norm in the exploratory retrospective workshops. Finally, the participants have made a connection with their interactive experiences for the following two similarities. Our informant had discussed the similar product characteristics or use qualities; at the same time, they made associations with their storytelling with those moments of change in an interactive history. In short, the timeline has anchored (Huang and Stolterman 2014) the reconstruction.

Accumulating the Knowledge of Prolonged User Experience

Our research followed the analytical argument from Huang and Stolterman: five critical moments describing the changes in function, interface and the goal of use in mobile photography. Also, our study had collected additional storytelling from our informants, formed new timelines, arranged and annotated more moments and stories of use. Our research initiative was the first step toward responding and enriching an analytical argument from prior HCI research, such as exploring new perspectives in mobile photography experience.

We consider this method proposal can be a supplementary approach to many well-established user researches. Our method features an immediate overview of the history of use, mapping various timelines, moments and told use stories. For fellow researchers, this map is flexible to add new elements. For example, each timeline can be a new starting point in future research or design practices. We can pick a timeline, such as camera module or data transfer/storage, and use it as a new reference timeline for future a retrospective research. The findings of a replicated similar study can be merged back to the original map. We anticipate a recursive HCI research practice can incrementally build up a better understanding of user experience over time.

7. Conclusion

In this paper, we developed research methods based on prior HCI analytical studies. We adopted an existing visual analysis and used it as structured procedures in our user research. The result is encouraging: our informants contributed storytelling actively. The timeline served as a reference organizing unique storytelling with temporal orders. The timelines map also became a promising research knowledge analyzing a user experience over time. We are confident and the result from current research trial is helpful planning the next iteration research and design practices.

There is a continuing discussion of incorporating replicate research as a part of HCI research methods (Wilson et al. 2011). However, many critical, argumentative HCI research might not be easy to replicate. In this paper, we had demonstrated it might be feasible to replicate an analytical HCI research in a way transforming it into a research procedure in new studies. Our proposed method has the potential assisting comparison among similar studies: new retrospective user research can build on prior critical analysis, which resonates or contrasts to the previous research findings regarding user experience over time. We suggest our society considering more replication of concept, review, argument, and critical analysis in HCI.

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About the Authors:

Chung-Ching Huang is an assistant professor in the College of Planning and Design at the National Cheng-Kung University (NCKU), Taiwan. He initiated the virtual university-wide transdisciplinary "College X." He holds a Ph.D. from Indiana University, Bloomington, U.S. He promotes design thinking and doing, experience design and service design, also complex problem solving in Taiwan education.

Erik Stolterman is Professor in Informatics and Senior Executive Associate Dean, School of Informatics, Computing, and Engineering, Indiana University Bloomington, U.S., and professor, Institute of Design, Umeå University, Sweden. He is widely published in HCI, interaction design, design practice, philosophy and theory of design. Latest book: "Things That Keep Us Busy--The Elements of Interaction" (MIT Press, 2017).

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Activity Scenario Modelling: an emerging method for examining human-artefact interaction

Miguel MONTIEL[a]*, Ricardo SOSA[b], Darryl HOCKING[a]

[a] Auckland University of Technology, New Zealand
[b] Auckland University of Technology, New Zealand; Monash University, Australia
*Corresponding author e-mail: miguel.montiel@aut.ac.nz
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Abstract: Everyday activities are jointly shaped by people and artefacts. This points to the need for tools that designers can use to examine the joint agency of people and artefacts. This paper reports progress in developing Activity Scenario Modelling (ASM), a design approach that can be used for such purpose. ASM combines techniques of video analysis, discourse analysis and social network analysis. The paper provides an overview of the theoretical foundations of ASM and illustrates it by modelling an activity scenario from an online tutorial on tea-making. The paper also describes a research agenda to apply ASM in design for sustainability efforts.

Keywords: design; agency; activity-scenario modelling; sustainability.

1. Introduction

Everyday activities are jointly shaped by people and artefacts (Bennett, 2010). The 'toasting' of a slice of bread varies due to the way people set up the toaster, the toaster's features, the amount of sugar and protein in the slice of bread, etc. (Jopson, 2015). Given the above, sustainability (in design) is currently considered a property of sociotechnical systems (Ceschin & Gaziulusoy, 2016). This points to a need for tools that designers can use to examine how sustainability arises from human-artefact interaction. Activity Scenario Modelling (ASM) is a method we have conceived for such purpose. ASM is a method in development. This paper reports both the achievements and the subsequent steps in the development of ASM.

The most important achievements in our research so far are two. The first one is the conceptual framework that we have formulated to examine the joint agency of people and artefacts. Such framework considers five types of roles that people and artefacts can play. These roles are articulatory, kinetic, sensory, regulatory and symbolic roles. Each of these roles accounts for a mode of interaction between people and artefacts (Norris, 2004). Namely, physical coupling, joint mobilisation, sensory exchange, co-regulation and

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world-viewing. In section 2, we describe in detail the aforementioned roles and modes of interaction and the process by which we defined them.

Our second achievement, is the method for modelling activity scenarios. This method combines techniques of video analysis (Korkut & Eren, 2019), discourse analysis (Phillips & Hardy, 2002) and social network analysis (Cherven, 2015). The combination of these techniques enables the assessment of interdependencies between the roles that people and artefacts play. To illustrate the method, in sections 3 and 4 we model and analyse an activity scenario (AS) from an online video tutorial on 'how to make a cup of tea using a tea bag'. The video tutorial is available at: https://tinyurl.com/yc5swwkx.

In section 5, we describe the next steps in our research agenda. Through these steps, we seek to shore up ASM so that it can be used to design for sustainability. The term sustainability refers here to fostering ways of proceeding in which nature is cherish, not dominated (Bannon, 2016; Gaard, 1993; Haraway, 2016). In section 5, we explain how ASM could assist designers not only in identifying different expressions of human domination over nature, but also in challenging, reducing and/or suppressing such expressions.

2. Theoretical foundations of activity scenario modelling

People and artefacts can interact in various ways as everyday activities unfold. Because of this, everyday activities can be deemed as multimodal events (Norris, 2004). By tilting a kettle, people may set in motion the water contained in it. This manoeuvre involves not only the physical coupling, but also the joint mobilisation of the human body, the kettle and the water (Giard, 1998; Kröschlová, 2000).

A sensory exchange is also at place in the situation above. When pouring water, people may be somewhat aware of things like the weight of the kettle, the sound of the running water, etc. (Dickens, 2017; Rodaway, 2002). Sensory exchange can lead to adjustments in physical coupling and mobilisation (Krippendorff, 2005). For example, people can vary the pouring angle as the water outflows the kettle and the weight of the kettle decreases.

Adjustments are not given by human capacities only. Artefacts' capacities can also regulate how an activity is carried out (Illies & Meijers, 2014; Latour, 1992, 2005). For instance, the rate at which people modify the pouring angle can vary given the size of the kettle, the shape of its spout, etc. In other words, everyday activities are co-regulated by people and artefacts.

Human and nonhuman capacities integrate in people's worldviews (Halliday & Matthiessen, 2013). Worldviews are composed by the assumptions, notions, beliefs, etc. that people rely on to make sense of everyday situations. Worldviews are expressed in everyday speech (Forlano et al., 2016). Consider the following phrase: "So, as the water is coming now to a rolling boil, we'll turn the kettle off so again, it doesn't over boil and lose all the oxygen...". In this phrase, the speaker explains what is going on by referring to his capacity to turn off the kettle, the water's capacity to boil, the kettle's capacity to display its content, etc.

Physical coupling, joint mobilisation, sensory exchange, co-regulation and world-viewing are

some of the modes of human-artefact interaction that can take place in everyday activities. Roles in this study were specified from this non-comprehensive list of interaction modes. The types of roles considered in this study are shown in Table 1. These types are articulatory, kinetic, sensory, regulatory and symbolic roles.

Table 1 Correspondence between interaction modes and role types.

Interaction mode	Role type
Physical coupling	Articulatory roles are performed by participants who come into physical contact.
Joint mobilisation	Kinetic roles are performed by participants that mobilise or are mobilised.
Sensory exchange	Sensory roles are performed by participants that interchange data of some kind.
Co-regulation	Regulatory roles are performed by participants whose capacities modulate the deployment of an activity.
World-viewing	Symbolic roles are performed by participants that are referred in people's accounts of everyday activities.

2.1 Principles for role clustering

In activity scenario modelling (ASM), roles connect via internal and external links (DeLanda, 2019). Internal links bring together the roles that a participant plays in an activity. In principle, all the roles performed by a participant should interconnect. This is because the roles that a participant play are all afforded by its design (Nelson & Stolterman, 2012). Clusters of roles produced by internal links can be considered depictions of participants' design. These depictions are referred here as internal clusters (ICs).

External links, on the other hand, connect roles performed by different participants. Clusters produced from external links are called external clusters (ECs). ECs are depictions of the processes that make up an activity (Kaptelinin & Nardi, 2006). In ECs, connections are established only among roles of the same type. This is because the clustering of each type of roles accounts for a specific mode of interaction between participants.

Activity scenarios (AS) result from the tie-in of ICs and ECs. These additions occur when a participant performs roles in more than one process. An example of this is illustrated in Figure 1. EC1 depicts the process of 'boiling water' and EC2 that of 'pouring boiling water'. IC1 depicts the design of a kettle. As Figure 1 shows, EC1 and EC2 bond via IC1 because the kettle plays a role in both processes. The kettle's roles in EC1 and EC2 (i.e. R3 and R8) constitute 'cutting points' (Prell, 2012). This is because without R3 and R8, EC1 and EC2 would remain disjointed.

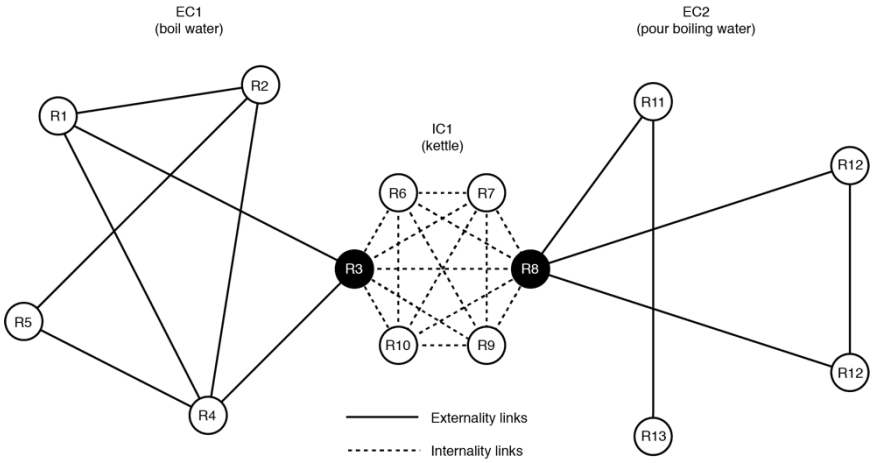

Figure 1 *EC1 and EC2 respectively depict the processes of 'boil water' and 'pour boiling water'. EC1 and EC2 bond via IC1 because the kettle performs a role in both processes (R3 and R8 respectively.*

In ASM cutting points are considered more central than roles that are not. Centrality in ASM is a measure of influence (Caldarelli & Catanzaro, 2012). As everyday activities unfold, some processes may affect how others are conducted. For instance, the strength of tea may influence people's decisions on how much sugar to add. In other words, the way tea is brewed can influence the way tea is sweetened. The above suggests that role-playing is interdependent (Juez, 2002). Role interdependencies are local when they occur within an ego-network (Prell, 2012). Ego-networks consist of a focal role ("ego") and the roles to whom ego directly connects.

Role interdependencies can also be remote. That is, a role can exhibit interdependencies with roles outside its ego-network. This is because roles that compose an ego-network have ego-networks on their own. In view of this, the effects of interdependencies can propagate among ego-networks. The links through which effects propagate are called here 'interdependence routes'. Given their position within an AS, a role can be part of a variable number of interdependence routes (Prell, 2012). The higher the number of routes to which a role belongs, the greater its potential to influence or be influenced by other roles and thus, the more central it is said to be (Bennett, 2010).

3. A method for modelling activity scenarios

In this section, we describe a method for modelling activity scenarios (AS). The method is called activity scenario modelling (ASM). ASM combines techniques of video analysis, discourse analysis and social network analysis. We illustrate the method by modelling an AS from an online video tutorial on 'how to make a cup of tea using a teabag'. The tutorial (available at https://tinyurl.com/yc5swwkx) shows a person making a cup of tea with no sugar, milk or any other accompaniments added. The tutorial is part of a set of online videos that informed our initial explorations on how to represent and assess activity scenarios i.e. networks of human and nonhuman roles. The steps that comprise ASM are described in the

following subsections.

Figure 2 Screenshot of the video tutorial used to exemplify the modelling of activity scenarios.

We decided to work with video tutorials on tea-making for several reasons. Firstly, tea-making is a widely practised activity. Secondly, online video tutorials are public, easily accessible and are created by people with different backgrounds, levels of expertise, etc. (Quinton & Reynolds, 2018) Third, in video tutorials people tend to comment on their actions as they perform them. Therefore, video tutorials can provide insights not only on people's ways of proceeding, but also on the concerns, beliefs, etc. that guide their actions (Pink et al., 2015). Fourth, ASM is a method under development. Thus, before working with users, designers, etc., we wanted to develop a sound understanding of how data collection can be done ethically and efficiently. The steps that comprise the method are described in the following subsections.

3.1 Activity subdivision and participant allocation

Everyday activities can be decomposed into processes (Kaptelinin & Nardi, 2006). For instance, toasting a slice of bread can be partitioned in processes such as 'get the slice', 'brown the slice with heat', etc. Thus, the first step is to subdivide the tea-making method shown in the video tutorial. This can be based on a definition of process categories (Braun et al., 2019). The categories we work with are two. These categories are 'transportation processes' and 'transformation processes'.

Transportation processes are given by the circulation of commodities (e.g. water, sugar, etc.) in an activity. Two commodities whose circulation is observed in the video tutorial are tea leaves and water. Correspondingly, two transportation processes were considered. These processes are tea leaves flow (p1) and water flow (p2).

Transformation processes are those that produce changes in the physical characteristics of commodities. Three transformation processes that can be observed in the video tutorial are boiling, brewing and mixing. In what follows, these processes are respectively referred as p3, p4, and p5.

The second step in ASM is to elucidate the participants of each process. This can be done one process at a time (Norris, 2004). This means that the tutorial is analysed repeatedly. Each time, designers can look at a specific process. Table 2 shows a non-comprehensive list of participants for p1...p5. Notice that some participants appear in more than one list. This is because they participate in more than one process. The cup for example, performs as container of both tea leaves and water. Additionally, the cup performs as a brewing and mixing vessel. Therefore, the cup is part of p1, p2, p4 and p5.

Table 2 Allocation of participants by process.

Process	**Participants**
p1 (tea leaves flow)	Human, cup, water, teabag wrap, teabag, saucer, tea leaves, spoon.
p2 (water flow)	Human, kettle, cup, water, teabag, saucer, tea leaves
p3 (boiling)	Human, kettle, water.
p4 (brewing)	Human, cup, water, teabag, saucer, tea leaves, spoon.
p5 (mixing)	Human, cup, water, teabag, saucer, tea leaves, spoon.

3.2 Role assessment

The next step is to examine participants' roles in each process. That is, assess what roles are participants performing in p1...p5. Participants can perform roles of the same type in more than one process. For instance, the tutorial's host performs articulatory roles in p1, p2, p3, p4 and p5. This is because he manipulates artefacts and/or commodities in all these processes.

Role assessment can also be done one process at a time (Norris, 2004). That is, a process is analysed repeatedly. Each time, designers can look at a specific type of role. Examination of articulatory and kinetic roles can be done visually. The reason for this is that physical coupling and joint movement are observable events.

When it comes to regulatory and sensory roles, visual assessment may not suffice. This is because data exchange and co-regulation can involve non-observable acts (e.g. perception, decision making, etc.) (Nevile, 2005). One way to deal with this is by deeming what people say about a process. To clarify, let's review a phrase from the tutorial: "So, as the water is coming now to a rolling boil, we'll turn the kettle off so again, it doesn't over boil and lose all the oxygen... (01:00)"

The phrase above is indicative of a sensory exchange between the human participant, the kettle and the water. Likewise, the phrase reveals the deployment of at least two human capacities. Namely, 'acknowledging when the water is boiling' and 'turning off the kettle'. The phrase also provides insights on the deployment of nonhuman capacities i.e. the kettle's capacity to 'display its content', the water's capacity to 'boil', the water's capacity to 'lose

oxygen', etc.

The importance of people's discourse is even greater in the appraisal of symbolic roles. This is because the way people make sense of the ongoing situation may not always be explicit. That is, making sense of what is going on can be a partially or exclusively cognitive act (Phillips & Hardy, 2002). Consequently, the inquiry of symbolic roles was grounded on systemic functional linguistic theory (SFL) (Halliday & Matthiessen, 2013).

SFL is a language theory that focuses on the functions of language (that is, what language does and how it does it), rather than on the structure of language. In this theoretical framework, for example, verb selection is considered a mechanism that produces certain coherent worldviews (Janks, 1997). We selected this approach because it admits inputs from the other modes of interaction we consider in this study.

Designers can use annotation tools to facilitate role assessment (Covarrubias & Martínez, 2012). Annotations tools can be composed in different ways (Gehl & Svarre, 2013). The annotation tool we use considers three elements. Namely, the examined process, the examined participant and the types of roles that the participant may play. Table 3 shows how these elements integrate in our annotation tool.

Table 3 Annotation tool showing the roles performed by participants of p3 (boiling).

p3 (boiling)	**Participant**	**Articulatory**	**Kinetic**	**Sensory**	**Regulatory**	**Symbolic**
	Human	X	X	X	X	X
	Kettle	X	X	X	X	X
	Water	X	X	X	X	X

As shown above, all participants of p3 (boiling) perform articulatory, kinetic, sensory, regulatory and symbolic roles. This, however, might not occur in other processes. Table 4 (below) shows the roles performed by participants of p5 (mixing). Notice that the human and the tea leaves are the only participants that perform the five types of roles in p5.

Table 4 Annotation tool showing the roles performed by participants of p5 (mixing).

p5 (mixing)	**Participant**	**Articulatory**	**Kinetic**	**Sensory**	**Regulatory**	**Symbolic**
	Human	X	X	X	X	X
	Cup	X		X	X	
	Water	X	X	X	X	
	Teabag	X	X	X	X	
	Saucer	X		X	X	
	Tea leaves	X	X	X	X	X
	Spoon	X	X			

3.3 Laying out internal and external links

After completing role assessment, the next step is to draw internal and external links between roles. For this purpose, designers can create a role matrix. A role matrix is a list in which roles are grouped under categories (e.g. human roles, kettle roles, cup roles, etc.). In a role matrix, roles are given a numeric id. Roles can also be labelled to indicate their type and the process of which they are part of. Table 5 shows the ids and labels for the roles performed by the kettle.

Table 5 Ids and labels for the roles performed by the kettle.

Id	**Label**
R26	Kettle_articulatory_p2
R27	Kettle_kinetic_p2
R28	Kettle_sensory_p2
R29	Kettle_regulatory_p2
R30	Kettle_articulatory_p3
R31	Kettle_kinetic_p3
R32	Kettle_sensory_p3
R33	Kettle_regulatory_p3
R34	Kettle_symbolic_p3

Designers can specify the source and target of internal links using the role matrix (Cherven, 2015). As stated in section 2, all the roles that a participant performs in an activity should interconnect (Nelson & Stolterman, 2012). This means that an internal link will go from R26 to R27, another from R26 to R28, and so on. Once internal links that depart from R26 are established, designers can move on to look at those that depart from R27.

Notice that internal links are non-directional. Thus, when modelling the internal links that depart from R27, there is no need to draw one from R27 to R26. The reason for this is that the connection between R26 and R27 was established in advance. Namely, when the links departing from R26 were drawn. Figure 2 shows the kettle's internal links. These links constitute the kettle's internal cluster (IC). An IC is to be modelled for each human and nonhuman involved in an activity.

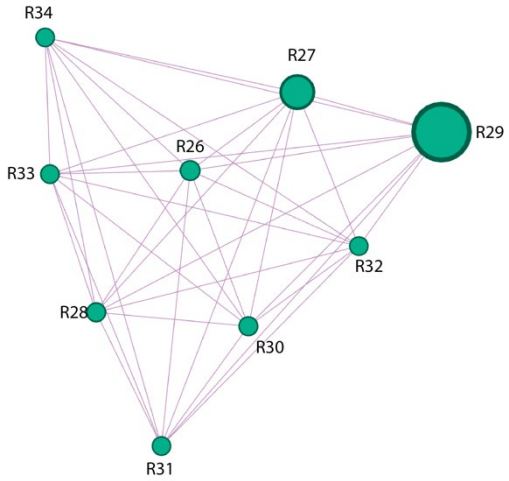

Figure 2 *Kettle's internal cluster composed by internal links that connect the roles performed by the kettle.*

Once ICs are modelled, designers can start modelling the external links of p1...p5. This results in an external cluster (EC) for each process. To facilitate the identification of the source and target of external links, designers can define linkage criteria for each mode of interaction. In this paper, we draw external links between articulatory roles in a restrictive manner. That is, we draw external links considering "who couples with who". The same is done for sensory roles i.e. external links are set based on "who provides data to who".

In contrast, external links between kinetic roles are established in a non-restrictive manner. This means that all kinetic roles in a process connect to each other. The same is done for regulatory and symbolic roles. Notice that linkage criteria admit different levels of resolution. Namely, designers may draw external links considering specific body parts, artefacts or commodities. Likewise, designers can set external links to model specific forms of co-regulation (e.g. water consumption, preparation time, etc.) or world-viewing (gender, identity, power relations, etc.).

3.4 Centrality reckoning

Activity scenarios (AS) are comprised by roles that interconnect via internal and external links. Given their position within an AS, roles may exhibit different levels of centrality. As established in section 2, centrality is a measure of influence (Caldarelli & Catanzaro, 2012). The centrality of roles within an AS can be calculated using different algorithms. The algorithm we selected accounts for centrality in a variety of networks (Brandes, 2001). We selected this algorithm because the structure of AS may vary in view of people's preferences, availability of commodities and artefacts, the activity being modelled, etc. Thus, we prioritised an algorithm that would allow us to consistently measure centrality in AS od different characteristics.

The selected algorithm works as follows. First, the algorithm finds the shortest

interdependence route between every pair of roles. Then, the algorithm quantifies how many of these routes pass through each role. The greater the number of interdependence routes that go through a role, the more central the role will be (Cherven, 2015). Figure 3 (below) shows the AS modelled from the video tutorial on tea-making. In what follows this activity scenario is referred as AS1. Role centrality in AS1 is indicated by the size of the roles. In other words, the greater the diameter of a role, the more central the role is.

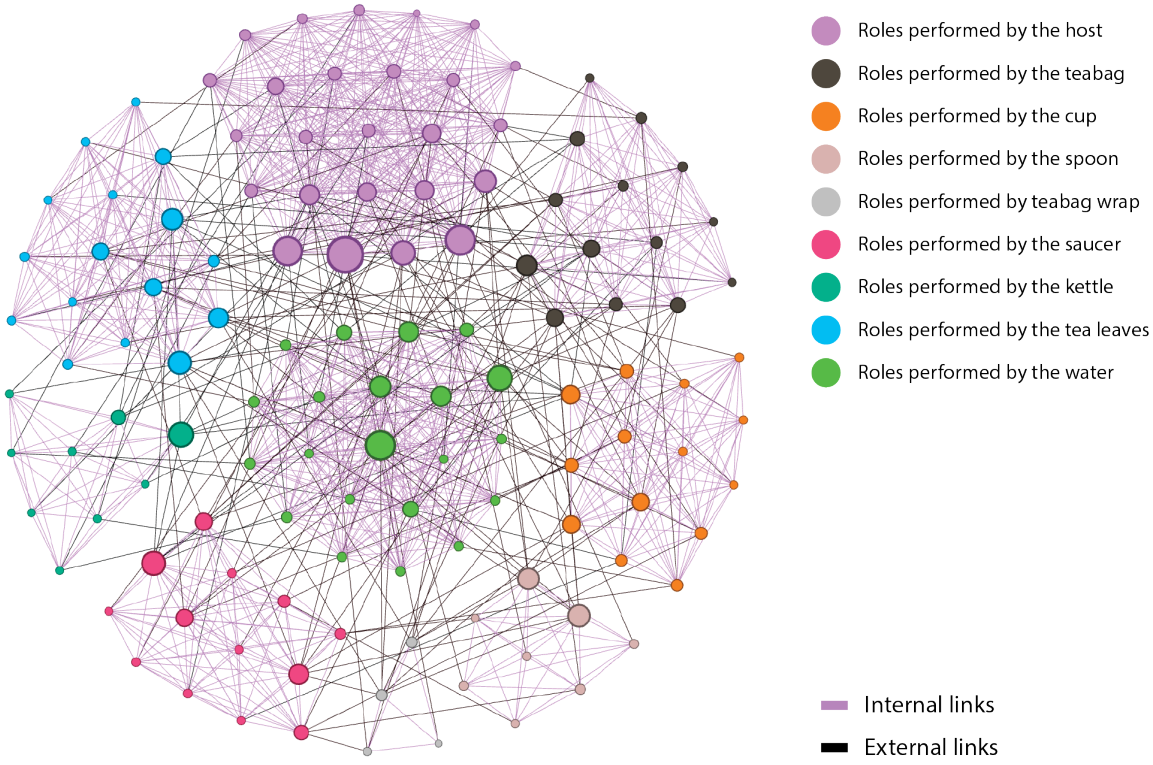

Figure 3 Activity scenario (AS1) modelled from the video tutorial.

4. Analysing activity scenarios

Once AS are modelled, the roles that composed them can be indexed based on their centrality. Insights provided by centrality analysis can be interpreted in different ways. One approach is to think of the most central roles as leverage points. That is, roles with high potential to influence the performance of an activity (Abson et al., 2017; Meadows & Wright, 2008).

To clarify, let's consider the following. R08 is the most central role in AS1. R08 accounts for the sensory role performed by the tutorial's host in p1 (i.e. tea leaves flow). As Figure 4 shows, R08's ego-network is comprised of internal and external links. Internal links (in pink) tie R08 to the rest of the roles performed by the tutorial's host.

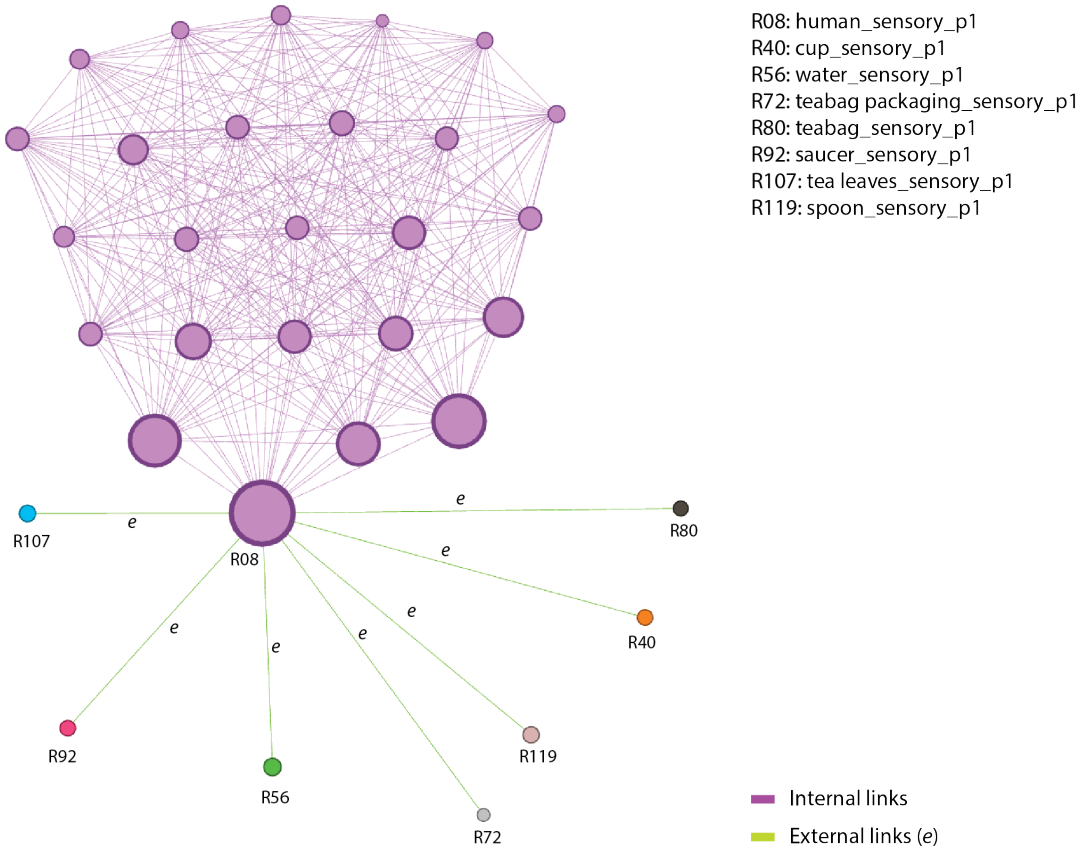

Figure 4 R08's ego-network.

External links (in green) on the other hand, connect R08 to other participants that perform sensory roles in p1. That is, external links account for sensory exchanges between participants of p1. In these exchanges, the tutorial's host is the only participant receiving data. Thus, the performance of R08 is estimated by the ways the tutorial's host senses and interprets data provided by other participants of p1.

Grasping sensory data is a learnt action. That is, the way people sense and interpret data is a by-product of personal history, social life, culture, etc. (Giard, 1998; Rodaway, 2002). Consider for instance how visual evaluation of tea strength can vary among individuals, generations, regions, etc. Acquired ways of grasping data can be referred as "perception styles" (Rodaway, 2002).

Designers can revisit the video tutorial to better understand the host's perception style. Succinctly, p1 starts with the host taking the teabag out of its wrap and concludes with the host placing the teabag in the saucer after removing it from the cup. As p1 takes place, the host is exposed to a variety of data (e.g. tactile, visual, etc.) (Dickens, 2017).

To cope with the above, designers can consider what the host says about p1 (Halliday &

Matthiessen, 2013). Asides of unveiling nonobvious data that the host may be sensing; this can help designers elucidate the relative importance of different chunks of data, how the host interprets data, etc. To clarify, let's consider the following phrase.

> "This is where people often go wrong with the teabag. They'll stand and dunk the teabag and as soon as the colour looks about right, they'll think it's ready to drink. Well, teabag tea is the same as any tea, it needs time for the full flavour to come out. So, we say that you must give it a minimum of three minutes to brew properly... (02:36)"

The phrase above suggests that the host's perception style is hierarchical. This means that, in the host's worldview, time tracking is more relevant than the visual assessment of colour. The host talks about the relevance of time at different moments. For example, at the beginning of the tutorial he comments: "Now, when people are using teabags they are often in a rush and they don't make the tea properly... (00:08)"

The above analysis is by no means comprehensive. Namely, the host's perception style may comprise more than time tracking and visual assessment. Another thing to consider is that perceptions styles vary among individuals. Since this paper examines the doing of one individual only, what we report here constitute insights, not overall findings. In other words, what we present here is not in-depth account of tea-making practices. Instead, through this paper we seek to provide directions on how to model and analyse activity scenarios.

5. A research agenda for activity scenario modelling

The research agenda we present here is aimed at enabling the use ASM to design for sustainability. The term sustainability refers here to fostering ways of proceeding in which nature is cherish, not dominated (Bannon, 2016; Gaard, 1993; Haraway, 2016). For this purpose, we have set both short-term and long-term activities. We have defined these activities taking into account the achievements and limitations of the work we have done so far. In regards to achievements, work with video tutorials has allowed us to identify five interdependent modes of human-artefact interaction. Namely, physical coupling, joint mobilisation, sensory exchange, co-regulation and world-viewing. The work with video tutorials has also enabled us to conceptualise and prototype a method to model and analyse the interdependencies between various modes of human-artefact interaction.

While online tutorials provided a suitable ground for our initial explorations, we acknowledge the limitations of this scheme of work. Online tutorials provide a good foundation to assess physical coupling and joint mobilisation. However, the access video tutorials provide to sensory exchange, co-regulation and world-viewing is limited. This is because, the non-observable acts (e.g. perception, decision making, etc.) associated with these modes of interaction are not always clear or made explicit by the hosts of the tutorials (Nevile, 2005). Another problematic aspect of working with video tutorials is resource variability (van der Bijl-Brouwer & van der Voort, 2014). That is, variations in the artefacts and ingredients that the hosts of the tutorials use. While these variations can facilitate the identification of a wide range of opportunities for intervening tea making; they can also difficult the comparative

analysis of people's performance.

Considering the above, short-term activities in our research agenda will focus on collecting data from primary sources. To do so, we will conduct one-to-one sessions with tea makers. In these sessions, people will be asked to make themselves a cup of tea (Kuijer et al., 2013). The utensils required for this task will be provided by us. With the latter, we expect to reduce resource variability to a manageable level (Mawhorter et al., 2014). As they proceed, participants will be asked to articulate what they are doing (Hanington & Martin, 2012). This approach will enable the documentation not only of participants' ways of proceeding, but also the ideas, motivations, beliefs, etc. that guide their actions. Tea making will be followed up by a short interview. One-to-one sessions will be documented via photographs, video/ audio recordings and field notes. Data collected during one-to-one sessions will inform the modelling of activity scenarios (AS). We will model an activity scenario for each of these sessions. Subsequently, we will integrate individual activity scenarios into an 'overall AS'. The overall AS will account for the collective performance of our participants (van der Bijl-Brouwer & van der Voort, 2014). Asides of informing the next step in our research agenda, the overall AS will constitute the anchoring point between ASM and design for sustainability (DfS).

The next step in our research agenda consists on co-design sessions. These sessions will be directed towards making the performance of our participants more sustainable. Co-design sessions will be divided in two parts. During the first part, we will examine the symbolic interactions documented in the overall AS. Specifically, we will look at how the natural substances (e.g. water, tea leaves, etc.) are discursively constructed by our participants (Halliday & Matthiessen, 2013). We will pay special attention to discursive constructions that allude to a sense of domination over nature (Bannon, 2016; Gaard, 1993; Haraway, 2016). When such constructions are identified, we will examine how is that they relate to other modes of human-artefact interaction (i.e. physical coupling, joint mobilisation, sensory exchange and co-regulation). During the second part of the co-design sessions, participants will be divided in three groups. The first group will be asked to select and modify one or more of the artefacts that comprise the overall AS. These modifications can be directed at challenging, reducing and/or eradicating specific expressions of domination over nature. The second group will be asked to conceptualise design solutions that can be introduced into the overall AS to allow people to perform without a sense of domination over nature (Boehnert, 2018). The third group will be asked to identify changes in standards, regulations, policies, etc. that manufacturers and governments could implement to incentivize tea makers to proceed in a non-dominating way (DiSalvo, 2012; Fry, 2011).

The long-term research activities will focus on examining the cumulative effects of design solutions conceived to challenge, reduce and/or supress domination over nature. For this purpose, a longitudinal study will be conducted. That is, the artefacts conceived in co-design sessions will be prototyped and included in subsequent one-to-one sessions. Design solutions will also be modelled and included into the overall AS. These steps will be undertaken iteratively. Complementarily, we will explore connections between ASM and

evolutionary computation. The cross over between ASM and evolutionary computation can be achieved in different ways. One alternative is to use ASM to inform the implementation of multi-agent systems (Epstein & Axtell, 1996; Kronefeld, 2004). That is, systems in which the properties of agents and the interaction between agents are defined in alignment with the outputs of one-to-one sessions and co-design sessions (Montes de Oca Munguia et al., 2009). A second alternative is to use the outputs of one-to-one sessions and co-design sessions to develop cultural algorithms (CA) (Kobti et al., 2004; Reynolds & Ali, 2007). Namely, populations of agents that exchange information, resources, etc. associated with the resolution of specific problems (e.g. making a cup of tea). With the above, we expect to develop a better understanding of the long-term changes (intended and unintended) that design solutions may bring about in everyday activities.

The research agenda we described above is aimed at bridging ASM and design for sustainability (DfS). We foresee that this connection can occur in four ways. First, ASM can assist the identification of expressions of human domination over nature that are embedded in everyday activities. Secondly, ASM can enable the reorganisation of everyday activities in ways that do not perpetuate domination over nature. Third, ASM may facilitate the elucidation and critical analysis of the long-term changes that design can bring about in the way people interact with artefacts and nature. Fourth, ASM can provide a framework to challenge standards, regulations, policies, etc. that regulate our interaction with artefacts and nature.

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About the Authors:

Miguel Montiel is a PhD student at Auckland University of Technology in Aotearoa New Zealand. He is interested in the assessment of how everyday activities are jointly shaped by people and artefacts. He also studies changes in everyday activities that derive from the introduction of disruptive artefacts.

Ricardo Sosa is Associate Professor at Auckland University of Technology and holds adjunct positions at Monash University and Nanyang University of Technology Singapore. He teaches and conducts research in design and creative technologies with an emphasis on creativity for social justice.

Darryl Hocking is a Senior Lecturer at Auckland University of Technology, New Zealand. His research focuses on the interactional genres and communicative practices in art and design settings and how these impact on creative activity. He is the author of the book Communicating Creativity: The Discursive Facilitation of Creative Activity in Arts (Palgrave Macmillan, 2018).

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SYNERGY

The method of Immersive Behavioural Observation (IBO) — a conversation between theory and practice

Shalini SAHOO[a]*, Stefan W. SCHMIDT[b]*

[a] Royal College of Art, United Kingdom
[b] University of Wuppertal, Germany
*Corresponding author e-mail: shalini.sahoo@network.rca.ac.uk
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Abstract: Observational field work is an essential part of design research. In this paper we introduce a new method for design research called Immersive Behavioural Observation (IBO). We developed the IBO method in order to analyse meaningful bodily relations to our environment, particularly in transit spaces. Human beings constantly interact with their environment and are often unconsciously guided by their surroundings. The IBO method aims to understand relations that point to a background structure embedded in space which shapes the human interaction in it. The method makes explicit an implicit, tacit knowledge that is part of our practical and purpose driven understanding of and within a place. The IBO method has its foundations in anthropological field research methods like participant and direct observation. It is also deeply influenced by phenomenology, especially Maurice Merleau-Ponty's analyses of the lived body experience and Martin Heidegger's analysis of a functional environment or "totality of involvements."

Keywords: embodied observation; phenomenology; lived body experience; transit space

1. Introduction

The method of Immersive Behavioural Observation (IBO) has been developed by us for the benefit of doing an "objective-subjective" □ field research. This seemingly paradoxical expression refers to subjectivity based on a shared or defensible notion of objective reality or truth. The IBO method has its foundations in traditional anthropological field research methods like participant and direct observation. Thus, we will firstly, in section two, introduce the methodological considerations in the research. This is based on the design task and the epistemic base of the work. In this section we analyse existing field research methods and discuss the nature of the new method that contains the qualities of the traditional methods but mitigates their failings at the same time. Subsequently, section three illustrates the application of the IBO method in six steps during the field work. This is a practical introduction to the theoretical parts that constitute the IBO method. The IBO

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method is discussed in detail here, with respect to its nature, building elements and the main process. Section four discusses the IBO method in comparison to other traditional methods; section five draws final conclusions.

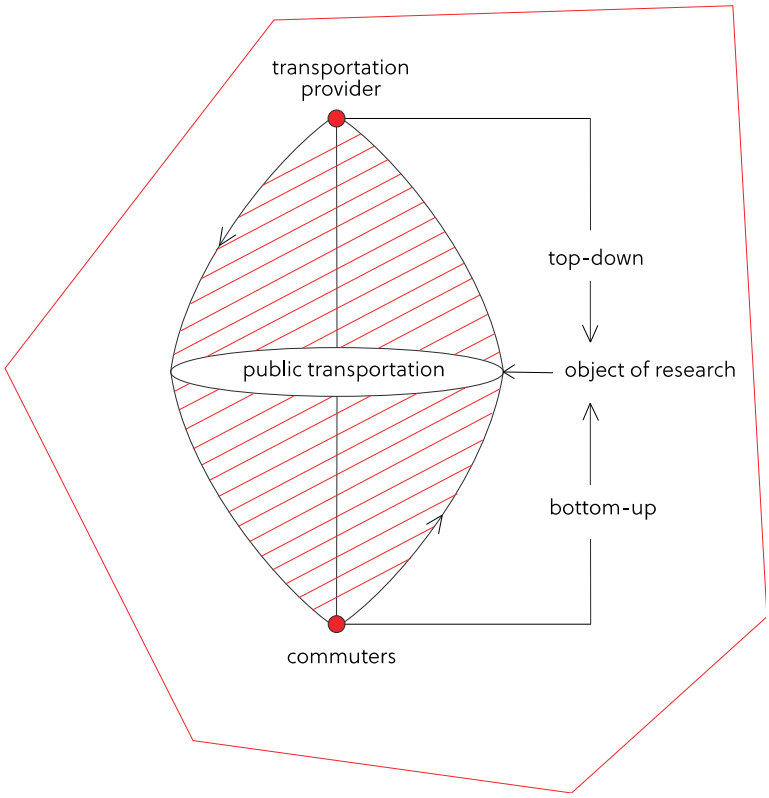

Figure 1 The system's context of the object of research

2. Methodological considerations

2.1 Design Research Task

When the IBO method was developed, the first area of investigation was at an object level (see Figure 1). The aim was to understand transit areas like stations, trains, bus stops and airports, with respect to commuters and their embodied interaction with the materiality of the space. The task was to gather insights on how commuters interact within and with the space. The built environment affects how humans behave and feel in the space, and the ways humans experience an environment effect its 'atmospheric' (Böhme, 2006) qualities as well. Therefore, it is not just the architecture of the station that influences the commuter's state of being, but the commuter themselves who also, co-create the atmospheric quality of the station. The aim of the object-level enquiry was thus, to identify, document and analyse the interaction between the commuter and the transit space. To understand how commuters in transit spaces behave at an embodied level while simultaneously achieving their goal, that

is, transiting from point A to B. As the French phenomenologist Maurice Merleau-Ponty points out, the lived body movement is the pivotal element in understanding the body-place-relationship because our body is not in space, or in time but inhabits space and time (Merleau-Ponty, 2010, p. 161). "By considering the body in movement, we can see better how it inhabits space (and, moreover, time) because movement is not limited to submitting passively to space and time, it actively assumes them (ibid., 117) [...]." Movement reveals a more fundamental form of intentionality. Thus, Merleau-Ponty understands motility as basic intentionality, as motor intentionality.

The intentions of the users of public transportation are articulated in their corporeal orientation and behaviour within the space. Through bodily movement, space incarnates meaning and significance. Over time, the body becomes acquainted with space and places are shaped. As far as bodily space is concerned, it is clear that there is a knowledge of place that co-exists with that place, but this knowledge cannot be simply converted into descriptions. This bodily knowledge is what Merleau-Ponty calls habit. Michael Polanyi calls it the tacit knowledge, "… of which we have knowledge that we may not be able to tell" (Polanyi, 2013, p.10). So, Merleau-Ponty's notion of habit and Polanyi's concept of tacit knowledge are related; we refer to it as behaviour, that is, the embodied interaction of the commuters towards the materiality of the space based on the task they aim to fulfil within the space. The body belongs to place as much as place belongs to the body. Therefore, transit spaces exist only in the lived presence of the commuters who sustain and vivify it (cf. Casey, 2009, p. 327).

2.2 Epistemological Foundation

The aim of the collected field data is to free the design and architectural decisions from mere styling and understand the more veracious requirements of the human in interaction with the built environment. The approach here is not simply user centred but more human-material-interaction centred. Material here is everything we perceive via our sensory apparatus; like olfactory encounters, tactility of surfaces, aural quality within the space, light, humidity, temperature – primarily everything that we perceive via our senses. A study in human-material interaction documents precisely the human body in interaction with a dominant material quality of the built environment, in the given context. For example, in Figure 2 we see the commuter in interaction with the bench on a cold winter morning. He is seen misappropriating a copy of the free Metro newspaper to make his seating on the humid and cold bench more comfortable.

Figure 2 North Ealing, London.

Figure 3 Sports Complex Central, Hong Kong.

Figure 3 shows us the stairs leading to the sports park in Hong Kong. This park area is temporarily closed for cleaning. The shaded stairs leading to the sports complex is used as

seating not only by the members waiting for the park to open but also by others who need a quick break from the humid heat. Both of these examples show us how people redesign the built environment by merely using it, either alone with a prop as in Figure 2 or by physically locating themselves in a particular relation to the place as in Figure 3. Thus, we see that the data we are trying to collect exist in the interaction between the human user and the materiality of the built environment.

The information gathered in the field was aimed to serve in improving the interaction between the user and the built environment within transit spaces. Since the world is given to us in the medium of our lived bodies, we are by the very act of living exposed to places and their materiality. As John Zeisel states, "to design environments suited to what people do in them, we must understand environment behaviour." (Zeisel, 2009, p. 136). It is precisely here, in the shaping of the materiality where designers lay the foundation for a more harmonious interaction with the place. In a way, one could say that design does not simply shapes a place but the place-body relationship.

This redesigning is often a sign of a sense of identity and responsibility towards the space, as Zeisel asserts that people who use the environments continuously also redesign them (Zeisel, 2009, p. 103). Richard Sennett calls this phenomenon 'the open city' (Sennett, 2018). For Sennett the open city is an ethical space that tolerates differences and promotes equality, he writes, "but would more specifically free people from the straitjacket of the fixed and the familiar, creating a terrain in which they could experiment and expand their experience." (ibid., p.9) Healthy cities, active communities and an inclusive urban scape cannot be (completely) designed beforehand but enacted by its citizens (McGuirk, 2018). The role of the city planners, architects and designers, according to this, consists in facilitating the adaptive redesigning of the city and its transit spaces for and by the citizens.

Summarising the discussion above the requirements on the field data and the nature of information to be collected in field are as follows:

Table 1 The nature of the information to be collected in the field lays down the requirements on the field research method.

	Requirements on the field data	**Nature of the information collected in field**
1	To capture an elusive moment existing briefly between the user and the built environment.	**Contextual information:** The information we need from the field research is generated in the transitory interaction between the human user and the materiality of the built environment. This information is situational and context dependent. It needs to be interpreted in the same.
2	The information is perceived and articulated by the observer in the field, and needs to hold grounds against the usual accusations on self-collected data.	**Observer inclusion:** To be able to collect rigorous field data, the observer plays an important role. The perspective through which the observer observes the observed is an important factor that influences the quality and the nature of the field information collected.

3	An objective-subjectivity that may be used to generate a more rigorous set of field data.	**Recognises subjectivity:** The inclusion of the observer in generating data also recognises the fact that the information cannot be purely objective. But the inclusion of the observer brings in a veracity to the collected 'subjective' nature to the field data.
4	It was aimed to support design and architectural decisions that are bottom-up. The collected data was meant to understand and facilitate adaptive redesigning.	**Bottom up approach:** The field data orients itself to the user and their interaction with(in) the place. The collection of the data concentrates on the user without being overtly user centred in nature. Though, one may say the data concentrates on the interaction between the user and the place.

2.3 Analysis of existing methods

While looking for a valid method, that fulfilled the requirements on the field data and supported the nature of the information to be collected in the field, as in Table 1, we realised that the tradition of participant observation as developed in the field of anthropology from the likes of Frank Hamilton Cushing in the early 1879 (Kawulich, 2005) and Bronislaw Malinowski in 1920 (Malinowski, 1977), would only partly fulfil the research criterion. Participant observation is a qualitative method, enabling researchers to collect field data by consciously participating in the field. This is done by studying people over a longer period of time in their natural setting, by observing and participating in their activities (ibid.). The field recordings are based on observations and impinging the system that one wants to understand and document. It is an obtrusive method. Since the observed are aware of the observer, it may change the quality of the information gathered, as in the Hawthorne effect (Mccambridge, Witton and Elbourne, 2014).

As already explained, the quality of the information to be gathered is contextual and ephemerally bound to the situation. Since this information exists in the corporeal interaction of the user with(in) the place one may also call it tacit information. Tacit information is in the embodied perception of the world, via the experiencing body. This sort of knowledge, as Polanyi makes clear, is difficult to articulate very clearly (Polanyi, 2013, pp. 3-25). It is at the physiognomic level, as gestalt psychology also asserts (Koffka, 2014), the active shaping of experience happens in the pursuit of knowledge. In the context of a transit space, the researcher is aiming to collect embodied information about human-material-interaction.

Direct observation is a sub-form of participatory observation, also known as observational study. It is also a qualitative method of collecting data in which the researcher observes subjects in their usual setting without altering it (Gehl/Svarre, 2013, pp. 269-280), that is, without going in an active contact with the subject of observation. This method is largely an unobtrusive method, though it may be at times variably intrusive (Zeisel, 2009, p. 112). Direct observation is a bottom up method and was extensively used to study public life. The early documentation of this method is seen in several seminal writings about the urban landscape in the mid of the 20th century (Gehl/Svarre, 2013, pp. 269-280).

The qualities of these methods that fulfilled our field research criterion were as follows: qualitative research; prolonged stay in the field; empathy towards the observed; humility towards the field; accepted subjectivity of data collection by observation and sharing the same space-time context, as the observed. The characteristics that made the above methods not completely compatible to the research requirements were as follows: both, participant and direct observation methods, have been criticised for their structural unclarity. This brings in the usual accusation of a lack of rigour in self-reported behaviours outside a lab-setting; also, the irregularity of the collected information based on researchers gaining different understanding on the same topic has been frowned upon (ibid.). According to Zeisel, direct observation was used and developed in various forms, like observing environmental behaviour, to collect information for practical purposes like policy making or architectural planning. These methods lacked what Zeisel calls a foundational standardised procedure for observing and a theoretical framework for interpreting observations (Zeisel, 2009, p. 113).

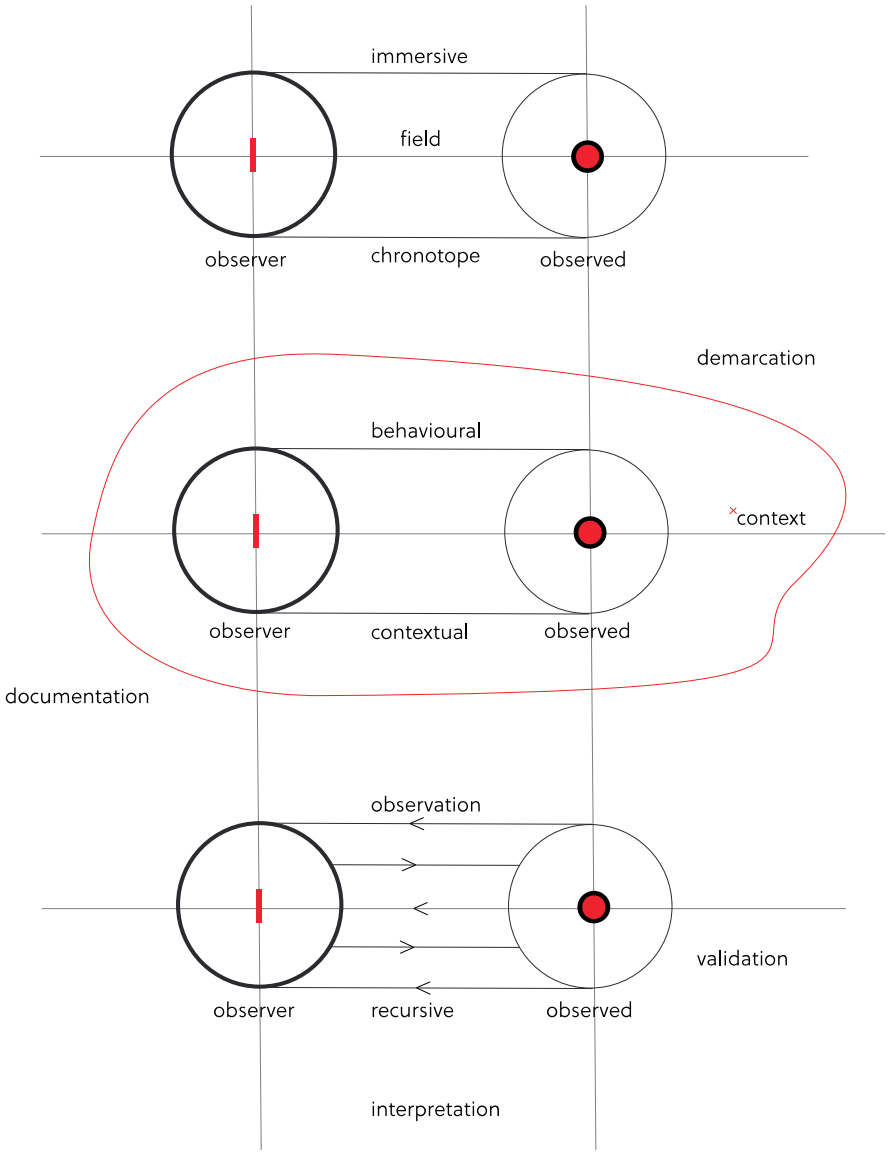

Figure 4 Showing the various components, elements and processes in the IBO method.

3. The Immersive Behavioural Observation (IBO) method

3.1 The Method

The IBO method is qualitative and subjective in its approach. It has been developed to collect data about passenger experience within transit spaces. The aim is to gain a closer insight into the research problem's wicked context. The epistemic foundations of the method lie in phenomenology, particularly in the analyses of Merleau-Ponty and Heidegger. Merleau-Ponty provides insights into bodily experience that enable tacit knowledge; at the same time, it also enables the researcher to share the placial experience with their own lived body, i.e., to immerse into the spatiotemporal situation (see section 3.2). Whereas Heidegger helps to understand the practical context in which the commuters and the researcher act. In a way, that means IBO can be considered as a form of practical phenomenology. Its goal is not just to analyse transit spaces, i.e., to gain insight in human-material-place interaction but also, eventually, to change, redesign these places based on the insights provided by IBO, so that these places become more human oriented.

The IBO method identifies, observes and works with phenomena. These phenomena constitute the field data that is collected through this method. The subjectivity in the IBO method is grounded on a shared perception of the world. Via the IBO method we work with an 'objective subjectivity', i.e., a subjectivity not seeded in fancy or muse but in the objective understanding of a joint domain of truth which accepts the diversity of individual experiences while still presupposing one shared reality (Gerhardt, 2016, pp. 131-144). IBO is used to study the behavioural and tacit patterns of users in their natural environment. It is used when other obtrusive methods like questionnaire and dialogues, involving direct participant contact is not supportive for data collection. The IBO method generates 'circumstantial evidence'.

The three stages that build the process in the immersive behavioural investigation are demarcation, documentation and decoding (see section 3.4). Of these the first two, demarcation and documentation help us in developing the first level construct of pulling together the data. Even though observation is a natural phenomenon, to be a skilful observer one needs structural clarity. This is what the first two stages, demarcation and documentation, aim to achieve. The collected information is processed in the third, decoding step to generate the second order construct of sense making and meaning generation. The last process involves validating the field findings by the method of agile dissemination. In IBO, the research is focused on the object (i.e., the observed); the observer here demarcates the field of observation (i.e., that which is to be observed). The three major components in which the practice of the IBO method is anchored are: the shared chronotope, the context and the circularity of perception between the observer and the observed. These are elaborated respectively in the next sections.

Before we delve into the more theoretical explanations of the IBO method, we present below in six steps how information about the human-material-interaction in train stations are

collected with the help of this method:

1. In the field, we tune into the space being attentive to our sensory perception in it. These are amongst others the temperature, light intensity, olfactory encounters, and to the aural qualities of the environment.
2. In a world of excessive sensory input demarcating the field before the actual observation brings in a sense of consciousness to our perception. This also contributes to a greater sensory accuracy towards the task.
3. We orient ourselves in the space so as to map it. In case of train stations, we locate the exits and entry points, note the busiest zones and seek an optimal area to position oneself for the documentation.
4. Once we have positioned ourselves, we observe the commuters around us. The observation focuses on the following aspects:
5. Appearance: This is everything that might indicate a category of study, like gender, age and physical appearance.
6. Corporeal movement: How do commuters enter and orient themselves in the space? Is the gait confident and quick? Is it seeking? Is it slow and relaxed?
7. Corporeal positioning: How and where do people position themselves when waiting? How is the distance to the other maintained? How are seatings used? Are there artefacts like train timetable, lighting, dustbins, infotainment screens, who's proximity is sought by commuters when they wait?
8. Interactions and gestures: How do commuters interact with each other and the artefacts surrounding them in the transit space?
9. The observation is oriented on the above demarcation as stated in point 2. The information collected is documented with notes, sketches or candid photographs.
10. The documentation is the only phase that happens in the field. The other two phases, demarcation and decoding, happen largely off the field.

Table 2 Representing the character, major components and the practice in the IBO method.

Nature: The essential character that defines the foundation of the method.	**Elements:** This refers to the major components defining the basic structure.	**Process:** This is the chronological listing of the practice.
Immersive	Chronotope	Demarcate
Behavioural	Contextual	Document
Observation	Circular	Decode

3.2 Nature of IBO

Immersive

The researcher in IBO is doing the observing by immersing themselves in the chronotope (see section 3.3). This immersion in the chronotope generates a sense of identification (both

consciously and unconsciously) and generates empathy with the observed.

Behavioural

Experiencing space is never a mere passive exposure but always an active appropriation of space. The "behavioural" in the IBO method refers to this appropriation of the space where the everyday person is considered to be an agent involved in the environment.

Observation

This is experiencing via observing intently the everyday tasks of the subjects in real space and time. The sight is the quickest of all our senses, however, it is the totality of our sensory apparatus that navigates and orients our perception and experience through and in space.

3.3 Elements of IBO

Chronotope

This term denotes the entanglement of time and space similar to the Minkowski space, which describes the four-dimensional space-time continuum used in theoretical physics. But at the same time, it points to the experiential entanglement of time and space as it was originally used in literary theory, introduced by Bakhtin (Bakhtin 1981, 84–258). The chronotope entails patterns of orientation and perception of those who find themselves in a place at a certain time.

Context

Built environments exist only in an interaction with the users. In IBO "context" refers to what Heidegger calls the "totality of involvements" [Bewandtnisganzheit] (Heidegger, 2001, 116). Involvement here describes the practical meaning, i.e., the role that things or material play in our actions. To think chronotope and context together means to understand how lived body experience plays an essential role in understanding the practical meaning of human-material-interaction.

Circular

Circular is used here at two levels. At the direct observational level, it implies that the observer (sharing the same chronotope with the observed) experientially comes back to oneself to understand or relate to a particular observed phenomenon in the field. The second implication is the recursive interaction with the field of knowledge. This helps the researcher identify low-frequency observations with high impact and distinguish these against high frequency observations with low impact.

Figure 5 Central Station, Bremen.

The Figure 5 shows us how metal benches remain unoccupied during cold winter days, the temperature during the shot was -11°C. We see three commuters standing near the 1st metal bench. The two women, near the second metal bench are squeezing together on the wooden plank. The pedestal with the wooden plank was a part of an incomplete construction for a ticketing machine.

3.4 Process in IBO

The three steps, demarcation, documentation, and decoding define chronologically the processes that build the IBO method.

Demarcation

Even though the method of observation is a common tool that humans use daily, observing in the field without omitting details or transferring untested feelings with the field data is an act that requires a conscious effort. This is where demarcation plays an important role. Though the act of demarcation happens in the field in which the researcher shares the same chronotope as the researched, it is determined by the main research objective that requires the field work. The process of demarcation followed by documentation generates information that constitutes the first order construct. “Construct” here doesn’t mean ‘making up’ the phenomenon which we want to analyse but to demarcate it, to accentuate it and bring it in the foreground.

The world is submerged in a plethora of activities. We are constantly using our sense of distinction at various levels to navigate us through this plenitude of information. For example, if my objective is to locate a salesperson in a supermarket, I would only look for people in the particular uniform. What we choose to observe depends upon the objectives with which we direct our consciousness (Zeisel, 2009, p. 101). This is what demarcation deals with. It is about the articulation of our objectives based on asking the right questions. Therefore, the core act of demarcation is the articulation of the task on to the field. This helps one to draw the distinction between what will be observed to what will be overlooked because of directed attention.

Figure 6 Central Station, Bremen.

Figure 6 shows commuters gathering in a particular formation within the train station because of several train delays and the freezing temperature outside. This example also shows us that the process of demarcation holds ground only when the observer shares physically the same chronotope as the observed. To realise the uneasiness of the cold or humid temperature that makes the commuters orient themselves in a particular way and maintaining the contextual awareness of the field, that is in this case, the train station and the delays.

Figure 7 Inside a metro train, Vienna.

In Figure 7 commuters remain standing during a journey despite the availability of vacant seats. The journey lasted for most of them between 30-40 minutes. The standing commuters were young, the journey was recorded at around 18:00 h. For most of these long-standing passengers it was important to support their back in two axes preferably a corner and have their hands free instead of using the hangers above.

Documentation

In the IBO method the collection of data happens essentially within the shared chronotope with the observed. A focus of the documentation lies on the particular cognitive and symbolic ordering of space and how the users orient themselves in these spaces. In the process of IBO, the observer's sharing of the chronotope with the observed is integral to the process of documentation. The distance to be maintained with the observed is based on the intended task. By documenting the interaction of the object in its natural chronotope, we accept knowledge born out of lived interactions, which are shared bodily experiences in the everyday world. IBO deals with embodied observation, where the body of the observer is used as a navigational and perceptional tool. The perception of the observer is informed by the whole of their sensory apparatus, that is, the visual in relation to the other senses.

The documentation of the embodied observation is done particularly by candid photographs, taken over a prolonged period of time (see Figures 2 and 3; in contrast to the field-sheets which include also various notes, see Figures 5, 6, and 7). Unlike visual anthropology where the use of the camera to gather visual information is essential for capturing everything

otherwise overlooked by our limiting perception (Collier/Collier, 2009, p.6) the method of IBO uses the candid photography to make a quick note of what has already been registered by the senses. Time is a crucial factor for documentation and ample time is spent to acquaint oneself with the place. A recursive engagement with the object of knowledge is essential. Apart from this, field information may be gathered as sound recordings, field notes, sketches, floor plans, maps etc. The information collected in the field are to be maintained as observational notes, with clarity of time, schedule and content; comments and emotional descriptions to the field notes are to be refrained from at this stage (Zeisel, 2009, p. 95). The candidly taken photographs and other materials are only objects for future retrospection and are not meant to be in themselves an act of contemplation. These documented materials are to be regarded as an impression of the lived experience and not as the experience itself.

Decoding

In the IBO method, the third step of decoding entails the interpretation of the data. This interpretation is the second order construct. The IBO method allows us to record behaviours within their original unadulterated context and natural time frame. Our inferences induced directly from these embodied observations in the shared chronotope is the second order construct. Second order construct also means to understand and elaborate the experiences we shared in the field carrying out the immersive observation. The IBO method documents phenomena, these are 'circumstantial evidence'– coming into existence in the human-material-interaction. This information is the first order construct and is the material we work on in the decoding process. Here we follow the inductive reasoning to come to inferences and generate the second order construct. The inductive method implies finding a certain reasoning and then observing if the same reasoning functions in other cases as well.

As mentioned earlier the method of IBO abstracts users in categories defined by their purpose, by their gender or by their age. For example, if the IBO method is used to understand the human-material-interaction in a hospital, the actors in the field of observation would be classified into patients, nurses, doctors, other staffs and visitors. In IBO the individual's history and their (current) emotional states are not necessarily considered, although IBO does consider the stimulus-response procedures of social conditioning. IBO investigations, though detailed, are made considering the general categories and not by registering situations at the individual level. This level of abstraction is important in the study of public life, as it makes the working with large number of data manageable. The generalisation also helps in preserving the privacy of the individuals in this space.

The 'circumstantial evidence' generated by the IBO method refers to the directly observed and documented phenomena in the field. Unlike direct evidence, circumstantial evidence allows for more than one explanation. It follows the inductive reasoning to come to inferences. In decoding, the inductive method implies finding a certain reasoning and then observing if the same reasoning functions in other cases as well. As mentioned earlier, the context of the recorded phenomena, the demarcation with which one embarked the field plays an important role here. This is also what allows circumstantial evidence to have more

than one explanation. Therefore, context and demarcation of the recorded phenomena also collaborate in drawing conclusions. As together they may strongly support one particular inference over other alternative explanations that may be ruled out.

The final stage of the IBO process validates the inferences developed in decoding, the second level constructs. The validation of these findings is achieved by discussing the initial analysis of the field data via the 'agile dissemination' method. An agile dissemination process could be sub-categorised as a tool under the participatory design method, where important phases of the research development are simultaneously disseminated or shared with varied user groups. The agile dissemination is carried out to share key insights of the field research. This opens the research and its developments to various stakeholders, users and expert audiences. The agile-dissemination method comprises of presentation and discussions. During an agile-dissemination session the presentation is structured according to the IBO method. It introduces the research task, the context of the work, the field and the demarcations. This is followed by the presentation of the observed phenomena and the inference categories that give us an insight to them. After the presentation the field research inferences are opened for critic and discussions. The reactions and quality of discussions vary largely depending upon the group amidst which the agile dissemination happens. In the case of the public transportation systems, when the validation happened with transportation providers and policymakers, the discussions did not challenge the field findings but went ahead to discuss the actual decision itself. The first process in the IBO method, that is, demarcation ensures self-scrutiny, the agile dissemination, which is the last process, ensures external scrutiny.

Agile dissemination also, plays an important role in validating field results within their respective cultural contexts. As explained earlier, the documented phenomena in the IBO method are to be understood in the nuances of the given context, and not removed from it. The researcher in the IBO method is an outsider and a marginal participant; the benefit of this is that the field remains true to its usual flow of things. The downside to this is that the observer might document a particular phenomenon accurately but not understand it in its larger socio-cultural context. This might lead to varying degrees of misinterpretation of the field data. This is where agile dissemination compensates the field findings. The principal lead in the agile dissemination discussions is the researcher in the field; they are obliged to report all the conflicts and assertions they receive during the sessions but they are nowhere obliged to abide by any of them. Agile dissemination is an explicit procedure that increases the likelihood that different explanations to a certain observed phenomenon in field are comparable, enabling a more grounded interpretation and evaluation of the field findings.

4. Discussions

The IBO method attempts to compensate what Zeisel and others call a foundational lack of standardised procedures for observing and interpreting by building in a theoretical framework (Zeisel, 2009, p113). This is done by bringing in a procedural clarity in the

method by identifying and defining the major components and the processes of the method: demarcation, documentation, decoding. The results then need to be validated through agile dissemination. The researcher demarcates that which is to be documented against that which may be ignored by the observation. Demarcation is based on the articulation of the intention with which the researcher defines his or her task in the field. Documentation helps us collect the information that constitutes the first level construct. Decoding involves building the second level construct from the gathered field material. The final process is that of agile dissemination of the analysed material. This assures validation of the second level construct by external scrutiny.

In articulating the conditions that make up the core foundation of the IBO method, this method does not just make tacit knowledge that implicitly underlies our action explicit, it also aims for methodological transparency, i.e., to make its steps and the result from each step explicit so researchers are enabled to reflect on the process.

Table 3 Comparing the pros in more traditional field research methods with the new IBO method.

Pros	**Direct Observation**	**Participant Observation**	**IBO Method**
Non-obtrusive	yes/maybe	no	yes
Qualitative research	yes	yes	yes
Prolonged stay in the field	yes/maybe	yes	yes
Empathy towards the observed	yes	yes	yes
Humility towards the field	yes	yes	yes
Sharing the same spatio-temporal context as the observed.	yes/maybe	yes	yes

Table 4 Comparing the cons in more traditional field research methods with the new IBO method.

Cons	**Direct Observation**	**Participant Observation**	**IBO Method**
Obtrusive	no/maybe	yes	no
Structural unclarity	yes	yes	no
Lack of rigour in self-reported behaviours outside a lab-setting	yes	yes	no/maybe
Irregularity of the collected information based on researchers gaining different understanding on the same topic	yes	yes	no/maybe
Lack of a foundational standardised procedures for observing	yes	yes	no
No theoretical framework for interpreting observations	yes	yes	no

5. Conclusions

IBO as a design research method asks the question what it means to not just cognize the world but to understand it as shaped by design, particularly our embodied experience within spaces. In accordance with Ludwig Wittgenstein, Otl Aicher explains that usage as a new truth criterion: "listening and looking become an act of philosophy, and not a thinking operation within a complete system anymore. wittgenstein is now saying to his pupils: 'don't think, look!" (Aicher, 2015, p. 88). In a way, this is what IBO tries to do: to observe the interaction, in this particular case between the human and the material within transit spaces. But in order to understand the complex relationship between the user and the built environment, to simply look at it is not enough. This is the reason why the observation in IBO has to be immersive, so as to partake in it via the medium of the lived body. IBO investigates the relationship between the lived body and its interaction with the materiality of the built environment, via sharing the same chronotope as the observed. Here, the processes of immediate experience and intuition gain a certain significance in comparison to mere abstract rationalism and science for understanding reality. The IBO method by being immersive in nature and sharing the same chronotope as the observed enables a sense of identification with it, resulting in a natural empathy towards the observed and the spatial context.

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About the Authors:

Shalini Sahoo is a designer and a PhD candidate at the Royal College of Art, London. Her work involves investigating human-material-interaction within transit spaces. Shalini's main area of interests involves cybernetics second order, design ethics and material culture.

Stefan W. Schmidt is a lecturer in philosophy at the University of Wuppertal and a lecturer in design theory and history at the University of Applied Sciences, Düsseldorf. His research interests lie in phenomenology, aesthetics and theories of space.

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Phantom Volume: A spatial explanation for domestic clutter

Heidi OVERHILL[a]*

[a] Sheridan College Institute of Technology and Advanced Learning, Canada
*Corresponding author e-mail: overhill@rogers.com
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Abstract: Philosophical assumptions influence empirical design. For example, physical shape is typically described in terms of 'positive form and 'negative space.' Here, a third type of shape is proposed, called "phantom volume," comprised of the geometrically-predictable forms delineated by movements of a product, its parts, accessories, the user's body, and the cone of vision. Phantom volumes are critical to product function, because things cannot be used if access is blocked. This observation suggests that domestic "clutter" may be defined as the physical effect created when the phantom volume of one object is obstructed by the positive form of another — proposing a mechanical origin for psychological frustrations. The concept is illustrated with 3D renderings of a domestic coffee maker, revealing unexpectedly large and irregular phantom volumes. The quantitative 3D methodology might offer future applications in planning, research, or student assignments.

Keywords: phantom volume; clutter; kitchen design; 3D visualization; hegemony of habit

1. Introduction

This paper is part of a broader investigation into the design of contemporary Western domestic kitchens, using the kitchen as a case study to examine the impact of philosophical frameworks on problem definitions in design. Here, the kitchen is examined as a physical site, in which product 'forms' include not just solid shapes, but also the volumes of space required for free movement of the product and user, described with the neologism "phantom volume." The concept is illustrated using the arbitrary example of a domestic coffee maker, for which a 3D visualization reveals unexpectedly large and irregular phantom volumes. This exploration follows a research strategy of 'narrow and deep' — studying a limited subject in order to permit a greater depth of detail.

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2. The domestic Western kitchen

Typical Western kitchens are notable for an almost-universal adoption of a regular "type-form" (Heskett, 1980, 84), consisting of a waist-high counter set against one or more walls, and fitted above and below with boxy cabinets. This form is rationalized with references to qualities like personal virtue (Beecher & Stowe, 1869), and efficiency (Frederick, 1913), and codified into the 'kitchen work triangle' (Ranney, 1949; NKBA, 1996). Both kitchen design solutions and objectives appear to have formed a "hegemony of habit" that may not well suit contemporary kitchens, which often contain more than one worker, as well as multiple new appliances (Steggel & McFadden, 2015).

Kitchen renovation is a large industry; estimated by the National Kitchen and Bath Association to be worth US$157 billion in 2017 (NKBA 2019). It is therefore not surprising to find considerable research in the area, including recent explorations of computer applications (Dourish & Bell, 2011; Smart Kitchen Summit, 2019). Ironically, the dissemination of such research may be hindered by its potential commercial value. Investigations by the National Kitchen and Bath Association appear to be available only in expensive self-published books. A five-year study of kitchen design, completed in 1998 at the Rhode Island School of Design (RISD) saw exclusive rights to its Universal Kitchen sold to the Maytag Corporation (RISD, 2011), and apparently never seen again.

Kitchen innovation may also be hindered by conceptual "habitualization" (Shklovsky, 1917/1988). Six test kitchens at the Virginia Tech Centre for Real Life Design were recently built using only standard cabinetry, precluding exploration of the form (Virginia Tech, 2019). Enduring acceptance of the standard might be an example of "path dependence" not unlike that of the QWERTY keyboard (David, 1985), further reinforced by prescriptive building regulations (Queen's Printer, 2008) and manufacturing standardization (Sonderegger, 2006).

Non-standard conceptual proposals for the kitchen are common, including a 1956 "House of the Future" by Alison and Peter Smithson (Owens, 2001), the 1969 "Kitchen Satellite" of Luigi Colani (Archer, 2019), and the 2011 Philips bio-digesting "Microbial Home" (McGuirk, 2011). However, these appear to make little impact on everyday practice. There apparently still remains a need to "make strange" or "defamiliarize" the kitchen to inspire practical results (Bell, Blythe & Sengers, 2005). This might be seen in research that addresses the kitchen using frameworks taken from fields as varied as anthropology (Cieraad, 1999), design history (Sparke, 2009), human-computer interface (Bell, Blythe & Sengers, 2005), material history (Cromley, 1996), or world food waste (Gustavsson, Cederberg & Conesson, 2011). This paper seeks to contribute to the field with a novel quantitative exploration of the kitchen as a physical thing.

3. Conventional form and space

Product design manipulates the forms of artifacts. As taught in design school, form-giving pays attention to the contours and arrangement of positive forms, and to the empty negative spaces that surround them. In the words of influential Pratt Institute design educator Rowena

Reed Kostellow (1900-1988):

> "A talented and intuitive designer may well arrive at sensitive positive volumes, but unless the important relationship of the negative volumes or concavities to the positive forms is explored, his [sic] visual solution is only half controlled" (quoted in Hannah, 2002, 112).

Negative space is not just an aesthetic issue, but is also critical to function. The importance of negative space was expressed by the legendary poet Lao Tzu (c. 6th century BC) in a passage quoted by Victor Papanek in Design for the Real World (1972, 23) — available today in multiple translations.

> "Thirty spokes share the wheel's hub;
>
> "It is the center hole that makes it useful.
>
> "Shape clay into a vessel;
>
> "It is the space within that makes it useful.
>
> "Cut doors and windows for a room;
>
> "It is the holes which make it useful.
>
> "Therefore profit comes from what is there;
>
> "Usefulness from what is not there" (Feng & English, 2011).

The importance of negative space in design is illustrated by a recent Australian project using 3D printing to create nesting boxes for endangered owls. Criteria for the boxes specify the shape and texture of the interior volume, and the exterior negative forms that must fit around selected tree trunks (Parker et al., 2020). Positive form is needed only to define the important negative spaces.

For the context of a kitchen, negative and positive space are illustrated in Figure 1, using the example of a domestic coffee maker. The hole inside the handle of the carafe is a negative space which allows the user to grasp it. The negative space inside the carafe holds coffee.

Figure 1 Positive form and negative space in a domestic coffee maker, where the negative

space inside the carafe handle permits manual grasping. 3D Illustrations are by Gerald DesRochers, 2017, © Sheridan College Institute of Technology and Advanced Learning

4. Phantom volume

4.1 Phantom volume of a sample product

The domestic coffee maker also demonstrates the existence of the third type of shape: "phantom volume." Figure 2 shows phantom volumes associated with the coffee maker. These are neither positive nor negative, but consist of the total space potentially occupied by the product as its parts are unfolded or lifted out. Any obstruction to this space will prevent use of the machine. Note that the shape of the phantom volume is geometrically precise, constrained by the size, location and motion of hard physical parts. In other words, the phantom volume is a predictable consequence of the design of the positive shapes.

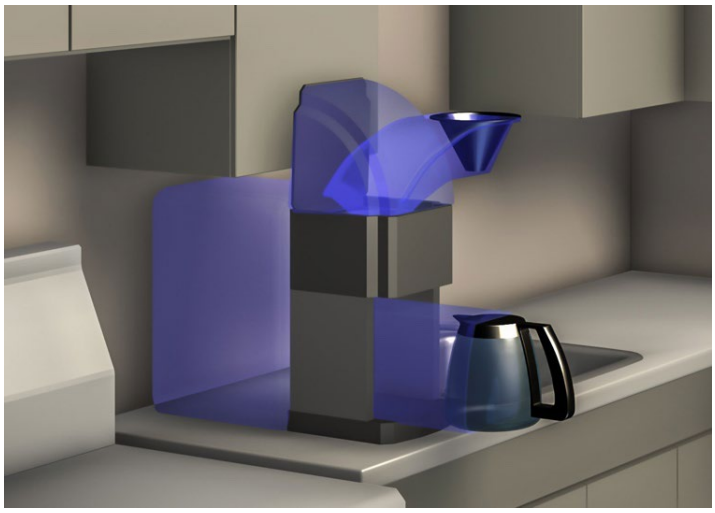

Figure 2 *Phantom volume of a domestic coffee maker, as defined by its movements in operation. The coffee maker must slide forward before the upper lid can be opened.*

As revealed by this exercise, the coffee maker's phantom volume is large and irregular. It is also unexpected, as nothing in the appearance of the product on display in a store would warn the buyer to expect this shape at home. In addition, the phantom volume may not have been fully anticipated in the design process. For example, the flip-up lid over the water reservoir cannot be opened while the machine is tucked neatly under the upper cabinets. To open the lid, the machine must be pulled forward, whereupon the open lid blocks access to the cabinet doors. If fresh coffee grounds are stored there, as might seem convenient, then the doors and lid must be opened and shut alternately, several times, before a transfer of grounds can be made into the machine, and the package returned to storage.

The need to pull the machine away from its resting position means that it occupies a double-sized footprint on the counter. The counter near the sink is a busy location, where

dirty coffee mugs might be gathered to await washing. If these must be pushed aside to accommodate the moving coffee maker, the user is invited to feel bad about his or her poor housekeeping — an emotional pang that would not arise if the appliance had a smaller phantom volume. It is the appliance, not housekeeping, that defines the mugs as mess.

4.2 Phantom body volume

Phantom volume is also required to accommodate the moving human body. In the 1940s, photographic research measured volumetric body "space shapes" defined by activities like getting dressed, to be used in architectural planning (Callaghan & Palmer, 1944). Here, phantom body volumes are defined in terms of their relationship with product use, as shown in Figure 3. Any obstruction of the user's body space, such as with a bag of groceries set on the floor, will render the machine inoperable until the obstruction is moved.

Blockage can also occur if a second user tries to perform a different task in the same location, as the second user's body volume intersects with that of the first user. In an ideal kitchen, body volumes will not intersect. Such intersection is irritating as well as disruptive. The complaint "you're in my way" carries emotional content (Hall, 1966, 53). Again, the essential problem is not generated by any particular actions of the users, but arises in a straightforward manner out of physical qualities of the design.

Figure 3 *Phantom volume required for the user's body in relationship to the coffee maker. Note also counter space occupied by the can of fresh coffee, coffee filters, and compost bin.*

Body phantom volumes are not as predictable as that of the appliance, because they vary with small motions like arm position (Overhill, 2014). Unlike the geometrically constrained shape of the machine's phantom volume, phantom body volume is a zone of probability; an area in which the body might be located. This space is also elastic, in the sense that the human body can, if needed, be nudged aside, or even squished.

4.3 Phantom volume of the cone of vision

Another phantom volume arising out of the user's body includes the cone of vision between the user's eyes and the device. This must be kept open for the appliance to be used. In

this example, the coffee maker's water-level indicator and power switches are located on opposite sides, so that the user must sway back and forth to see them alternately, thereby modestly increasing the phantom body volume.

Obstruction of the cone of vision is more significant in other kitchen locations, like storage shelving or the refrigerator, where small items may be concealed behind larger things. As soon as something is hidden from view, for practical purposes it no longer exists. This describes small jars after they are tucked into deep refrigerator shelves, where only an unmarked lid can be seen, not the label. A previous inventory done of the refrigerator in this same kitchen revealed four open jars of the same brand of Dijon mustard. Presumably, three of these had been acquired under a misapprehension that someone else had used up the previous jar, explaining why a visual search had failed to locate it (Overhill, 2000).

Poor visual access may play a role in the legendary gender inequality of kitchen work. When statistics show that men fail to share housework with female housemates, the cause is generally assumed to be male selfishness (Wilson, K., 2006). However, spatial analysis might offer an alternative explanation. The closed type-form of kitchen cabinetry, originating in the 1920s, conceals its contents behind smoothly 'streamlined' cabinet doors (Hanks & Hoy, 2005). This approach does not significantly disadvantage a single user. The archetypical housewife can memorize the location of hidden items, making them accessible to 'recall memory.' But when a second worker shares the space, he or she may unexpectedly relocate utensils or supplies, leaving the first user uncertain of where — or even whether — to initiate a search for something that might have been lost or used up, like the mustard. When a second worker shares kitchen tasks, both people rely on 'recognition memory' to visually identify needed items. To be usable, things must be visible.

Thus, in a sharing scenario set in the context of closed cabinetry, it might actually be more efficient for one user to bar others from interfering. Theoretically, people who wash the dishes reduce work for others, but an ensuing search for misplaced things may be more time-consuming than doing the job yourself, as well as frustrating.

4.4 Phantom volume of retrievability

Visual access is related to physical access. The reach and gestures of the arm and hand parallel the muscle motions of the eye, and its field of vision (Wilson, F.R., 1998). Just as visibility relies on an unobstructed cone of vision, smooth handling relies on an unobstructed cone of reach. Reach is more demanding than vision, because things may be visible, yet hard to access, like a teapot on a high shelf, or a magazine underneath a vase of flowers. The goal of "retrievability" has been defined by Adam Savage of the television program Mythbusters (2003-2016), who described it in terms of his toolbox.

> "The finished boxes housed everything I needed, but I repeatedly rebuilt the insides until finally no tool had to be moved out of the way to get to another. That's first-order retrievability" (Savage, 2016).

Such "first-order retrievability" is evident in bookcases, where centuries of iterative co-

evolution between the shapes of books and their shelves has optimized both visibility and handling (Petroski, 1999).

Figure 4 *Book shelving in the Museum of Ferrante Imperato, Naples, 1599.Image from Ferrante Imperato (1599). Dell'historia natural di Ferrante Imperato, Napolitano, Libri XXVI. Public domain due to age.*

Figure 4 illustrates a Renaissance "cabinet of curiosities," where bookshelf evolution was not yet complete, and stored books were still piled flat in stacks. While visually accessible, books on the bottom of a stack would require awkward handling to retrieve; a problem later solved by filing the books vertically. If contemporary kitchen shelves lack an equally smooth relationship with their contents, it may be because kitchen goods have co-evolved to suit retail displays, rather than with their ultimate location in the home (Hine, 1995).

Imperato's cabinet of curiosities also illustrates the point that many household goods, even in the kitchen, are 'functional' not in the sense of performing a physical task, but in terms of display. Heritage china and expensive stand mixers convey symbolic values, for which purpose they must be seen. As in today's libraries and museums, Imperato's cabinet has solved this problem by displaying items in a single layer, making everything always visually accessible. This single-layer solution is not seen in contemporary kitchens.

4.5 Phantom volume for accessories

The example of the coffee maker shows that phantom volume is needed also for accessories. The background of Figure 3 shows counter space occupied by the coffee can and filters. These accessories arrive in the house at the same time as the coffee maker, and are necessary for its function, but its design makes no accommodation for them.

For appliances like washing machines, necessary accessories include operating manuals and warranties, which again seem not to be considered in design planning. Figure 5 shows

ad hoc storage for the operating manual of a high-end domestic clothes dryer. The manual gives instructions for how to open and clean the lint filters; a complicated process for one of them in particular that is difficult to memorize since it needs to be done perhaps only once every year or so, by any one of three regular users. Storage of the manuals could easily be integrated into the core machine, in the same way that photocopiers offer laminated instruction cards in a small pocket. (Electronic displays of critical instructions can also be provided, but are less effective because they vanish when the power fails.) Physical integration of the manuals into the core machine would simplify its phantom volume.

Figure 5 *Left: ad hoc storage of operating manuals*
Right: mysterious access hatch to filter compartment. Photos by author

4.6 Phantom volume of user travel

Kitchen phantom volumes also, of course, include space needed for movement of the user around the room. See Figure 6 for an illustration of coffee prepping, which requires emptying used coffee grounds into the compost container, rinsing the filter in the sink, and filling the machine with fresh coffee grounds and water. Overhead phantom volume is required for an upper cabinet door when it is opened to fetch a clean mug to measure water. Other users cannot access the sink or cabinet during this operation.

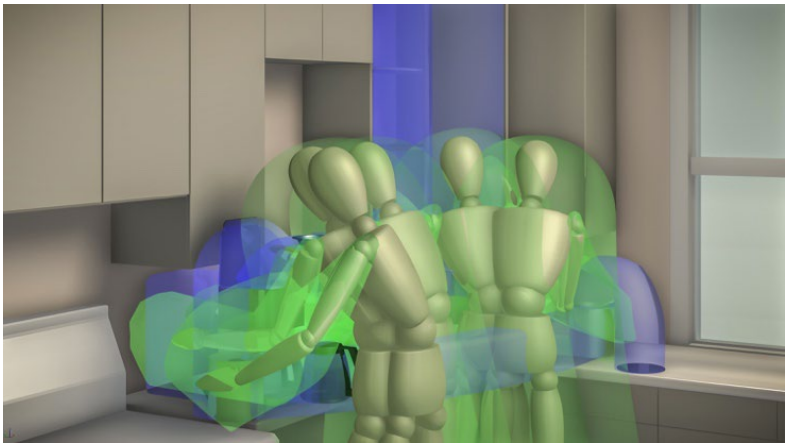

Figure 6 *Phantom volume of cleaning and loading the coffee machine, including retrieval of a clean mug from the cabinet.*

Once the coffee is ready, further phantom volume is required to pour it. See Figure 7 for a volumetric summary of pouring coffee and adding milk from a carton stored in the refrigerator. Note the over-swing of the thick refrigerator door, which can become problematic if a guest is standing nearby.

The large phantom volume required for milk pouring obviously increases the chance of collision with other kitchen users. Illustrations of kitchen work that indicate movement of the user with a dotted line, as in classic diagrams of the kitchen work triangle (Kohler, 2018), do a disservice to design planning, because they conceal the extent of body volumes. They describe only the vector of movement, not its spatial form.

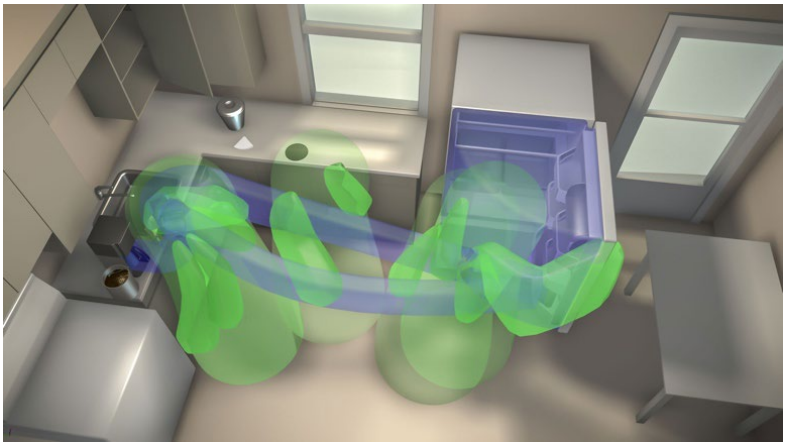

Figure 7 *Phantom volume of pouring coffee and adding milk.*

4.7 Tacit recognition of phantom volume

Tacit acceptance of the importance of phantom volume may be seen in some contemporary designs. For example, refrigerators with freezers in a bottom drawer minimize phantom volume because the forward movement of a drawer is more intuitively predictable than

the over-swing of the thick door. In addition, because the open freezer drawer is wide and shallow, it provides better visual access to its contents than does deep shelving inside the boxy refrigerator form.

Newer four-wheeled suitcases also improve phantom volume when compared to two-wheeled ones. Because they can roll upright, they minimizing the floor area ocupied when compared to a tipped-over triangle. Such reduced phantom volumes makes a considerable difference to the density of passengers queued in train-station ticket lines or airplane aisles.

Phantom volumes are also tacitly recognized in elder care, where accidental falls are “the leading cause of injury deaths” (Stevens, 2002/2003, 7). Causes of falls include “clutter, storage problems, and tripping hazards such as furniture or throw rugs,” exacerbated by the physical ailments of aging. Heuristic or rule-of-thumb remedies include tidying to remove obstacles, and physical exercise to increase strength and stability (Pynoos et al., 2004, 57). Here, the theory of phantom volume might offer more precise insight, by quantifying the influence of shuffling on tripping. Shuffling, which is to say not fully lifting the feet, lowers the phantom volume of walking closer to the floor, where it begins to intersect with formerly-insignificant small physical obstacles.

4.8 Emergence

Phantom volume is an emergent characteristic. It resides in neither the product nor the user alone, but rather in the relationship between them.

Problem-solving under the tenets of Modernism urged that problems be studied in pieces; carving “where the natural joints are, and not trying to break any part” (Plato, c. 380 BC). This approach has been very productive in understanding the parts that compose wholes, such as the chemistry that underlies biology. It is less useful for understanding the emergent characteristics of assembled parts. In phantom volume, it is not the static parts that are of interest, but rather the relationships or ‘joints’ between them and users. Intersections between things and users is not revealed by a study of either in isolation.

In this understanding, fault can be found in design’s tendency to focus on subsets of a subject rather than the whole – such as by studying the power consumption of a washing machine in isolation from the messy gestalt of laundry (Strengers, 2014, 28).

4.9 Missing phantom volumes

The concept of phantom volume might also describe situations where a physical object ought to be present and isn’t. For example, a phantom volume could be established to define as the shape of “potential grabbing” that would be reachable by an unsteady elderly person. That volume would then form part of the performance specification for a physical solution for the unsteadiness, like a handrail or grab-bar.

5. Clutter

5.1 Existing definitions

"Clutter" is defined by the Oxford English Dictionary as a "collection of things lying about in an untidy state" (2019). Similar definitions can be found in psychological studies of home life, where one source describes clutter as "an overabundance of possessions that collectively create chaotic and disorderly living spaces" (Roster, Ferrari & Jurkat, 2016, 32). Thus, while the clutter itself is a physical phenomenon, its definition often seems to focus on personal failings of the clutterer, who first accumulates a needless abundance, and then fails to impose order on it. The resulting chaotic environment generates stress, driving a cascade of other dysfunctional behaviours (Vartanian, Kernan & Wansink, 2016).

Along with implicit criticism of the clutterer, definitions of clutter often imply remedies. One examination of possessions in British homes defined clutter as "the underside of storage" because storage is the "veritable panacea" to remedy the anxiety and shame induced by a disordered house (Cwerner & Metcalfe, 2003, 229 & 233).

A more-positive perspective can be found in the "joy" promised by popular writer Marie Kondo in her prescriptions for household tidying (2014). In other contexts, clutter can even be seen as positive, in the sense that a home cluttered with heritage knickknacks and linen may commemorate family lineage (Makovicky, 2007, 291). Clutter or mess can also be a valid sorting strategy for items that hold "an ambiguous status in the home," like the contents of the junk drawer (Swan, Taylor & Harper, 2008). It might even be an invitation for creativity, in the bricolage of a garden shed (Dourish & Bell, 2011, 174).

Moving away from qualitative judgement, quantitative measurements of clutter can be found in discussions of clinical hoarding disorder (Mayo Clinic, 2019). Numerical tools like the ICD Clutter Hoarding Scale® (ICD, 2018), or the Clutter Image Rating Scale (YSL, 2019), measure levels of physical mess as an aid to medical or psychological diagnosis.

Measurement of clutter is also found in the field of graphic interface design, where an accumulation of "excess items" is known to cause "a degradation of performance at some task." Rather than blaming users for their confusion, graphic designers understand the problem as preventable, and to that end measure characteristics like set size or visual complexity (Rosenholz, Li, & Nagano, 2005). However, if graphic approaches offer insightful observations about clutter, these seem to be only metaphorically applicable to three-dimensional domestic environments, probably because, unlike graphic representations, artifacts usually cannot be reduced in size or detail (Buckland, 1991, 358).

5.2 Clutter as a conflict of physical and phantom volumes

Here, a new quantitative definition aimed at three-dimensional environments proposes that clutter is the physical effect created when the phantom space of one object is obstructed by positive form of another. In technical terms, the blocked object might be described as the "patient" of a active physical "agent" doing the blocking (Schlosser, 2019). When

access is blocked, a planned task must be preceded by preliminary work to move aside, put away, get out, or otherwise relocate items in order to liberate the needed phantom volume. This straightforward definition describes a physical effect based on geometric spatial relationships, leaving aside symbolic and social issues to be examined with other tools.

While the problem of domestic clutter is not big, it is real. Many contemporary Western households are plagued by mounting accumulations of possessions (Arnold et al., 2012). At the same time, many homes and apartments are shrinking in size. More careful consideration of phantom volumes might ameliorate at least some spatial woes.

The 3D methodology used here to identify the shape of the phantom volumes is time-consuming. However, it might find future application in spatial planning, in research, or to facilitate increased precision in ergonomic analysis or scenario building. It might also suggest student assignments intended to heighten awareness of spatial interactions. Users of this approach might ultimately assemble a library of gestural 3D phantom volumes, to complement existing catalogues of physical forms.

6. Conclusion

The vocabulary term “phantom volume” focuses critical attention onto non-tangible volumetric forms established by the motions of a product in use. Phantom volumes are generated by movements of the product and its parts, by the space needed for accessories, and by the spaces occupied by the user’s moving body and its cone of vision. Cone of vision is particularly important in the kitchen, where storage may conceal items from view, particularly when multiple workers organize the contents in different ways.

The definition of phantom volume identifies an apparently-overlooked aspect of product form. It shifts attention away from static physicality onto the temporary spatial volumes delineated by products and users in movement. While phantom volumes are invisible when not in action, they are essential to proper product function. Any physical obstruction to them prevents proper use of a product, and generates an impact here defined as “clutter.”

A sample analysis of one kitchen appliance suggests that products may carry unexpectedly large and obstructive phantom volumes, which might be improved by better advance planning. The spatial definition avoids moralistic attribution of clutter to user laziness or disorganization, and instead points to design oversight in failing to optimize the spatial geometries of use. The 3D visualization technique used in this study might find future application in planning, research, or student assignments

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About the Author:

Heidi Overhill is a professor at the Sheridan College Institute of Technology and Advanced Learning, and a PhD candidate in the iSchool of the University of Toronto, where she is examining the domestic Western kitchen as a site of 'information.'

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Design Guidance for Location-based Play: a review of research frameworks

Lorna MACDONALD[a]*, Ben MATTHEWS[a], Stephen VILLER[a]

[a] The University of Queensland, Australia
*Corresponding author e-mail: lorna@itee.uq.edu.au
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Abstract: How to best make use of design research contributions in a domain to distil the guidance they offer for design students? We outline a typology of design guidance for location-based interactive experiences, compiled from a review of existing design tools, research frameworks, and empirical studies that cited an intention to support the understanding and design of location-based play. Motivated by our reflections on teaching courses that focus on non-traditional, novel interaction methods, we sought to extract value from design tools knowing how useful they can be to students working in unfamiliar genres. Design tools fell across two broad intents: facilitating generation and supporting understanding. Guidance within these is further characterised as establishing benchmarks, generating and developing ideas, alternative considerations, design documentation, structural elements and qualities of experience. Less visible was guidance for the process of design, for translating design into development, and for how designers might respond to the advice.

Keywords: design guidance; location-based; playful interactive experience; design tools

1. Introduction

The last twenty years have seen a surge of research on the design of interactive mobile experiences. The research contributions of this work have taken a range of forms—theoretical or conceptual frameworks, methods, design tools, guidelines. Many (but not all) are based on empirical studies of the deployment and evaluation of systems in laboratories, or in the field. The purpose of our paper is to review a subset of this work with a specific focus on the *design guidance* these research contributions provide to those developing playful interactive experiences. We have several motivations for conducting this review.

In the first place, frameworks are a popular but sometimes nebulous and variegated form of research contribution. The kinds of outcomes that can be labelled “frameworks” can include conceptual distinctions, programmatic agendas, tables, and hierarchical categories. They can also include design tools, flowchart-like maps and general principles. For this

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reason, it can often be difficult to distil from a framework useful information, guidance and/or advice for future design projects. It is also the case, as our review below will evidence, that research contributions (of which frameworks are a popular type) can neglect or obscure practical guidance in favour of other important theoretical, conceptual or methodological reflections, which may appear more likely to have general application beyond the particular cases discussed, and greater academic heft. But more practically, in teaching interaction design, frameworks and tools can be a useful way of condensing a large amount of theory, experience and understanding. As such, a targeted review of these frameworks to organise what guidance they provide design would provide a valuable resource to educators, and would likely be of value to practitioners as well.

In the past twenty years, the landscape of location-based infrastructure and mobile computing has dramatically changed. While initial research in this space was conducted often as university or lab-based "toy" projects, with limited deployments, it is now possible to quickly generate and deploy apps on public release. This changes the nature of the work that frameworks need to do, as they are not just about the conception and deployment of systems, but also must be adaptive to the data and use that widescale deployments can generate in very short periods.

As such, this paper reviews prior work including frameworks, conceptual schema, design tools, etc. that have been proposed for the design of locative, playful interactive experiences. Our review sought to understand the breadth and styles of design support being generated through this research. The papers surveyed below have been selected based on the following criteria: a focus on design rather than only evaluation; a focus on interactive location-based experiences; and a focus on playfulness (or at least open-endedness). With respect to design *guidance*, we have analysed the content of the frameworks found in the literature in so far as they can be turned towards offering practical advice or application to new projects in the domain of location-based play. It is this focus that distinguishes our review. Naturally, this is not the first review of work in this general design space. We are preceded by, for instance, Rashid et al.'s (2006) early review of location-based games, which provides overviews of the architectures, infrastructures and open challenges for the early generations (2000-2005) of mobile locative games, such as *Botfighters* and *Mogi*. A key contribution of their review was to anticipate some of the possibilities for location-based games afforded by then-emerging RFID and Bluetooth technologies. In a different vein, Avouris and Yiannoutsou (2012) provided an educational review of location-based games, focusing on the new opportunities they provided for mobile and context-driven learning. To this end, they make a number of observations regarding how the interplay between physical and virtual spaces, strength of the game narrative, the games' objectives and durations of play all have important consequences for what players can learn within the environment. These reviews have mapped a number of the essential technical, ludic and educational possibilities of this sub-genre. Our review complements these in two respects. Firstly, its focal aim is distinct, distilling types of design guidance for design students and others who are looking to create novel location-based experiences through the systems they design. The content of our

review differentiates it as well, however. These earlier reviews were constructed based on an analysis of the specifics of the games/systems themselves. Our review, in contrast, has focused on the research contributions advanced in the papers presenting the systems. These contributions include conceptual frameworks, principles, methods, tools etc. that have been proposed through the design and evaluation of location-based games.

1.1 Challenges

We encountered several practical challenges in conducting the review that are particularly instructive of several aspects of research in the design of interactive systems. Much of this relates to the fluidity with which certain terms can be (and are) used. This is not limited to search terms that define the domain (e.g. playful experiences, mobile games etc.), but also to the terminology used to define the outcomes of research (e.g. tools, methods, frameworks, approaches etc.). This breadth in foci and outcome is exacerbated by the variety of meanings that are often attached to "design" which can refer to form, system, function, configuration, process, method or approach (see, for example, Pobiner & Mathew, 2007) with different connotations and emphases among those, particularly concerning the kind of design guidance that these contributions offer. We mention this not to belabour the difficulty of the task, but to begin on a note of humility—we have certainly missed incorporating some highly relevant work from this review owing to mismatches in the terms we were using to search. While tasks such as this would certainly be made much easier through attempts to standardise terminology, we fear that likely would hamper as many research trajectories as those it would make easier[1].

The impetus for the review came through reflecting on our collective experiences teaching courses that focus on novel interactions with technology, where students are tasked with expanding their understanding of what interaction entails and how we can engage with technology beyond traditional paradigms. Supporting their design activities through these courses inevitably involves discussion and consternation about firstly defining, and then designing, non-traditional types of interactive experiences. With the widespread uptake of mobile location-based games such as Pokémon GO and Ingress, an increased interest in creating these styles of experiences has arisen.

In light of the challenges faced in the domain terminology, the interactive experiences we surveyed generally shared the following characteristics, regardless of the term used to define them:

- The significance of physical space: movement of participants through space, consideration for the characteristics of space, interactions contextualised to space, augmentation of physical space and embedding of characteristics of space into the

1 Because of the fluidity of the terms in this space, much of what is gained by using one term rather than another is not in what it uniquely denotes, but in the connotations of the language used. This is particularly valuable in design when it is often more important to open up possibility spaces than to nail down concrete distinctions

play narrative.
- An essential interactivity: between participants, across physical and digital worlds, with and within the location.
- A playful quality: experiences (including games) designed for play and entertainment.

These experiences are interchangeably and with subtle differentiations described using the higher-level terms *playful*, *experience* and *game*; with further qualification as:

- Interactive experiences (Benford & Giannachi, 2008; Mitchell & Olsson, 2018; Wouters et al., 2016)
- Playful experiences (Arrasvuori et al., 2011; Lucero & Arrasvuori, 2013, 2010)
- Mixed reality experiences and games (Hinske et al., 2007; Wetzel et al., 2017)
- Pervasive games and experiences (Arango-López et al., 2019, 2017; Benford et al., 2005; Guo et al., 2010; Hinske et al., 2007; Jegers, 2007, 2009; Magerkurth et al., 2005; Montola, 2005; Nieuwdorp, 2007; Walther, 2005, 2011; Walz & Ballagas, 2007)
- Urban games and experiences (Mitchell & Olsson, 2018; Wouters et al., 2016)
- Location-based/location-aware games and experiences (Broll & Benford, 2005; Maia et al., 2017; Neustaedter et al., 2013; Walz & Ballagas, 2007)
- Ubiquitous games (Chalmers et al., 2005; McGonigal, 2006)
- Alternate Reality Experiences (Gutierrez et al., 2011; Hansen et al., 2013; Kourouthanassis et al., 2015)
- Shared interactive narratives (Benford & Giannachi, 2008)
- Augmented reality experiences (Gutierrez et al., 2011; Kourouthanassis et al., 2015)

Walther collects a number of these under the broader genre of pervasive games: incorporating mobile games, location-based games, ubiquitous games, virtual reality games & augmented reality games where each shares the key characteristics of "(1) the explicitness of computational tasks; and (2) the overall importance of physical space" (2005, p. 4). On the other hand, others bring pervasive games and experiences under the umbrella of mixed reality experiences (Hinske et al., 2007; Wetzel et al., 2017). Various attempts to examine and align the discourse around pervasive games (Arango-López et al., 2017; Hinske et al., 2007; Nieuwdorp, 2007) bring some clarity to what it means for a game to be pervasive. However, these discussions have been focused on the realm of pervasive games & pervasive computing, excluding other defining terms considered in our review. Location-based and location-aware games and experiences can be found as a subset of pervasive games but also as a genre in their own right.

In defining the boundaries of this review, oft-cited domain and design related works were examined and although relevant to understanding the broader discipline, were ultimately excluded. For example, Benford et al (2005) provide an account of their experiences in bridging the digital and physical worlds through pervasive game-play and while identifying

the challenges faced they stop short of formulating guidance for design. Kourouthanassis and colleagues (2015) offer a set of interaction design principles for mobile augmented reality applications, however, the focus is on interactions with the mobile application rather than the nature of the experience being designed. While relevant to later stages of the development process, the principles do not offer guidance for the design of the experience or considerations to be made. Technical frameworks, for example, CREANDO (Arango-López et al., 2019), LAGARTO (Maia et al., 2017), fAR-PLAY (Gutierrez et al., 2011) and others, offer software platforms for the implementation of interactions in an experience and are often created to realise particular styles of experience. The platform fAR-PLAY (Gutierrez et al., 2011) for example, supports the implementation of augmented reality experiences designed according to a treasure-hunt metaphor.

More broadly, the space and place work of Harrison and Dourish (Dourish, 2006; Harrison & Dourish, 1996) and Messeter's definition of *place-specific computing* (2009) offer conceptual framing and provide relevant distinctions for understanding the role of and implications for location in interactive experiences. McGonigal (2006), Hinske et al (2007) and Magerkurth et al (2005) each offer discussions and classifications for the various experiences feature the characteristics focused on in this review. While providing depth and distinctions regarding the particularities of genre, play and game, their intent is directed more to academic discourse than design activity.

2. The Review

This review was particularly concerned with:

- Understanding the scope of design guidance available
- How design tools are presented to the broader community
- Where possible how it was developed
- Finally, how these tools and frameworks can be translated into design guidance

Here we will describe each of the design tools reviewed including its stated intent and its form of delivery. Except for the PLEX and MRE cards (Lucero & Arrasvuori, 2010; Wetzel et al., 2017) both available online with supporting websites, the design guidance reviewed was only available through research-focused publications.

Walther (2005) provides a **conceptual framework** for the analysis of pervasive games. The stated intent is to assist in the design and understanding of pervasive games, however the focus of the paper is clearly on defining the ontology of pervasive games as a distinct (media) domain. It does this by introducing fine distinctions regarding the temporal and spatial dimensions of pervasive games, and by mapping out a conceptual space of possibilities through a review of existing games. The framework consists of four axes: distribution (of computational services), mobility, persistence (always available) & transmediality (games transcend a single medium and cast players as creators not just consumers of the game scape). Though described as mutually orthogonal dimensions, Walter represents these

four axes in a two-dimensional Cartesian plane. Within this possibility space, games operationalise three core units, building on Juul's (2003) work to add pervasive-specific concerns: game rules, game entities and game mechanics. The four axes act as dimensions for the conceptual breadth of pervasive games, while the core units provide mechanisms to describe a pervasive game instance.

In a later work, Walther (2011) expands upon the implications of game-play and game-spaces in pervasive games. Providing a discussion of the distinction between game-mode and play-mode, Walther aims for a definition of pervasive ludology that expands on traditional ludological understandings of game worlds and the interplay between "gaming (to progress) and playing (to be present)" (Walther, 2011, p. 141). Pervasive game spaces are explored further in regard to perception, layering and access under three distinct and interrelated definitions. *Tangibility space* dealing with the material interactions in the game-world, *distributed information space* the virtual realm of the game-world as mapped to the material and *accessibility space* the way in which players move between the tangible and virtual realms. To support designers and researchers negotiating the realm of pervasive games and its particular style of gameplay, four **design heuristics** are proposed. *Exploration* proposes spaces that allow for open exploration while supporting structured player progression through the game. The *mapping* of the multiple game spaces from the varying perspectives of game-play, game-rules, game-world. *Persistence* asks designers to consider providing players with physical and narrative escape from the "always 'on'" (Walther, 2011, p. 145) nature of the game-world. *Ludic and semantic structures* ask that narrative be designed not only in terms of game mission but also as a changeable construct that responds to and reflects how the game is played. These heuristics offer support for the varying and variable spaces a pervasive game constructs and the player inhabits over time.

Montola offers three key "**expansions on the magic circle**" (2005) as a frame for understanding how games might be pervasive. Traditional games, digital and non-digital, are played with negotiated understandings of who is playing, the time and location at which the game is played; demarcations of what counts as an action "inside the game" versus what is not. This social contract ("the magic circle") is established for the duration of the game. Montola's analysis shows how pervasive games expand, violate or renegotiate these boundaries: spatially, temporally and socially. The location of the game may shift during the game; the temporal bounds of the game become less clear as it interleaves with everyday life or as start and endpoints become less defined; who counts as a "player" can become blurred as bystanders become participants and strangers form alliances. This conceptual framework provides criteria by which to understand and envisage pervasive games, and how the concept of "game" is evolving to encompass the novel opportunities and experiences enabled by pervasive gaming.

More pragmatically, the **PLEX suite** (Arrasvuori et al., 2011; Lucero & Arrasvuori, 2013) comprises a framework of 22 ludic categories (e.g. thrill, discovery, fantasy, humour) and a card deck with corresponding activities. The explicit intention of the suite is to support ideation and inspiration for the design of playful experiences. The PLEX card deck offers

a design tool derived from the framework to assist in the idea generation process. Each framework category is represented on a single card, with the name of the category, a representative image and a short explanatory phrase, e.g. “CAPTIVATION: forgetting one’s surroundings”. The authors provide two game-like structured activities for employing the cards, one for the rapid generation of new ideas and the other for developing richer ideas through scenarios. Both approaches situate usage of the cards in the ideation phase of the design process. In evaluation, the PLEX deck plus activities received mixed reviews, with some designers finding the structure and stimulus generated quick and concrete ideas, while others found it overly constraining, inhibiting their creativity. With respect to this review, the PLEX suite is oriented entirely towards playfulness; it does not explicitly address location-based content.

In a similar vein but with location featuring more explicitly, the **Mixed Reality Experience (MRE) cards** (Wetzel et al., 2017) focus on generating and developing ideas for mixed reality experiences. There are three types of cards: opportunities, challenges and questions; each of which offer prompts related to specific mixed reality considerations, e.g. physical, location, gameplay, players, time, management, technology, audio and sensors. Two techniques are provided for using the cards to generate ideas, *limited choice* and *random choice* where designers combine *opportunity* cards from the MRE set with *theme* cards to create unique combinations for game ideas. Not included in the card set are the *theme* cards required for these techniques; the design team is tasked to source for an additional inspiration with the recommendation to select cards with visuals that allowed for creative interpretation. To further develop an idea, *opportunity* cards are used to expand the idea, then *question* cards to solidify the idea and finally *challenge* cards to test for flaws in the idea. At the end of this process, the idea is documented, along with the cards used, to capture the outcome of the idea development.

The **PLEX** (Lucero & Arrasvuori, 2010) and **MRE cards** (Wetzel et al., 2017) are both design tools that are the result of an iterative design process, with content and representation refined through evaluation sessions with designers of varying experiences and backgrounds. The cards and techniques for use are presented as a progressively refined outcome of a series of deployments.

Benford & Giannachi (2008) introduce “**temporal trajectories**” as a mechanism for understanding and managing individual and shared story-lines in long-running, multi-player narrative-based interactive experiences. Temporal trajectories offer considerations for how to commence, resume and end individual stories as participants enter and leave the narrative play; and how to interweave and reconcile individual actions in the broader shared narrative. This concept is further elaborated through a conceptual framework (S Benford et al., 2009) sensitising designers to the hybrid nature of space, time, individual roles and interfaces in these experiences and the ways in which users traverse and transition across the seams in these aspects.

The concept of “**seamful design**” (Broll & Benford, 2005; Chalmers et al., 2005) offers

considerations for how the technological limitations affecting an experience might be exploited and designed *for* rather than mitigated against. The approach is described through case studies of location-based mobile games designed to allow players to exploit and appropriate limitations such as poor network connectivity as gameplay strategies. This work provides an alternative approach to infrastructure and environmental constraints that exploits the "glitches" to enhance the participant experience rather than disguising them.

Mitchell & Olsson (2018) offer three "**inspiration patterns**" for encouraging social play between strangers in the design of urban location-based games and experiences. Further patterns are in production for connecting people in urban interactive spaces that consider different challenges. Many playful interactive experiences involve collaborative or collective interactions between multiple participants who may or may not be known to one another. To overcome the awkwardness of engaging with strangers, these patterns offer stimuli for exploring potential interactions. This particular set of patterns explore rhythm as a central theme, *sharing vibrations* encourages designers to consider how the actions of one might be experienced by another; *actions that need another* promotes interactions that require collective or coordinated effort; *crosswire outputs* suggest switching connections between participant inputs and outputs. Each of these patterns promotes an awareness of the actions of others, to create connections through shared, playful experiences.

A player-centric process is advocated by Walz & Ballagas (2007) to influence player behaviour in a pervasive game. Presented through the lens of the REXplorer game, this article proposes a set of "**pervasive persuasive tactics (PPT)**" as useful for design. The player-centric process is not described here, however, the importance of understanding the player is emphasised prior to introducing the design tactics. *Formal tactics* highlight the spatial and locational qualities of the game board, traversal and navigation of the game board, interaction styles and devices, reward structures and replayability. *Dramaturgical tactics* consider the game narrative and experience in regard to character design, interaction forms, emotive and spatial connection to narrative. Walz & Ballagas illustrate each tactic with examples from REXplorer providing insight into use more generally in the design of pervasive games. Focused on developing the game experience concept, the tactics ground the design work in the creation of meaningful connections between narrative, location and player.

Interactive experiences that are embedded into the urban environment will often involve situated interactions as part of the play. Usually of a public nature, these situated interactions can suffer from a lack of participant engagement by failing to capture the interest of passers-by sufficiently. Wouters et al (2016) offer a model for understanding how to leverage and maximise participant interaction with public interactive systems through the **honeypot effect**. The model presents the various roles of participation from non-engaged passers-by, to interested audience members, to committed actor participants. It also maps potential trajectories through the model, along with the flow of interaction and influence as people transition between the user roles.

Building on Sweetser & Wyeth's GameFlow model (2005) for evaluating player experience in

computer games, the **Pervasive GameFlow (PGF) Model** proposed by Jegers (2007) is both a set of heuristic design guidelines and a player experience evaluation tool. The model consists of 8 elements that contribute to player enjoyment, each with an associated set of criteria against which it can be measured. For example, the criterion "Pervasive games should enable the player to shift focus between the virtual and physical parts of the game world without losing too much of the feeling of immersion." can be used to design and measure player "immersion" in a game (Jegers, 2009, p. 12). While the model provides criteria to orient to in design, it does not offer guidance on how these might be achieved and is presented through evaluative rather than generative case studies.

For understanding what is and isn't a pervasive game, Guo et al (2010) offer **TeMPS**, a conceptual framework based on a review of existing pervasive, social games. They distinguish pervasive games from other forms of computer games through 4 key perspectives *Temporality, Mobility, Perceptibility* and *Sociality*. In their review, games are scored against each of the perspectives. Temporality is judged by whether game time is open-ended, allowing players to enter and exit the game at will without being bound by fixed time limits or timed rounds. For mobility, a game is considered pervasive if it allows play anywhere in any location, or with physical movement within a fixed location. Perceptibility judges a game on the ways in which the player interacts during play and how the reality of the game is presented back to the player. Finally, sociability considers whether the game supports players interacting with each other as collaborators and as competitors. It also considers whether the game has additional value, such as educational or health outcomes, beyond its base entertainment value (Guo et al., 2010). When reviewing the game score, insights into the pervasive and social nature of the game are revealed. Looking forward to design, the breakdown of each of the perspectives offers insights into the factors that contribute to the "pervasiveness" of an experience.

Content creation and management for large-scale location-based interactive experiences can be an onerous task when one considers the potential for participation to happen anywhere, at any time, with anyone. Inspired by the long-term, global success of the location-based game Geocaching[2], Neustaedter et al (2013) offer lessons for designing **scalable location-based games** based on a study of player participation in Geocaching. The Geocaching game is unique in that it is primarily player-driven, where players create, place and promote geocaches; and players seek out, engage with and post about geocaches. The game is facilitated online by Groundspeak Inc. with content creation and maintenance carried out by the players. Neustaedter and colleagues derive a series of lessons for designers to consider for creating experiences that can scale in audience and location size: keeping content creation lightweight for both players and game-designers; for games that support player-based content creation allowing for the creation of elaborate content; support development and evolution of customs over time in the game as separate to game rules; allow lightweight monitoring and reporting of game elements, other players and non-players by players; and the ability to maintain the content generated by other players. These lessons are each

2 Geocaching website: https://www.geocaching.com/play

presented with supporting examples from Geocaching and connected with supporting and cautionary examples from alternative location-based experiences.

In a similar vein, Hansen et al. (2013) define a set of design objectives and associated strategies for creating **reusable alternate reality games (ARG)**. The objectives to promote reusability are that an ARG is *replayable*, *adaptable* and *extensible*. Replayability allows for players to experience the game multiple times, the depth may vary from a retracing of a path to the generation of an entirely new experience. Adaptability speaks to the ability for the game to be translated to new contexts. If a game can be added to with minimal effort, for example through expanding the narrative into new areas, it is considered extensible. These objectives are interrelated and a game that is considered reusable may achieve these at varying depths. Multiple design patterns with examples are provided to support each objective, for example, "Multiple seasons or episodes: a game is organized so that new episodes or seasons build off of prior ones" (Hansen et al., 2013, p. 6) is given as a pattern to support extensibility. In presenting the objectives and associated design patterns, Hansen and colleagues are also careful to describe the barriers to reusability.

3. Summary

From the review above, it becomes clear that even in a narrowly defined domain such as location-based playful interactive system design, there is a very broad range of design-relevant concerns that emerge. Some frameworks establish a conceptual landscape and are concerned with defining (or redefining) phenomena such as play, space, or time. Others have been much more detailed, focused on design components of play or the mechanics of games. For this reason, we have organised our discussion to introduce a rough typology of the kinds of design guidance that can be found within these studies.

The order of the typology below generally aligns the guidance with approximately where in the design process, for the creation of playful location-dependent interactive experiences, it is likely to be most applicable. Such a process is likely to involve early attempts to understand the *thing* they are trying to design, revealing the rules or criteria that define the bounds of that location-based, interactive space, and becoming aware of a range of additional considerations that could impact the design and design process. From this "pre-design" stage, one would anticipate the process to then generate ideas that 'fit' within the space, refine those ideas and consider how these might translate into a valuable experience for players.

The *design guidance* (Table 1) identified in these studies offers divergent and convergent resources for the generation, development and exploration of ideas.

Table 1 A typology of design guidance for location-based systems

	Description	Guidance	Examples	Papers
Benchmarks	Benchmarks define the genre of interactive location-based experiences, and criteria by which systems might be compared and evaluated.	Provide design students with **goals** and **boundaries** for systems, as well as genre-specific dimensions to consider.	Temporality, mobility, persistence, playability, spatiality	Walther (2005, 2011); Montola (2005); Benford et al. (2009); Guo et al. (2010)
Idea generation & development	Methods that support the generation and development of design ideas, mechanics and experiences for location-based systems.	These tools provide a **structure** for novice designers to guide them through generative activities in the process.	PLEX framework, MRE ideation cards	Lucero & Arrasvuori (2010); Wetzel et al. (2017)
Alternative considerations	Alternative considerations are suggestive of different perspectives to understand the domain, aspects that deserve greater attention.	These contributions are conceptual **reorientations** that may offer novel design **possibilities**.	Seamful interactions, reusable assets, scalable audiences	Chalmers (2005); Hansen et al. (2013); Neustaedter et al. (2013)
Design documentation	Some tools are also valuable as a means of documenting design processes, avenues explored, and decisions made.	These tools offer **pragmatic benefit** to design, helping teams keep track of **rationale,** the conceptual ground covered, and design alternatives considered.	MRE ideation cards (and variations)	Wetzel et al. (2017)
Structural elements	Some frameworks break down the individual components of interactive location-based systems and how they interact with each other.	These contributions are useful for explaining how the design and implementation of systems work, and how certain **elements** can (or need to) work together to generate particular experiences, which can work as rudimentary design **patterns.**	Game mechanics, rules, entities, transitions, patterns	Walther (2005, 2011)

Qualities of experience	Experiential qualities dimensionalise the experience outcomes of systems for players, and considerations to take into account in the generation of those experiences.	The guidance offered ranges between experience design **goals,** design **patterns, tactics, models** and **conceptual distinctions**, useful as general orientations for design, or as instructions to follow.	Pervasive persuasive tactics, temporal trajectories, pervasive gameflow model, design patterns	Mitchell & Olsson (2018); Wouters et al. (2016); Walz & Ballagas (2007); Benford & Giannachi (2008); Jegers (2009)

However, there is not a neat one-to-one fit from the type or content of a framework and the kind of guidance it may offer design. For this reason, some of the tools we review appear in more than one category above. Across the various contributions, the following intents can be used to categorise the design tools:

Establishing benchmarks for the experience being developed to understand the characteristics and bounds of the genre and how it differs from other styles of interactive experiences. Understanding the ways in which the experience stretches the bounds of traditional games through expansions on the 'magic circle' (Montola, 2005); mapping the space of pervasive games through the 4 axes of Pervasive Gaming (Walther, 2005); and defining the particular characteristics using the TeMPS Framework (Guo et al., 2010).

Card-based games have gained popularity as a design tool (Roy & Warren, 2019) for **generating new ideas**. The creators of the PLEX framework (Lucero & Arrasvuori, 2010) and Mixed Reality Experience (MRE) Ideation Cards (Wetzel et al., 2017) provide card-based design games that engage designers with stimuli and context-specific considerations in structured activities. Each of these provides a set of playing cards and instructions for how to use the cards.

The MRE card deck (Wetzel et al., 2017) extends ideation into refinement by providing alternative rules for **developing existing ideas.** The card deck itself remains constant, what varies in the applications for design are the type and number of cards used and the 'rules' for how the cards are used to achieve different intents.

Alternative considerations offer different perspectives for the design and development of experiences. Designing experiences that allow for reuse of assets & interactions and promote extended lifetimes for experiences (Hansen et al., 2013); highlighting & incorporating the 'seams' inherent in interactive, technology-mediated experiences (Broll & Benford, 2005; Chalmers et al., 2005); designing experiences able to scale in regards to location and audience (Neustaedter et al., 2013).

Documenting process and design activities to facilitate further development is proposed in the MRE card deck by the arrangement and annotation of cards and ideas generated during design sessions (Wetzel et al., 2017).

Mapping the structural elements of designs in this space provides another form of guidance. Some contributions are concerned with the elements that comprise the interactive experience, such as specific game mechanics. The pervasive game units offered by Walther - *rules* that govern play, digital, physical and human *entities* that facilitate play and the *mechanics* for interacting with and within the game-world (Walther, 2005); and further the design heuristics that consider how the game world supports play, how the spaces are mapped, how players move in and out of game-mode and finally how the narrative responds to gameplay over time (Walther, 2011). A variety of technological frameworks and platforms would provide this type of design guidance, however, each requires a more detailed system design to be in place before an appropriate selection can be made.

Unpacking qualities of the experience specifically considers the internal qualities of an experience regarding its interaction with audience and location, and how these can be generated in interaction. For instance, Mitchell & Olsson (2018) offer design patterns to facilitate and encourage play between strangers in public places. Others consider how to leverage the transition of players between bystander, participant actor roles (Wouters et al., 2016); Walz & Ballagas (2007) provide a series of "pervasive persuasive tactics (PPT)"; understanding how participants can traverse narrative as they enter and leave the experience over time with Temporal Trajectories (Benford & Giannachi, 2008); designing to enhance player engagement and enjoyment using the Pervasive GameFlow model (Jegers, 2009). These focus on generating various qualities of the experiential outcomes of location-based systems.

4. Discussion

It is notable how much of the design guidance that is on offer from this body of work is closely tied to (a) understanding the conceptual design space of possibilities and/or (b) providing tools to aid in the generation, refinement and evaluation of design ideas. This leads us to some observations on areas that appear to be absent from this work.

We note that there is an absence of guidance that considers how designers can move from ideation to deployment—the focus is squarely on framing the domain and ideation. So design guidance is readily available for those querying the domain in attempting to understand what distinguishes a playful, interactive, location-dependent experience from other works. And guidance also tends to provide conceptual rather than pragmatic support for the design of experiences. Considering the complexities of space (Walther, 2011) and the variety of considerations with regards to scalability (Neustaedter et al., 2013), reusability (Hansen et al., 2013), there would be significant effort involved in developing the ideas generated into a deployable experience, and none of the works reviewed considered deployment as a problem.

It was also surprising to us that there were no frameworks explicitly oriented to guide the process of designing location-specific interactive experiences or involving other stakeholders in design. Although some methods could be simply adapted to participatory activities

(such as the PLEX card suite), there was little guidance on the participation or involvement of players or other domain experts in design. Walz & Ballagas (2007) clearly express the imperative to understand potential players, but they do not expand on their approaches at the point of presenting their design tactics. Their player-centric approach is described through a case study (Ballagas & Walz, 2007), although this is presented as an account rather than as a guide for design. Jegers (2009) work centres around player enjoyment of pervasive games where the focus is on the ways designers can maximise the flow experience through design approaches in the game itself. The consideration of players as a central component to the experience appears to be missing from the majority of the guidance reviewed here. Where players are described explicitly as contributing to the experience, it is done through the lens of the gameplay and game elements. The consideration of motivation, access, resources, interests was not found in the reviewed works.

We were surprised to find little discussion of the nature of the physical locations beyond their physical characteristics. Where discussed, the impact of the physical context on the success and style of the experience appears to be considered more in terms of safety, navigability and access rather than from a socio-cultural perspective. With physicality and physical location a central characteristic of the design-object for the guidance reviewed, this seems to be a key omission. Especially given the potential for controversy as created, for example, by Niantic's[3] generation of Pokémon at places of significant tragedy and trauma such as the Berlin Holocaust Museum[4], New York's Ground Zero[4] and the Hiroshima Memorial[5] in Japan. While guilt should be shared by those who chose to actively capture Pokémon at these locations, embedding the possibility of gameplay with no consideration for the socio-cultural context falls squarely in the hands of the designers.

We can only speculate on these omissions—potentially this is due to a focus on what are considered the "trickier" aspects of the design process (generation) rather than the practicalities of moving from an idea to an implemented system. Or perhaps it is because researchers do not feel (or have not found) that location-based experiences necessitate a process at much variance with a generic user-centred design process. Whatever the case, it remains that there is ample support for idea generation and alternative considerations, and understanding the nature and components of playful experiences, but little guidance on some other aspects of design.

5. Conclusion

In this paper, we have presented a typology of design guidance proposed for the creation

3 Niantic are the creators of the popular Pokemon GO augmented reality game. Website at https://nianticlabs.com/support/pokemongo/

4 Framke, Caroline. (2016) Pokémon Go in the Holocaust Museum or Ground Zero: Nintendo has no fix yet. Vox Media. https://www.vox.com/2016/7/13/12161974/pokemon-go-holocaust-museum-remove-pokestop

5 Mulkerin, Tim. (2016) You officially can't play Pokémon Go at the Hiroshima Memorial or the Holocaust Museum. Business Insider. https://tinyurl.com/rp3bngd

of playful, location-dependent, interactive experiences. These design-objects are variously described as location-based games, urban interactive experiences, pervasive games, alternate reality experiences, augmented reality games by the literature reviewed. In conducting the review, we aimed to understand the scope of design tools available, how they are developed and distributed, and what design guidance is provided. With the exception of the card-based tools (Lucero & Arrasvuori, 2010; Wetzel et al., 2017), the design tools reviewed are provided as descriptions, graphs and tables within journal and conference articles. As mentioned, we encountered challenges in the review related to the varied terms used to describe not only the style of work to be designed but the design tools we sought to review. There are, no doubt, relevant design tools that have been omitted through this process. The typology produced defines guidance that provides criteria for establishing benchmarks to define and describe the design space; provides guidance and stimulus for generating, developing and documenting ideas; offers alternative considerations for the broader experience; ways to map the various structural elements of an experience; and approaches to unpack the qualities of the experience itself.

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About the Authors:

Lorna Macdonald delivers courses at the intersection of design, technology and humanity at The University of Queensland. Her interaction & technology interests lean towards the tangible and physical. Her research focus is on location-based systems & reinventing the value of design frameworks for education.

Ben Matthews conducts research in human-centred systems design. He's interested primarily in the social aspects of technology design and use, and methods for studying and involving people in design processes.

Stephen Viller is a researcher and educator in people centred design methods, particularly applied to the design of social, domestic and mobile computing technologies and understanding people in their everyday settings. He has over 20 years' experience in the fields of Computer Supported Cooperative Work (CSCW), Interaction Design, and Human-Computer Interaction (HCI).

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Humanities discourse in games classroom: research through design with Games4Impact

Sam YANG[a]*, Aslihan TECE BAYRAK[a]

[a] Media Design School, New Zealand
*Corresponding author e-mail: sam.yang@mediadesignschool.com
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Abstract: Game development education is commonly considered to focus on game production with branching areas of game design, game programming or game art; nonetheless, developing games include more than what these three disciplines—design, software development, art— bring to the table. Acknowledging the transdisciplinary nature of games, we present a classroom approach that explores the social, cultural and humanistic identity of games via research through design while also encouraging students to leverage the expressive power of games. The merit of this approach is using game making as a space to ignite inquiry on socio-cultural contexts and facilitate an exploration for complex topics in a playful manner. This paper presents a reflective practice, methods of inquiry, and case examples to effectively apply design research in a project-based classroom environment. Case examples demonstrate strengths of the application for student learning and for the actualisation of design research in the classroom.

Keywords: game design; design research; research through design; games4change

1. Introduction

This paper provides a window into a current classroom practice in which class time and space is used to contemplate on wider contexts of games in relation to social, cultural, political and all humanly aspects of art and science. By using games as a starting point, this practice encourages students to conduct critical discussions on social cultural and economic aspects of daily life, understanding social norms, individuals' roles and responsibilities towards building and conserving a healthy community. Our approach focuses on games and their influence on individuals and society using the cultural layer of games as an entry point for difficult conversations. Considering how critical inquiry for social and cultural norms, beliefs, and tendencies may not be easy to initiate, may be less interesting or seen less useful by application oriented learners, or even hard to actualize within an application focused learning environment, we question how these conversations can be held more effectively

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in a classroom. In response, we suggest game making to be an effective tool in humanities classrooms, towards making difficult conversations more accessible in applied learning environments.

Playing and making games have been suggested as powerful tools for learning, building empathy, crowdsourcing and research, and design for social innovation (Gee, 2003; Belman and Flanagan, 2010; Schreier, 2016; Bayrak, 2017; Bayrak, 2019). Moreover, the process of game making has been suggested to have enclosed research through design prompts (Laurel, 2003; Bayrak, 2019) that helps to uncover new knowledge and provide a fertile ground for exploration and learning. Norman (2010) advises that design education needs to encompass scientific enquiry, behavioural sciences, technology and human factors as well as the ability to work cross-disciplinarily. We believe our work aligns with this advice closely since a game making space is naturally multi-disciplinary, and our classroom brings together students from art and software engineering disciplines to explore a humanities spectrum of games together in the process of making games. Therefore, our classroom practice revolves around two goals; (1) encouraging discussions and research in social and cultural contexts by using games as an entry point, (2) encouraging students to actualize their findings in their practice by making games. In order to reach these goals, we ask students to work through a project-based brief exploring a chosen topic while also participating in classroom discussions, doing written analysis, critique and evaluation. This means students are encouraged to explore as per the demands of their project (of their choice) and develop knowledge in the process of making. Kafai (2006) argues that games enclose instructionist and constructionist perspectives; instructionist with lessons already embedded in, and constructionist by allowing students to construct their own games with the instructions they are building within. In this light, we see our brief for games for impact (games4impact) as a prompt for teaching students the socio-cultural impact of games. Attempting to develop games for impact means working towards uncovering not only the issues to be addressed with the help of a game but also the means of creating impact with a game. Within this context, we see the types of impacts as follows:

- Fostering systems thinking;
- Building social ties, creating identity;
- Facilitating social innovation;
- Fostering learning and motivating behaviour change;
- Facilitating self-expression and actualisation;
- Harnessing collective action.

Since a key theme of our course is situating games within a larger social and cultural ecosystem, we acknowledge that social, cultural and technological changes are interconnected and influential on digital media as driving forces while also being equally influenced by the digital media itself. Therefore, aligned with our goals, the strength of this classroom is two-fold: (1) designing to learn by using game design as a social, cultural, political, and psychological inquiry; hence, research through design (RtD), (2) designing to reach(-out) by researching how to design to leverage the abilities of the medium; hence,

design research (DR). With a project-based structure, we leverage the participatory and interactive nature of games towards promoting further contemplation on what kind of role games may play and how they can promote a positive change in society. In addition to the critical inquiry throughout the development process, final artefacts developed by student teams create further discussion on not only the issues attempted to be addressed but also the potential impact of a game on the audience with a reflection on the goals.

Our approach in developing this course can be considered as action research within an educational setting. Gapp & Fisher (2006) suggest that action research can be an effective approach for identifying creative solutions to improve the quality of teaching and learning. For us, the students taking this course are not only the subject participants of the developed course but also participants of the research process. The course materials, assignments, and workshops are progressively refined and updated based on reflections to improve the quality of teaching and learning. At the time of writing, the work presented here has been utilized in practice for four consecutive semesters in our games and humanities classroom at Media Design School, New Zealand.

2. Related work

Literature on games within the contexts of learning, physical and mental health, therapy, social and philosophical inquiry, etc. has been growing fast. Suggestions on utilising games for the betterment of society (Swain, 2010; Bogost, 2011; Schrier, 2016; Bayrak, 2019) agree that the full potential of games have not yet been fulfilled. Bogost (2007) argues for the expressive power of games through their procedural rhetoric, and that the ability of games to teach new things and create behavioural change comes from their ability to induce self-inquiry despite and with the help of their lightweight image of being a “plaything”.

2.1 Game design for a purpose

Game design as a practice is human-centred and values competency in teaching the player affordances of the game world, limitations of their actions, and consequences of these actions in-game. Games with a purpose are particularly designed to impart knowledge or induce awareness via the experience they offer. Despite the authorial intent—whether a game is designed with an in-built purpose besides entertainment or not— games influence the perception of their players as various cultural values develop within the gaming community both “by design”—with authorial intent—, and “by evolution”—with player contribution— (Bogost, 2008). Moreover, Bogost states: “games are not just stages that facilitate cultural, social, or political practices; they are also media where cultural values themselves can be represented—for critique, satire, education, or commentary.” Both Gee (2007) and Farber & Schrier (2017) suggested that games enable their players to develop empathy and provide an active space for social-emotional learning. Belman and Flanagan (2010) suggested four design principles for designing games to foster empathy while emphasizing a positive contribution of empathy on people’s attitudes and behaviours

towards other individuals or groups, pro-environment and pro-social behaviours. Flanagan addressed this as a challenge for critical play stating that "The challenge, then, is to find ways to make compelling, complex play environments using the intricacies of critical thinking to offer novel possibilities in games, and for a wide range of players." (Flanagan, 2009, pg.6).

With "Mechanic is the message", Brenda Romero (n.d.) emphasizes the importance of active engagement that compels the participants by making them "a part of the experience rather than a passive observer". Towards identifying how games as a medium become a vehicle, Swain (2010) developed a list of best practices while advising on (including other steps not presented here) learning objectives and play-centric design. Their core pointer within play-centric design is on iterative design towards creating original play mechanics that serve the purposes of the idea (learning objectives).

Flanagan & Nissenbaum developed values at play framework (2014) to encourage intentional design that aims to integrate human values into games. They argue that values are products of implicit and explicit decisions made during the design process. Therefore, a designer should consider how the content might be interpreted by a game's audience, and what kind of values the content suggests or infuses. Their card-based design method called grow-a-game (Tiltfactor, n.d) is available to the public both commercially and for free.

Games with motive are referred to as transformational games by Schell, drawing attention to the transformational effects of such games (Culyba, 2018). These games are designed to create a specific change (intention) that extends into the real world (transfer) and remains even after the player is done playing (persistence). The framework encloses an eight-step development chart with guiding questions so that the gap between current status (of the player in terms of their knowledge, habits, etc.) and transformation (player's transformed self) can be bridged with the help of the game developed via the framework.

2.2 Games and game design in classrooms

Especially for applied systems thinking, the contribution of games for design classrooms as a DR tool has been argued before (Bayrak, 2019). Prior to this, Kafai presented several examples for successful application of game design practice as a learning tool in mathematics classrooms (Kafai et al., 1998). Initial studies on game making as a learning environment were followed with additional research on the pedagogy of game making. Kafai suggested game design as a context for children's learning arguing that game making is constructionist in nature (Kafai, 2012). Constructionism leverages voluntary participation since the necessity to pursue knowledge originates from the demands of the project (Kafai & Burke, 2015); therefore, students pursue knowledge actively and become "producers of knowledge". Referring to the educational games developed by the students in her secondary school mathematics classroom, Kafai (2012) notes that students' tacit knowledge on games allows them to develop effective games for learning even though combining instructional material with game making may seem challenging.

Robertson et al. also presented games as powerful learning environments that motivates

independent pursuit of knowledge (2008), also emphasizing that “Making a game [...] is not a passive experience.” (Robertson et al., 2008, pg. 562).

3. Our classroom practice

We acknowledge the challenges of creating engaging classroom experiences for complex topics. In our experience of teaching this class for six semesters, two of which lacked well-defined project-based guidance, we quickly realized that classic approaches including taught classes, and show, analyze and debate sessions do not seem to work effectively without the help of applied workshops. As McLuhan (1967) pointed out with “Medium is the message”, media carries the polarity of its medium. With its grammar and interconnected nature, games create a culture, an environment to act on, and a response in the form of social implications. In this context, RtD helps to create design knowledge through the process of designing an artefact while also developing knowledge, empathy and awareness about the chosen topic in the process. DR, —for the tools, grammar, and elements of game making,— helps with developing more impactful experiences to deliver an intentional message. Therefore, our approach leverages both RtD and DR for an effective humanities course within the game development curriculum. Our course structure, assignment brief, and workshops are discussed in the following sub-sections. In addition, the following section presents example projects developed in class.

3.1 Course structure

This course runs over a 16-week curriculum with weekly lectures and workshops. Aligning with the multidisciplinary nature of game development, it welcomes students from both art and programming disciplines. The students enrolled in the course mostly do not have a design background but have taken an entry level game design course prior to this; therefore, they do not have a working knowledge of research through design or design research.

Component description states that the purpose of the course is to introduce students to non-technical, human aspects of game development through a series of lectures, discussions and practical exercises.

Learning outcomes are:

- Understand societal, cultural, and ethical issues relating to digital games;
- Investigate game design and critique gameplay from a societal and cultural perspective;
- Critically analyse games from historic and contemporary perspectives.

3.2 Assignment brief and assessment criteria

The assignment brief presents a set of guiding principles to the students and uses a weighted holistic rubric to assess student work. We acknowledge that the artefacts created within this course may all be very different from one another, may not exactly successfully fulfil

their purpose (as put forward by the students with their research statements) or may create adverse results that were not anticipated. We see all these possibilities in different parts of the success spectrum, mainly relying on the learning during development. This means student reflections on the shortcomings of the artefact is a success factor that is as valuable as an artefact fulfilling its initially set goals. Thus, students are expected to work in teams —participate in a healthy discourse with diverse opinions, to pick a humanities topic— research/investigate social and cultural contexts, to prepare a research statement—construct knowledge that informs and contextualizes their work in relation to the chosen topic, to develop a game—find working features to present their message, and to write a post-mortem—reflect on their learnings from the entire process.

The overview of Games4Impact assignment points to the potential of games to address social, political and cultural issues or promote positive change in society, and reads as:

> "Students are expected to collaboratively explore game design approaches and create an artefact to present their perspective on a topic/theory of their choice. Since the exploration and thought process is as valuable as the artefact itself, a 1000-1500 words essay should accompany the artefact as the research statement."

Assignment guidelines state that the artefact can be of digital or non-digital nature, and a focus on intention, purpose and communication is encouraged over technical complexity. In either platform, the expectation is developing suitable game mechanics to deliver the intended message. Some guiding questions are also provided: (1) What are the values that you want your artefact to reflect?; (2) What is the goal and how is it represented/addressed?; (3) How can the artefact merge the message or the goal into the gameplay of the artefact?

Table 1 Assessment criteria

Assessment area		**Description of the expectation**
1. Artefact	Purpose:	Artefact clearly presents the purpose and fulfils this purpose as presented in the Research Statement.
	Impact factor:	The artefact manifests the purpose and goals via the participation of its users.
	Suitability:	The intended experience is suitable for the purpose and the topic of exploration with the provided content and interaction.
	Structure:	Artefact comprises relevant elements that are suitable to the type of artefact—digital or non-digital, closely serving for the purpose and motivating the values via interaction.
	Cohesion:	The exploration is cohesively contextualised to fit in the style of the artefact; all elements are in cohesion for the intended experience.
2. Research Statement	Purpose:	Clearly outlines the intention and aims of the project while explaining how these are presented within/by the artefact.
	Comprehension:	Specificity and range of knowledge are presented to contextualise the ideas informing the artefact.

	Criticality:	Evaluates the relevance, impact and value of each point raised to situate the artefact in a wider context.
	Attribution:	The theory, ideas and the artefact are situated in a wider context with enough credible sources of scholarly nature. The attributions are correct, and referencing adheres to the required style-guide.
3. Individual Reflection		Individual Post-mortem is written in a suitable tone and form presenting the contribution of the individual.
		Clearly states and explains the contribution to the creation of the artefact.
		Critically reflects on the successes and failures of the artefact in addressing the chosen topic and its contextualisation.
		Presents a reflection on the creation process of the artefact, addressing what went right, what went wrong and how it could be improved.

3.3 Workshops: inquiry methods and class activities

Throughout the component, discussions are initiated in weekly lectures, then elaborated in workshops. The workshops in the first half of the semester are used to develop scientific inquiry skills, argument building, and academic writing while the second half employs a project-based structure to encourage practice-based inquiry. In addition, class discussions are also carried on in a private blog that is only accessible by the students enrolled in the course. The blog is used to offer a continuous discussion space highlighting values in diversity of opinions, perspective sharing, and compassion towards all members of the community. We consider our classroom to represent a well-coordinated social-emotional learning environment (Weissberg et al., 2015) that promotes healthy emotional and cultural discussions across team members and classmates. In addition to the presented material, students are given core readings to cultivate their understanding. These readings are motivating sources and mainly discussed in Section 2.

Core questions asked in class activities include:

- Do games reflect values: Whose values are they? How can we forge a value into the activity that a player performs?
- Mechanic is the message: How could the values be manifested through the basic mechanics of interaction?
- How would a game's constraints and affordances reflect values?
- How do a game's features embody values?

During the workshops, as games evolve, class activities pose questions that attempt to validate the current status of a game:

- Identify the value(s) reflected in your game.
- If we start to think of human values as a main point of interest, is there a core value that is explored/reflected in your game?
- How might the content be interpreted by your game's audience?

4. Example Cases: Student Projects

This section presents five example games developed in this class and discusses student learning as per (1) purpose—referring to the goals of the practice, (2) gameplay—structure of the experience, (3) process—referring to the design process, and (4) evaluation—results and concluding remarks. Table 2 shows a brief summary of the projects.

Table 2 Project summary

Game	Key Impact	Merit for RtD	Merit for DR
Rocket Run	Motivates behaviour change	Learned the core factors behind distraction and loss of motivation	Understanding how to develop appeal and create dilemma in gameplay
Wayward	Facilitates self-expression and actualisation	Explored motivating factors behind human behaviour and decision-making	Using learned systems to influence player choices
The Park	Harnesses collective action	Learned of innovative approaches towards solving pollution in urban spaces	Translating a social issue into an allegorical interactive experience
Devoid	Facilitates self-expression and actualisation	Self-realisation; gained an authentic understanding of the grieving process	Presenting serious and heavy content within an interactive experience
Burning Books 47	Facilitating social innovation	Expanded knowledge on books of cultural and social importance	Dissonance between research and development limited impact

4.1 Rocket Run

Purpose

Rocket Run discusses the topic of procrastination by presenting the player with a balancing act between short-term gratification and long-term goals. The player is tasked with landing a rocket ship safely while being distracted by an optional activity to collect points, drawing from O'Donoghue and Rabn's (2001) ideas on inducing procrastination.

Gameplay

Gameplay begins in the rocket ship that is steadily falling, indicated by a status bar at the bottom of the screen. Floating crates in space whiz past the rocket and can be blasted to collect points. The player cannot use the lever and the cannons simultaneously. To land

safely, they have three options: ignore the crates completely and hold the lever down to slow the ship's descend; collect points at the early stages and spend the rest trying to slow down; alternate between collecting points and slowly descending consistently.

Figure 1 Gameplay showing the player using the cannons to gain points from breaking crates.

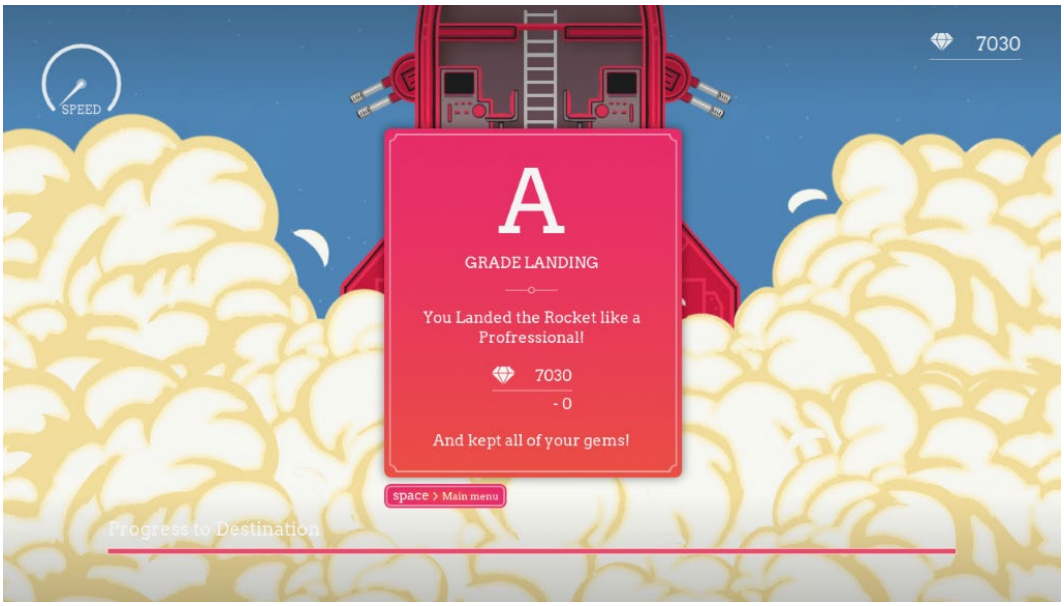

Figure 2 Win screen of the game indicating a successful landing of the rocket ship.

PROCESS

The team created several mini prototypes before landing on the current one. Careful scoping and iterations helped the team to focus on refining the game to better convey their message.

Evaluation

The final artefact successfully weaved the key message into the experience with nuance, while short-term gratification and long-term goals were adequately juxtaposed for player engagement. Artefact's success became more apparent in a playtest session where the participants realised that they have fallen for the distractions and missed the main goal. Despite the lack of scholarly engagement in the research statement, the argument was well structured showing that the assignment successfully incited an exploration for the topic. In their post-mortems, two students mentioned the effects of procrastination, promptly stating that "the irony of what happened in this project was something to be learned from." Overall, the outcome demonstrated a critical investigation and actualisation of learnings in practice.

4.2 Wayward

Purpose

Wayward aims to create a discourse around player motivation by exploring the concepts of intrinsic and extrinsic motivation. It attempts so by addressing the three needs as per self-determination theory (SDT) by Deci and Ryan (1985), and by providing the player with a quest without an extrinsic reward.

Figure 3 *Dialogue cut-scene with elderly woman, where she explains that there is no reward for the task that she requires help in doing.*

Gameplay

Gameplay begins by explaining the premise and instructing for daily actions. The next day presents a request for help from an elderly woman; this will undoubtedly cause them to be late to school, yet without any tangible reward. When the day ends, the concluding screen

references player's actions for the day and summarises the core message of the game. If the player chooses to help the elderly woman, they will inevitably be late to school. However, they will also spot the elderly woman outside their window smiling at them.

Process

The original idea was stress related to school assessment deadlines. Later, in the process of developing the idea, the students discovered that motivation had been the underlying core idea. Team focused on the message through several iterations, yet the clarity of the message proved harder than expected.

Evaluation

The final artefact was successful in its completeness, but the message still lacked depth as the choice for intrinsic motivation remained unclear. The elderly woman acknowledging the player with a smile attached an extrinsic reward to an intrinsically motivated action, therefore worked against the intended message. Team's research statement had a clear argument but lacked explicit engagement with credible sources. Nonetheless, students' post-mortems showed that they gained a greater understanding of the medium; hence, knowledge and practice were united. Despite a lack of success in application, team was successful in pursuing further conceptual meaning for their mechanics.

4.3 The Park

Purpose

The Park aims to bring awareness to the positive effects of beautification in urban spaces. The game locks the players into a specific path of action towards winning the game, which upon realisation also completes the message of the game.

Gameplay

The player can either pick trash off the ground to lessen filth or plant trees to increase beauty of the space. A higher beauty score lessens the appearance of new trash; however, trees cannot be planted until money is earned through picking up trash. Once all potential tree planting spots have been used and all trash is picked up, the game ends with a victory screen.

Process

Despite a delay in starting development, proper planning with a well-grounded research helped the students to focus on how to deliver the intended message within the remaining time.

Figure 4 Desaturated colours reflect the filthy status of the neighbourhood.

Figure 5 Saturated colours reflect the low filth and high beauty status of the neighbourhood.

Evaluation

The final artefact managed to communicate the message in a highly effective manner. The research statement engaged with a range of academic and news articles effectively with a solution-driven angle. Post-mortems noted a recently gained understanding of themselves and working within the medium through the process—an example of growth in systems thinking. Therefore, the assignment was successful at encouraging the team to investigate and transfer their research into practice.

4.4 Devoid

Purpose

Devoid explores grief and loss by placing the player in spaces visually reflective of the state of their mind, mainly aiming to represent the five stages of grief (Kübler-Ross, 1969). The artefact serves as a mode of self-expression for the team members, whose friend was battling cancer.

Gameplay

Gameplay consists of five rooms that the player wakes up in. Each room represents one stage of grief visually: (1) denial—a half-lit room with objects strewn across the room, (2) anger—a dimly-lit room messier than the first, (3) bargaining—a well-lit tidied room with a laptop in use on the bed, (4) depression—the same room as bargaining but with laptop closed and put aside, (5) acceptance—a brightly lit room that is neat and composed.

Figure 6 Room that represents denial.

Process

Since the students in this team were at the brink of losing a close friend to cancer after a long battle, they approached this game with strong emotional ties and a desire to create an impactful experience. However, this level of close attachment to the topic led to an unfortunate over-scoping.

Evaluation

The final artefact was incomplete; however, the process of making the game was not only a learning opportunity for the students but also a part of the message itself. The team's eagerness to begin the production phase caused a limited understanding beyond their own

personal experiences. This became evident in both the final artefact and research statement, both lacking criticality and depth. In dealing with strong emotions, the production process became a therapeutic experience for the students; thus, the assignment reached a different kind of success, perhaps resilience. Conversely, the assignment failed in achieving its goal of inciting a deeper understanding for the topic.

4.5 Book Burning 47

PURPOSE

Book Burning 47 discusses the topic of censorship by tasking the player for the fate of some "controversial" books. The books reference real ones that were banned by a governing body at one point in time; collectively representing information and freedom of thought. The two possible end states of the game illustrate the outcome of censorship at extreme levels.

Figure 7 Books on table for review.

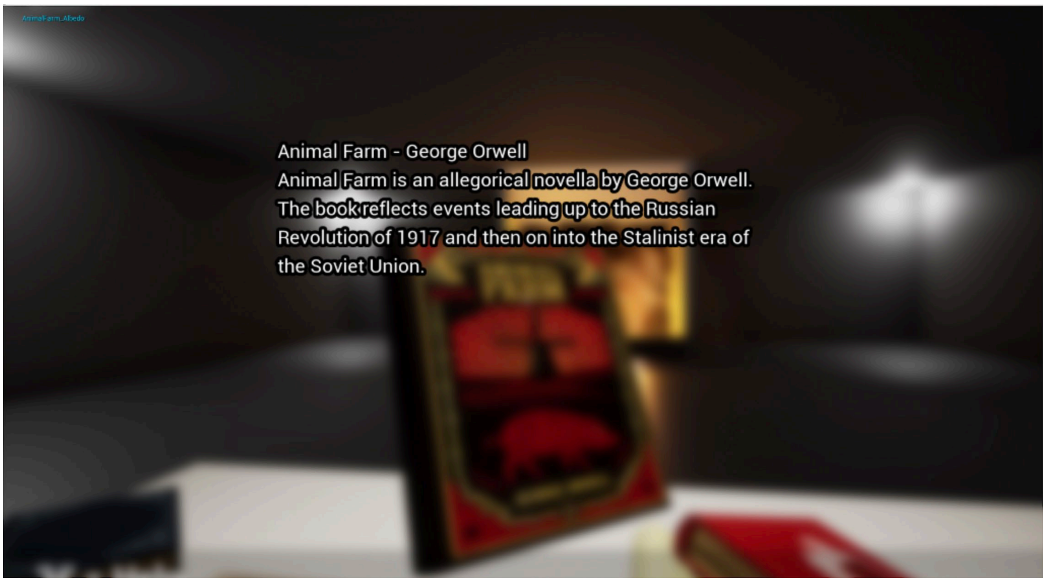

Figure 8 Animal Farm book picked up and description read.

Gameplay

In the game, players review books over four days while the state of the room changes each day, reflecting the impact of the player's actions on the regime. Burning books results in more propaganda filling the room, but empty bookshelves; passing books results in indications of rebellion through broken glass and messy floors. Burning books also leads to illiteracy signalled by book descriptions no longer being readable. At the end of the four days, a cut-scene presents either the empire gaining total control or being toppled.

Process

Although it took the team a while to settle on an idea, once solidified, the team had a strong grasp of their topic. However, they struggled to implement all features planned.

Evaluation

The artefact managed to convey the intended message to some degree even though some features remained incomplete. The research statement lacked depth yet presented a well-crafted argument. The core idea suggested a rhetoric; however, the final disposition remained simplistic and lacked nuance. Post-mortems indicated lack of research across the team, which potentially factored into the lack of actualisation. Therefore, the assignment failed to leverage collective action for exploration and research. Potentially, the students became familiarised with the books to some degree.

5. Learnings and Reflections

Teaching faculty noticed that rather than the successful creation of an artefact, the student journey in developing the artefact enhanced the student learning. This became visible via the research statements and the post-mortems. Since we started using the idea of making

a game as a prompt, student engagement clearly increased especially when compared with the older versions of the component. We see this as a success for the current teaching and learning environment. We use the research statements as a means to evaluate students' contextual awareness towards the chosen topic, how the assignment has prompted the team to conduct research and articulate their findings. As much as this can be analysed by the criticality/depth of their text and quality of the sources, we realised that the depth of understanding surfaces with the depth of the artefact, how the artefact presents the topic to its audience, and in its nuance of delivering a core message. Examples of this has already been discussed in the case studies section.

We believe that the faculty plays an important role in facilitating the process for the students. A lack of communication across team members has been an obstacle while discrepancies in each member's understanding and progress hinders a project significantly. Regular meetings proved effective in maintaining the focus on key learning outcomes. Where possible, the regularity of these meetings offers a good chance to keep the students on track for all three fronts: quality of research, strength of the argument through engagement with source materials, and effectiveness of their final artefact in conveying their points. In the case of developing Wayward, the team had great success on the two areas discussed in meetings which were their logic and application of ideas in the final artefact, but failed when it came to scholarly engagement; something the teaching faculty could have been more observant of. Moving forward, scheduling mandatory meeting sessions with each team would be ideal rather than mostly allowing each project to find its own course.

One consistent trend among our students is a tendency towards the production phase, and that the research segment prior to starting production is easily overlooked. This is due to the same excitement that encourages students to explore complex themes in the first place. As such, balancing these two parts will result in more successful learning outcomes. The more meaningful games came from teams that found a balance between research and application while attempting to find simple and effective features to present their topic through iteration. More emphasis on this is necessary so that a more structured approach for DR is put in place to aid the students in realising the core of their topic and how to articulate it in the game.

In earlier versions of the component, teams were required to present a core reading to guide their research and root their starting point. We observed this becoming problematic due to teams' sole reliance on that one reading without other considerations while moving forward. We hope that a change toward requesting a review with a suitable scholarly breadth can improve the ground research significantly although it creates an overhead for the teaching faculty in terms of breadth of material to be looked over.

In retrospect, lecture material has evolved to broaden the students' understanding of what can be considered a game for impact. This resulted in a greater range of chosen topics, as witnessed in examples such as Rocket Run and Wayward.

6. Conclusion and Future Work

We have presented a classroom practice leveraging RtD approach to enhance student learning for humanities in game development curriculum. We have shown that RtD and DR can be applied in a classroom setting naturally with implicit prompts. An extended, larger version of this class could also include a component requiring teams to research their audience in greater detail and consider publishing/presenting an artefact with an audience focus. Therefore, the potential for similar work in larger networks to serve for and ignite greater change and awareness in the society may increase.

Although our classroom practice is originally developed for a curriculum for game development education, we believe the idea of making a game as a process to explore social sciences and humanities discourse can still work for student groups who may not have trained for game development. Non-commercial dimensions of game-making relies on tacit knowledge and interest, and there is a large do-it-yourself community of game enthusiasts; therefore, prior experience in game making is irrelevant for experimental purposes. In the future, we are hoping to develop a tool to help facilitate the design process more effectively in the classroom. The inquiry methods, class activities and the set-up of our project-based classroom environment would hopefully inspire other educators and researchers.

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About the Authors:

Sam Yang is a lecturer at Media Design School, with a passion for digital illustration and concept art.

A. Tece Bayrak is a games scholar, teaching game development at Media Design School. She sees gameplay programming as art, also believes in the power of games for change.

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SYNERGY

Improving the Spectator Experience of AR Sports Events from a Service Design Perspective – Using HADO as an Example

Pei-Ling SHIH[a]*, Hsien-Hui TANG[a]*, Shu-Yi CHEN[b]

[a] National Taiwan University of Science and Technology
[b] Ming Chuan University
*Corresponding author e-mail: m10710902@gapps.ntust.edu.tw
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Abstract: Augmented reality (AR) has been used to improve the spectator experience in traditional sports events. For the first AR sports in the world, Meleap's HADO, the discussion of spectator experience in watching AR sports is lacking. To understand the problems and flaws in the spectator experience of AR sports events, we have conducted a two-phase investigation into Meleap's HADO. The first phase investigated HADO's live sports events, while the second phase examined their online sports events. We used questionnaires and semi-structured interviews and conducted an integrated analysis based on the quantitative and qualitative results to determine how to optimize HADO's spectator experience. Finally, as a reference for future studies, we summarized the challenges and issues found in the spectator experience of AR sports.

Keywords: augmented reality; service design; user experience design; spectator experience

1. Introduction

The global industry is undergoing changes thanks to technological advancement; as watching sports events on mobile devices has become a trend, this continues to inspire more personalized, socialized and diverse solutions. Many companies in the sports industry have realized that spectators frequently change the way they watch the games, and in response have created many innovative solutions combining sports events with technology. During the 2018 World Cup, for example, many sports channels and online stream platforms supported Virtual Reality (VR) live streaming. Compared to VR, which requires heavier equipment, Augmented reality (AR) is more portable and can provide instant rendering, which translates into quality user experience.

User experience refers to a user's physical and psychological reactions, emotions, preferences, perceptions and behavior in his/her interaction with a service, product or

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company (Norman, Miller, & Henderson, 1995). AR brings brand new experience for the users, including new types of sports events and new spectator experience. Past case studies and research on spectator experience is based on watching traditional sports games. Since our research case is the world's first AR sports game, it brings not only a whole new game watching experience to spectators but also a new area to discuss. Through our in-depth case study, we hope that we will be able to gain an insight into the current problems and challenges of watching sports events with AR, and to propose suggestions on how to improve spectator experience. The results will serve as reference for future studies.

2. Literature review and related work

2.1 Augmented Reality and Its Applications to the Sports Industry

AR applications in sports industry are divided into two categories: watching and participating. In terms of watching, AR has been widely adopted in sports broadcasting. Ericsson, for instance, introduced Piero AR in 2016, which allowed broadcasters to overlay 3D graphics in real time during live studio productions and sports games. On the other hand, when it comes to participating in AR sports events, AR is integrated into traditional sports. Meleap (hereafter, the Company), a Japanese startup, combined AR with dodgeball and created HADO AR sports to expand the sports industry, making it the world's first AR sports game.

AR has changed the way people watch and participate in sports games; we are now officially in the "AR competitive sports era". In the past, AR was mostly used to improve the connection and interaction between the spectators and the events. However, there has not been enough discussion over the spectator experience when watching AR sports games, indicating that there are still challenges to overcome when it comes to AR sports games' spectator experience, which also requires innovation.

2.2 Service Design

In the competitive service industry, products alone can no longer satisfy the picky consumers (Pine & Gilmore, 1998). Similarly, sports lovers are also pursuing a type of unprecedented experience. Spectator sport is about the experience of an intangible product; fans long for the experience, which will in turn create wonderful memories for them. Each live broadcast of a ball game must show the fans that it is highly worth watching—otherwise, it will lose its spectator (Huei-Fu Lu, 2011).

Currently, academia and the industry have a wealth of discussion and research in service design, but there is no agreed-upon definition. Service design is a newly emerging design that adopts a holistic, multidisciplinary and integrative approach (Ho & Sung ,2014). It is even more comprehensive and involves understanding the users, their backgrounds, service providers and social practice, then transforming such insight into the interactive development of evidence and the service system. Service design is also considered an explorative process that is meant to create new valuable relationships among different

participants and develop and integrate proper design capability as its core competence (Kimbell, 2011; Holmlid & Evenson, 2008). The principles for service design include user-centered, co-creative, and holistic evidencing and sequencing (Stickdorn & Schneider, 2013).

With the user-centered principle of service design and the assistance of a service design tool—customer journey map—this paper will focus on spectators' experience and explore its pain points and design opportunities. This research adopted the value of multidisciplinary and co-creation from service design, communicating with the Company to ensure consistent objectives.

3. The Case: HADO

Meleap, a Japanese startup that develops AR games, created Techno-Sports, which combined AR with traditional sports. The Company also founded HADO to shape the competitive sport of the future. HADO is a 3-on-3 team sport that combines AR and dodgeball. In a HADO match, players can shoot energy balls and block the other team's attack with a shield. At the end of the match, the team with the higher scores wins. HADO is the first competitive AR sport in the world. One of the researchers is a designer from Meleap; therefore, Meleap agreed to assist with this study on HADO and to provide necessary assistance and related information.

4. A Discussion on Spectator experience of HADO Matches

4.1 Aim

This study aims to investigate spectator experience in a competitive AR sports event in terms of service design. By studying HADO events, we are able to gain an understanding of their current service conditions and to analyze their challenges and shortcomings. Through design thinking and multidisciplinary collaboration, we proposed a direction to optimize the spectator experience of HADO events and summarized the issues and challenges for improving the spectator experience of AR sports events.

4.2 Research Process and Methods

To understand the problems and flaws in the spectator experience of AR sports events from both a physical and virtual perspective, we conducted a two-phase investigation into Meleap's HADO. The first phase investigated HADO's live sports events, including participating in the entire HADO Summer Cup event in Tokyo during August 2019. The second phase examined HADO's online sports events. Questionnaires and semi-structured interviews were conducted to obtain qualitative and quantitative data. These data then helped pinpoint the factors that affect spectator experience, and at the same time gave the researchers a clear direction on how to optimize HADO's spectator experience effectively (Figure 1).

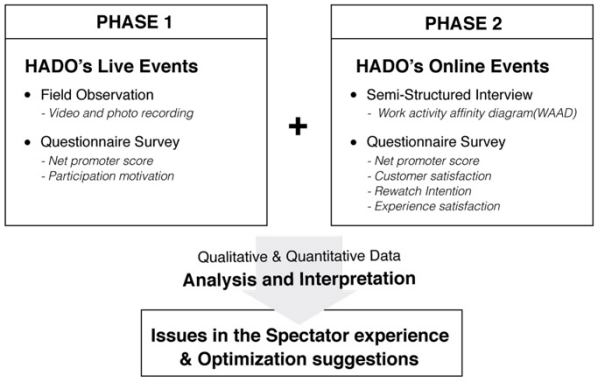

Figure 1 Research process and methods

4.3 A Discussion on the Issues in the Spectator Experience of HADO's Live Events

One of the researchers participated in the entire 2019 HADO Summer Cup event in Tokyo during August 2019. The content and procedures adopted in this research had previously approved by the company. We conducted questionnaires with spectators at the games to obtain feedbacks on their experience of the event. Finally, based on our field observation and the results from the questionnaires, the researchers constructed a customer journey map to identify the pain points and also explored design opportunities for better spectator experience.

Field Observation

Field observations at the HADO event's venue were conducted and photos and videos of the spectators' participation was taken. It was discovered that the way the audience in the venue watched AR games is quite different from the way traditional sports games were watched. In fact, all the AR special effects are not visible to the naked eye; the only way for the spectators physically at the game to see those AR effects is by looking at the projector screen, where the game footages with all the effects were projected to (Figure 2). In contrast, if they chose to focus on the real actions on the stage, they would only see players running around with awkward postures.

Figure 2 The way the spectators watch the game in the venue (left) versus the way the game looks like on the projector screen and online (right).

Questionnaire Survey and Result

The questionnaire used in this phase was approved by Meleap beforehand. The questionnaire includes questions about motivation for participating, participation experience, past experience of HADO playing, understanding of the game format, potential improvements for the game and net promoter score (NPS). NPS represents a customer's willingness to recommend a product to others, and is an indicator that can accurately quantify a customer's perception and directly reflects a customer's loyalty to a company or its services (Reichheld, 2003). The higher the number, the more likely a company will experience growth.

82 questionnaires were collected and the results were compiled and presented in Fig 3. The results show that 32% of the spectators attended the event out of curiosity toward AR sports, and approximately 60% of them attended the event for the first time. Since they were just introduced to the game and had little knowledge about HADO, they had to observe the game to understand its format. In addition, most spectator members pointed out that having to watch the game on a projector screen to see the AR effects is the part that needs to be improved the most. The overall NPS score of 10 points is a clear indicator that the current spectator experience does need to be improved.

Quesion	Results
NPS Score	NPS **10**
Where did you hear about the event?	**70%** by referral. The rest either have participated in HADO events before or heard about it on the social media.
Why did you come to see the event?	**32%** of them came to the event out of the curiosity for AR sports events.
Have you seen or participated in a HADO event?	Approximately **60%** of them came to see the game for the first time. **30%** of them has played and watched HADO before. **10%** of them have never played HADO but have been to an event before.
Past HADO experience	Only **30%** of the audience has experienced HADO before.
Understanding of the format	**50%** learned about the format by watching; **20%** by reading the event brochure and the last **30%** already knew about the format in advance.
What are the improvements you would like to see about this event?	Most of the respondents pointed out that having to **watch the game on the projector screen** needs to be addressed. Other parts that need to be improved are: event schedule, performances, activities and merchandise store.

Figure 3 Survey Results from Spectators of HADO Live Event

After future analysis, the spectators were divided into different groups based on the feedback from the survey (having played or participated in HADO events), combined with the respective NPS. The result is shown in Fig 4. The first quadrant is the target spectators of this event—those who have never played HADO, with this event being their first. These accounted for more than half of the respondents and yet only had an NPS of 4, which is far from ideal and is a clear indicator that spectator experience needs to be optimized. The third quadrant represents the spectators who had played and participated in HADO events before, and the number of respondents is second only to the target spectators. However, this group

is more willing to recommend HADO events to others. It is plausible that spectators may be more willing to recommend HADO events if they have played HADO themselves, with more knowledge of the game as a player and a spectator.

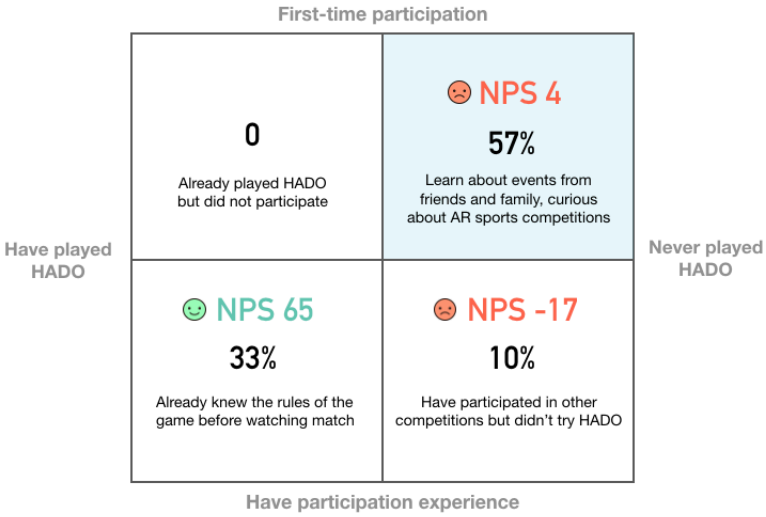

Figure 4 Spectator Group Analysis

Customer Journey Map

A customer journey map is often presented as a part of the research deliverables of a design process (Følstad & Kvale, 2018). It visualizes different stages of a user's experience of or interaction with a product or service, allowing each detail of the journey to be reviewed. The map shows a customer's characteristics, emotional responses and problems while interacting with services (Ho & Sung ,2014). It helps us to find gaps in customer experience and explore potential solutions, so that we can make intangible experience visible and with the map, facilitate a common understand between team members (Stickdorn & Schneider, 2013). While constructing a customer journey map, it is essential to clarify a service's touchpoints where interactions with users happen, and to understand users' perception and thoughts towards a service by collecting qualitative data, such as interviews and photographs. Based on the abovementioned field observation and insights from the questionnaires, a customer journey map was constructed and illustrated in Figure 5. The map details the pain points of the spectator before, during, and after watching the event.

From the emotional lines in the customer journey map, we can perceive that spectators' unpleasantness occurs at the points of entering the venue, watching the game through the projector screen, and waiting for the game to begin. However, these issues are independent events. We found that before watching the game, a spectator typically felt interested and excited about the AR sport event at first, but this sense of surprise and excitement would gradually reduce after he or she started watching the game. Whether it's a lack of understanding about the game, the way of watching the projection screen, or other issues,

it causes the overall experience of watching the game to be dull. Based on the above discussions and findings, this study summarized how the service could be optimized in the following 3 points:

1. Lack of understanding of the event and ruleset before watching the event: the spectator had to learn about the details of the game while watching, which prevented them from actually getting engaged in the game. As most spectator members had never played HADO before, it was difficult for them to understand the technicality and difficulty of the game, not to mention imagining a player's perspective with AR goggles on. If spectator members have the chance to understand the details of the event beforehand and even to play HADO themselves, they can focus on the competition and will have a more enjoyable experience during the game.
2. User experience issues resulting from the way the game is watched: spectator members who had never been to an AR sports event became very excited at the beginning of the event. However, the excitement gradually faded as time went on, especially when experiencing frustration while watching the game. The greatest pain point in watching the game was that the spectator had to look up at the screen to see what was happening in the game, even though the players were playing right in front of them. They had to constantly switch between looking at the players and the screen, which caused strain on the necks. More importantly, using a projecting screen is fairly common in traditional sports events and concerts; thus, the features of AR are not demonstrated in live events, leaving an expectation gap after watching the game.
3. Lack of interaction during the game: there was no interaction among the spectator members or between the spectators and the players during the game, which meant that the sense of engagement might be absent while a spectator was watching the game.

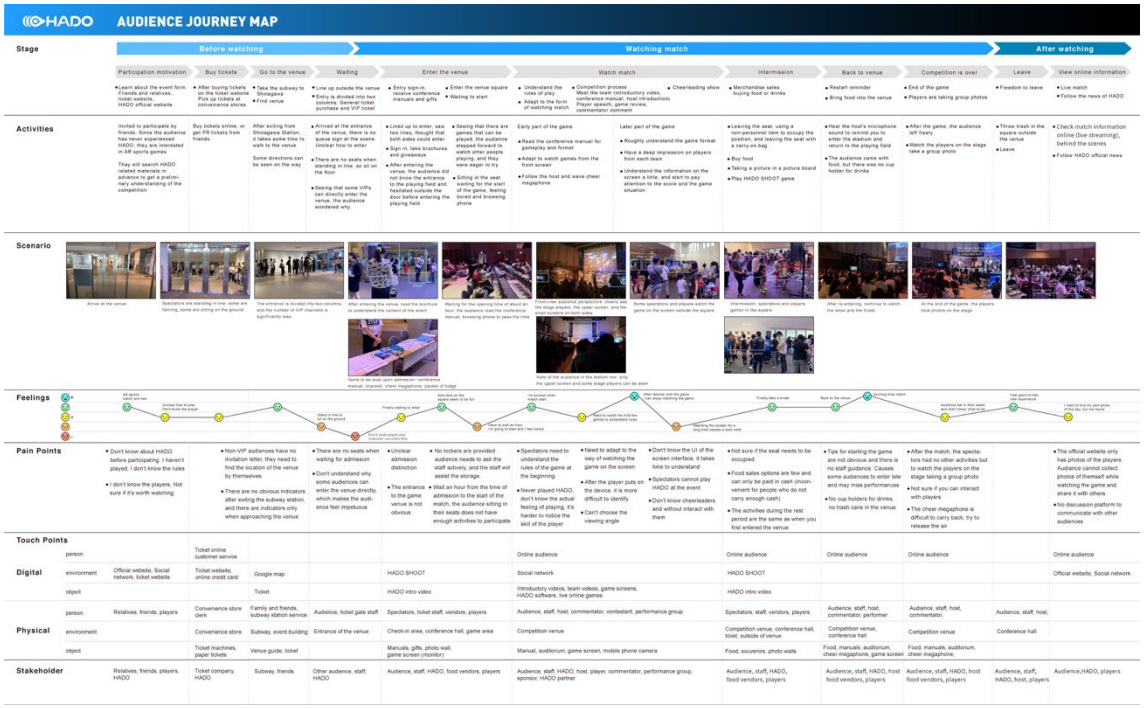

Figure 5 *Customer journey map of a HADO event, which includes users' actions, interaction scenarios, emotions, pain points, touchpoints and stakeholders before, during and after watching the game, giving a clear presentation about the problems and issues in the spectator experience. (Visit the following link for CJM: https://reurl.cc/qD4zbN)*

4.4 Discussions on the Issues of Spectator Experience in HADO's Online Events

After the survey at the physical event in phase 1, we had a certain level of understanding of the issues of spectator experience in HADO events. The research in phase 2, with interviews and questionnaires, focused on the experience of live streaming content of the 2019 HADO Summer Cup.

Investigation Process

First, we tried to understand the interviewees' past experiences in watching HADO events, and asked them about their understanding and perception of AR, as well as expectations towards AR sports events. Next, we introduced the basic game details and rules of HADO to the interviewees. All the provided information is according to official information from HADO. Then we conducted interviews to discuss their opinions and expectations towards HADO events. Lastly, we asked the interviewees to watch 2019 HADO Summer Cup online to simulate the real situation of watching an actual game and then asked them to fill out a questionnaire. Once completed, we continued the interviews, in which we provided them with video clips taken directly from the game venue and solicited their opinions to obtain more feedback on attending the game in person, in addition to their online spectator experience (Figure 6).

Figure 6 Interviewees watching the event online and getting interviewed

Participants

HADO combines e-sports and traditional sports. To further understand how those who watch games online think about HADO events. A total of 10 participants were interviewed and their backgrounds are listed in Figure 7.

No.	Gender	Age	Occupation	Years of watching	Channel	Match type
A	Male	24	Research assistant	15	Online, TV	Football, DOTA, Card
B	Male	39	Engineer	10	Live, Online, TV	Basketball, Badminton, DOTA
C	Male	41	Product designer	5	Live, Online, TV	Basketball, SLG, Card
D	Male	35	Brand agency	20	Online, TV	Football, Basketball, Card
E	Male	35	Industrial designer	4	Online, TV	Football, Racing car
F	Male	24	Back-end Engineer	15	Live, Online, TV	Baseball, Basketball, DOTA, Olympic
G	Male	31	Data analyst	10	Online, TV	Basketball, Tennis, Olympic
H	Female	30	Translator	6	Live, Online, TV	DOTA
I	Female	20	Student (eSport)	1	Live, Online	DOTA, RCG, FPS, Card, PS4
J	Female	25	UI Designer	5	Live, Online	DOTA

Figure 7 Participants backgrounds.

Contextual Analysis

Contextual analysis is the process of interpreting, consolidating and communicating a user's work activity data (Beyer & Holtzblatt, 1998). The main point of contextual analysis is to convert raw contextual data into work activity notes, and to convert work activity notes into work activity affinity diagram (Rex & Pardha, 2012). In this study, the interviews were transcribed, and the transcription was reviewed to check for any differences before being encoded. The integration and communication process compiled the work activity notes into a work activity affinity diagram (WAAD) to determine the problem categories and insight

opportunities. We compiled the interviewees' feedback into a WAAD (Figure 8) and then matched the issues to different stages of a spectator's journey during the game (Figure 9). The results were shown in Figure 10.

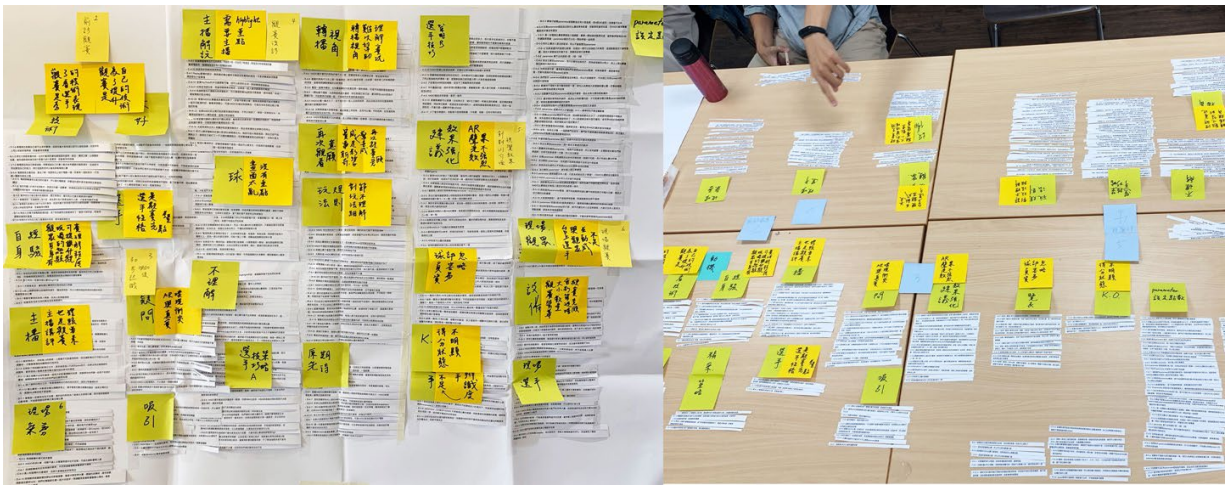

Figure 8 *WAAD Analysis – Transcribe, encode and compile interviews to clarify user's problem categories and insights.*

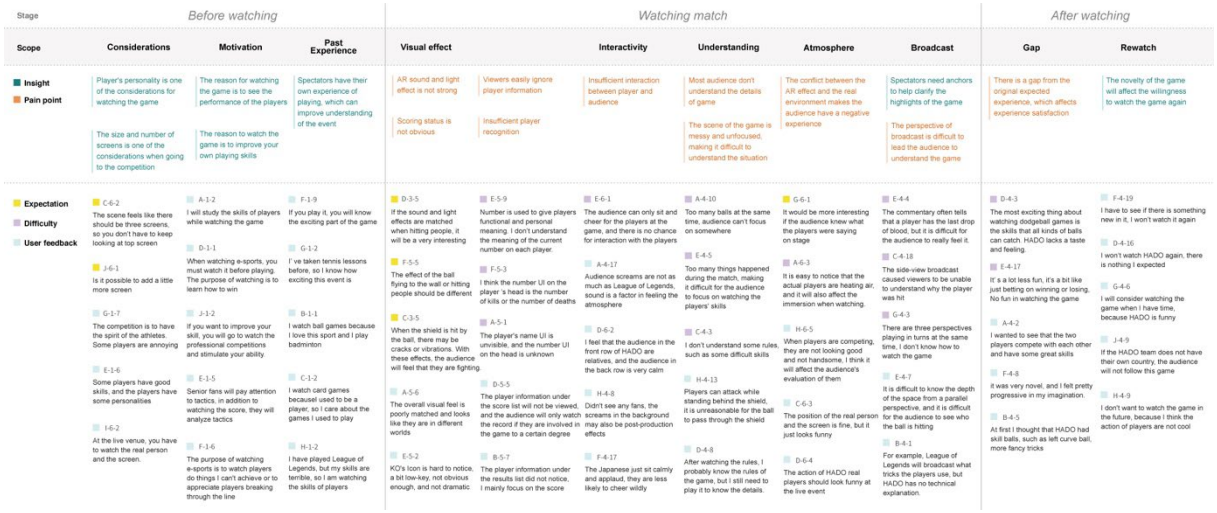

Figure 9 *WAAD corresponding to different stages of game watching, clearly showing the issues with user experience and insights obtained in each stage. (Visit the following link for WAAD: https://reurl.cc/vn41Xo)*

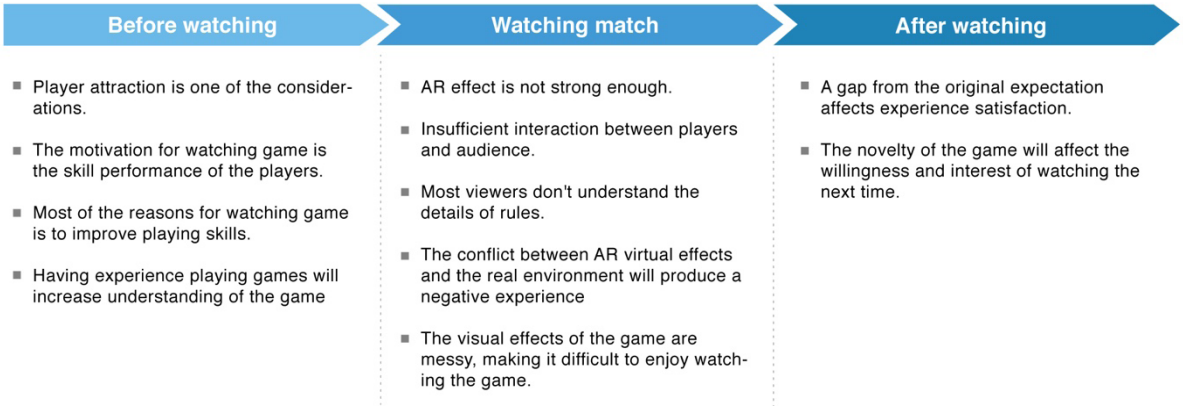

Figure 10 User's Insights from Contextual Analysis.

1. BEFORE WATCHING:

The interviewees' main motivation for watching games in the past was about techniques: they watched games to observe the players' techniques and learn from them.

> *"People who watch e-sports are mostly players themselves. They watch to improve their own skills" (D-1-1)*

> *"I want to watch the amazing pros play to improve and inspire myself" (J-1-2)*

Spectator with prior experience had little trouble understanding the game: most interviewees who had experienced the game before had a certain level of understanding of the game, and therefore could easily enjoy watching it.

> *"I have played this myself so I know when exciting things happen in this game" (F-1-9)*

> *"I have taken tennis lessons before so I know how exciting this game can be. That is why I want to go and see the game." (G-1-2)*

2. WATCHING THE MATCH:

The AR visual effects, as well as the sound and lighting effects, need to be optimized and improved: most interviewees cared a great deal about the AR visual effects and would compare them to the ones they had seen in other sports events. In general, they had higher expectations for the visual, sound and lighting effects.

> *"There should be different effects when a ball hits the wall or a person." (F-5-5)*

> *"The game would be more interesting if the sound and lighting effect were in sync with the ball hitting an opponent." (D-3-5)*

Lack of interaction while watching the game: there was not enough hype in the online discussions about the game. The game did not offer the spectator much opportunity for interaction, which would also affect the spectator experience and people's willingness to go and watch the game

"If the live spectator could hear what the players are saying on the stage, the game would be even more thrilling." (G-6-1)

"Other than cheering for players with a cheering megaphone, the spectator did not have much interaction with the players." (E-6-1)

Spectator's lack of understanding of the rules resulted in a poor spectator experience: many details of the rules are not explained clearly during the game. On top of this, most spectator members have never played HADO. Therefore, the spectator experience is affected when the spectator does not fully grasp why things are happening in the game.

"You get a basic idea about the rules after watching the illustrations but you will only know the details after playing the game yourself." (D-4-8)

"I do not know some of the rules nor why certain techniques are considered advanced in the game." (C-4-3) "

Potential negative experience resulting from the way the spectator watches the game: the locations of the actual players and those of the projected players on the screen can affect the spectator's immersion in the game.

"Watching the game live is like watching the players punching the air, which affects the spectator immersion." (A-6-3)

"There is nothing cool when you just watch the players. I think this will affect the spectator's perception on the players." (H-6-5)

3. After watching:

Expectation gap in AR sports events: most interviewees had set their expectations towards AR effects based on movies and anime that they had watched—they expected to see next-level effects. However, there was a big gap between their expectation and reality and, as a result, most of them were not willing to return.

"I thought it would be fancier. I thought I could see something flying and spinning, all those spectacular and amazing effects. That would have been more entertaining. HADO is all about visual effects so the game should be more entertaining." (D-4-11)

"At first, I thought I could see some fancier moves, like curveball or something." (B-4-5)

"This game is all about both sides fighting. They should make it look like anime, like Dodge Danpei Manga where the ball would loop-de-loop or like The Prince of Tennis, where the players play like they have superpowers." (C-4-27)

Game excitement will affect the spectator's intention to return: with a lack of willingness to go and watch the game, whether or not future events have any surprises or special features will be the deciding factor for the spectator to come back.

"It depends on if HADO comes up with something new. If not, I will not come back." (F-4-19)

"I don't want to come back to another HADO event. It is not what I expected if this is all there is to it." (D-4-16)

Questionnaires and Quantitative Analysis Results

This study mainly relies on qualitative analysis, supplemented by quantitative data. The questionnaires for the satisfaction toward the HADO's online event in this study included customer loyalty indicators, experience satisfaction and other factors that interviewees believed were crucial to their spectator experience. Each value that an enterprise provides to its customers is called a driving factor, which creates customer loyalty. When these factors have proper interaction, customer loyalty will gradually build up (Naoki Endo & Yukiko Takei, 2015). The results obtained from the questionnaires were analyzed and compiled using the slope of linear regression to understand the correlation between loyalty indicators, experience satisfaction and the driving factors. The higher a coefficient of determination (R squared) is, better model explains and predicts future outcomes, which provides a clear direction for improvement. Experience satisfaction questionnaires comprised five factors, including sensory factor, emotional factor, service experience, thinking factor and association factor (Huang, 2007; Schmitt, 1999). With the exception of NPS, the questions in this study's questionnaire all used the Likert scale.

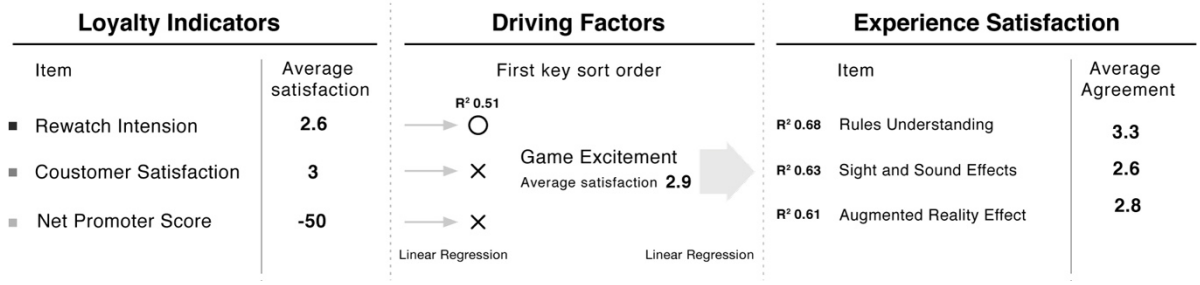

Figure 11 Quantitative Analysis Structure.

Customer loyalty is a quantifiable indicator that measures a customer's devotion. This study uses *overall customer satisfaction*, *rewatch intention* and *net promoter score* (NPS) to measure customer loyalty. The result shows a -50 of overall NPS, average 3 in overall customer satisfaction and an average 2.6 in rewatch intention, a clear indicator that customer loyalty needs to be improved. The interviewees considered game excitement as the most important driving factor, for which HADO only scored a mediocre 2.9.

The study used the slope in linear aggression to compile data and understand the correlation between customer loyalty indicators, experience satisfaction and driving factor satisfaction; it discovered that, other than moderate correlation between NPS and overall customer satisfaction, there is no correlation in other combinations. The results from the qualitative interviews show that most interviewees have higher NPS and overall satisfaction because the event is something they have never experienced before. However, rewatch intention truly reflects viewing satisfaction, therefore representing the most relevant indicator when it comes to the experience itself.

Rewatch intention and *game excitement* (first-ranked driving factor) are moderately correlated (coefficient of determination $R^2 = 0.51$). Therefore, enhancing game excitement will effectively boost the spectator's rewatch intention. To understand factors that affect game excitement satisfaction, we analyzed game excitement and *viewing satisfaction* and discovered the three aspects with the highest correlation to game excitement: *rules understanding*, *sight and sound effects* and *augmented reality effect*. Optimizing these three factors will boost the spectator's satisfaction toward game excitement, which will in turn affect rewatch intention.

5. Results

After comparing the questionnaires and contextual analysis of both live and online HADO events, we verified that the issues are consistent. By combining qualitative and quantitative data, we were able to pinpoint the factors that truly affect spectator experience, giving us a clear direction on how and where to assign resources to effectively improve it. Lastly, we listed the core pain points and direction for optimization of HADO's spectator experience (Table 1).

Table 1 Spectator experience Issues in HADO's Live and Online Events

	Before watching	**Watching game**	**After watching**
Phase I Questionnaire with live spectator	Lack of understanding of the event Curious about AR sports events	The way to watch the game needs optimization Lack of interaction while watching the game	Different than previously expected
Phase II Questionnaire three aspects in the experience factor that affects rewatch intention	Level of understanding of the game rule	Sight and sound effect AR effect	
Contextual analysis Pain points and discoveries	Having experience playing games will increase understanding of the game Poor spectator experience due to a lack of understanding off the rules	AR, sight and sound effect require improvement Lack of interaction while watching the game	A gap from the original expectation affects experience satisfaction. The novelty of the game will affect the willingness and interest of watching the next time
Concluded issues	Self-experience, understanding of the game format and details	Sight and sound effects, AR effects, interaction while watching	Expectations for AR events

A lack of understanding of the game rules and without prior HADO experience resulted in poor understanding of the game, which was the main issue for the spectator before watching. Therefore, it is necessary to help the spectators to understand the game. However, HADO cannot be played at home; we can only play it at some of the HADO stores. Thus, it is suggested that Meleap should utilize other contact points (website, mobile app, etc.) to allow users to get a glimpse of what it is like to play HADO, which will help them understand the game better while watching.

AR is a technology that provides unique visual experience; however, some spectator members believed that the AR effects in the game, as well as the light and sound effects, were not impressive enough, and deteriorated their satisfaction of in-game excitement. Moreover, we found that a lack of interaction during the game left so most spectators without memorable or interesting experience.

This researcher also suggests that the Company combine online and offline event communication channels to provide spectator with a seamless user experience, in order to enhance game interaction (Mirsch, Lehrer and Jung, 2016; Trenz, 2015). Finally, to reduce the expectation gap toward an AR sports event after watching the game, the Company can refer to the visual effects from other e-sports events, anime, video games or movies, and incorporate them into HADO's AR spectator experience design.

6. Conclusion and Suggestions

6.1 Challenges and Issues of AR Spectator Experience

Although we pointed out the problem of lacking understanding of the game rules in the previous discussing on HADO, it's actually a problem that all games will face. Therefore, it won't be discussed in this section. Based on the discussions and analysis on the issues of spectator experience in HADO events, this study categorized the challenges and problems of AR spectator experience into two aspects: user expectation and AR characteristics. These can serve as reference for any future studies involving AR event spectator experience (Figure 12).

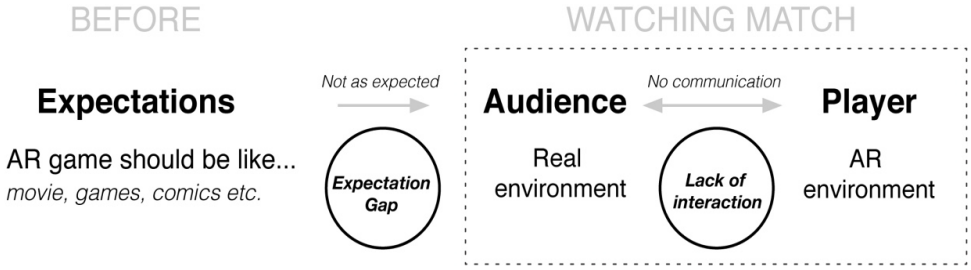

Figure 12 Challenges and issue in AR Spectator experience.

Challenges and issues of AR spectator experience as a result of high user expectations: for most users, watching an AR sport event is a completely brand-new experience. They base their understanding of AR on the special effects they have seen in animations, movies, anime and videogames—which have very sophisticated effects. Being used to such high-quality visual and sound effects, they have very high expectations and standards toward AR effects.

Issues and challenges from AR sports events: compared to traditional sports events, the biggest difference with AR sports events is that the special effects on balls or other objects can only be seen on screen. However, this combination of real and virtual worlds restricts the spectator's interaction with the players. In a traditional sports event, live spectator members can see the game with their own eyes, and the players can hear and respond when the spectator cheers for them. However, in an AR sports event, the players are in a mixed (virtual and real) environment once they put on AR goggles. Even though they can see the real environment, a wall still exists between them and the reality. This relegates the players and the spectator in two different environments with little to no connection or interaction.

6.2 Design Opportunities

Based on the above discussion, we divide the design opportunities in the future into two parts: 1. Way of watching games, 2. Entertainment.

Previous discussion mentioned that the way of watching game through a projection screen is still to be optimized. The way of watching game is the basis element of all game watching experience. Only with a good and comfortable way of watching can user meet the basic needs. Although The most ideal way is providing spectators with an AR device that can simultaneously see the AR effect of the game, high cost and technological difficulties causes it unachieved currently. We suggest that in the future, developing an application as the second screen for spectators, such as a mobile App, or a device which is provided at the off line venue to assist game watching. These tools should be helped audience to get real-time information about the game, and it's a role of an assistant. In addition, due to the limit of AR technology, the playing field must have at least two walls to position player's location, and with the placement of the projection screen. These causes that spectators have only single watching angle and they are in an undesirable situation. So, we could consider how to design a venue that can break the established pattern. Summarize the design opportunity about the way of watching are divided into physical and digital channels: physical channel is spatial planning and design of the physical field; digital channel is App or software design.

The foregoing discussion found that AR games bring a lack of interactivity between physical and virtual environment, and it is difficult to establish a connection between the spectator and the event. In addition to increase activity in live events is necessary solution. however, with the development of the Internet, the integration of online and offline cross-channel experience is an aim we should pay attention to. we suggest that a digital tool can be used to develop some interactions and activities, it can motivate the motivation of connection and build the relationship of offline and online spectators, and spectators and players. F

or example, using app to create activities that help spectators interact with the game, establishing activities that both online and offline spectators can participate in together, etc.

6.3 Future Work

This study is the first to explore and discuss user experience design in watching AR sports events. With a unique case study, this research conducted an in-depth analysis of the current issues facing the experience of watching AR sports events, and proposed suggestions for optimization. We will continue to explore other design strategies to optimize the experience of watching AR sports events and seek the best solution by multidisciplinary co-creation. We will then test and verify this strategy to determine an appropriate method to test service design prototypes in spectator experience.

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About the Authors:

Pei-Ling Shih is a Master's student in National Taiwan University of Technology. Her research is focus on user experience design and service design.

Hsien-Hui Tang is a Full Professor at the Design Department at National Taiwan University of Science and Technology and the director of the Design Innovation Thinking Lab. His research and practice interests lie in user experience & service design innovation.

Shu-Yi Chen is an Assistant Professor in the Department of Information Management at Ming Chuan University, and the co-supervisor of the Design Innovation Thinking Lab. His research interests include user experience, human information interaction, and human computer interaction.

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Visual Representations of Taiwanese Endemic Bird Species on Digital Media

Chia-yin YU[a]*

[a] Fu Jen Catholic University, Taiwan
*Corresponding author e-mail: 140467@mail.fju.edu.tw
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Abstract: This study investigated the aptness of digital-media visual representations of Taiwanese endemic bird species. First, expert interviews were conducted to obtain crucial graphic design-related bird features. Second, we applied graphic rendering and overall-conformation extraction to three stylizations—2D design and color block, 2D design and gradation, and stereoscopic effect and gradation. Degrees of similarity were tested, involving 239 participants aged 20–45. The results showed that (1) the crucial features in bird-related graphic design are body-part color, overall tone, the conformation of individual body parts, overall contour and style, and wing color. (2) Graphic designs based on the 2D design and color block approach yielded the greatest recognizability. (3) In single-colored birds, color contrasts constitute the most apparent features. (4) The conformation of bird body parts should be retained in bird-related design for better visual representations and recognizability. Further study will adopt interactive information design and explore digital-media applications of visualized bioinformatics.

Keywords: endemic bird species of taiwan; visual graphics; animal graphic design; flat design

1. Introduction

Among endemic species in Taiwan, birds are the most crucial indicator of environmental quality. By observing birds, the importance of environmental protection can be better appreciated, and the relationship between natural–environmental changes and the lives, health, and safety of an area's residents can be better understood. Thus, this study investigated the aptness of digital-media visual representations of Taiwanese endemic bird species. In addition to size limit, this study aimed to understand how graphical representations of birds on digital media balance between visual fatigue and visual aesthetics as well as between features of appearance and their recognizability. Different levels of graphic design stylization and degrees of similarity were tested to investigate how stylized designs affect recognition accuracy, which could be design references for designers to make

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visual information more efficient on digital media.

2. Literature Review

2.1 Graphics

Graphics are typically reproductions of figurative objects. For easier visual communication, reproduced graphics are simplifications of the original object. Most reproduced graphics are of the form of an explicit simile, or a 'signifier'. According to Riding and Ashmore (1980), human beings are either verbalizers or imagers when absorbing visual information. Verbalizers use words to analyze what they see, and imagers use inner, habitual mental images when seeing. The difference between them lies in their preferred method of absorbing information. In contrast to words, graphics are more salient and memorable (Ashcraft, 1993; Messaris, 1997). In designing the graphical representations of real objects, simplification is the most commonly applied method. In graphical simplification, an original object's main elements are extracted and their inter-relationships are represented. These extracted elements are considered to constitute an adequate representation of the original object. The method of simplification can be divided into two types: extraction of overall conformation and extraction of partial features (Hsu & Wang, 2010). In extraction of overall conformation, the proportion of the whole structure and its features are retained. Viewers can identify the original based on the simplified overall conformation and proportion. Extraction of partial features, by contrast, puts less emphasis on the overall structure, focusing instead on retaining important features of the original. Viewers can recognize what the graphics represent based on their experience (see Table 1).

Table 1 *Examples of graphic simplification*

Extraction of the overall conformation	Extraction of partial features

2.2 Stylized design

Hiebert (1998) believed that the transformation of graphics from figuration to abstraction is a process of simplifying existing objects. As the level of abstraction increases, designers can add more conceptual ideas to the design, allowing them to convey their desired message through the graphics. In addition to mere abstraction, designers also employ various other techniques to accentuate detail, through stylization, when simplifying objects to convey their desired message. Stylized objects or graphics not only deepen the impressions of viewers but also enable greater self-awareness through the viewer's interpretation of the meaning

behind the graphics, in addition to enabling constant self-examination (Grubb & Grathwohl, 1967; Kleine III, Kleine, & Kernan, 1993; Atakan, Bagozzi, & Yoon, 2014a; 2014b). Meyer and Laveson (1981) classified graphics (from realistic depictions to pure abstractions) into five levels as follows: (1) natural photography, where the visual features of objects are realistically depicted through photography; (2) pictorial illustration, where the visual features of objects' appearance are realistically depicted through refined presentations of textures and the selective presentation or augmentation of detail; (3) graphical renderings, where shape and contour details of objects are preserved through painting techniques, thus representing color and texture in the form of blocks; (4) graphic symbology, where the shape and contour details of objects are transformed into flat graphics and color blocks by removing color, texture, and the stereoscopic effect; and (5) abstract symbology, where conceptual ideas are represented by skewing the original shape and contour details of objects (see Figure 1).

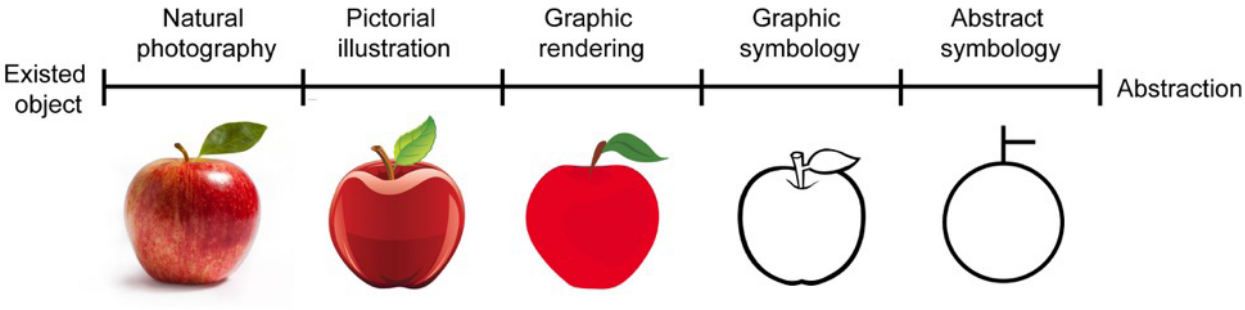

Figure 1 *Stylization levels proposed by Meyer and Laveson (1981) (re-illustrated and used in this study)*

2.3 Endemic bird species in Taiwan

According to the official website of the Endemic Species Research Institute, Council of Agriculture, Executive Yuan, 15 endemic bird species were spotted in 2017. As depicted in Table 2, 10 species are of an identical color, three species have small differences in appearance (the collared bush robin *Tarsiger johnstoniae*, Taiwan firecrest *Regulus goodfellowi*, and yellow tit *Parus holsti*), and two species have large differences in appearance (Mikado pheasant *Syrmaticus mikado* and female Swinhoe's pheasant *Lophura swinhoii*).

Table 2 *Endemic bird species of Taiwan*

Taiwan hill partridge (Arborophila crudigularis)	Taiwan blue magpie (Urocissa caerulea)	Taiwan barwing (Actinodura morrisoniana)	Taiwan Liocichla (Liocichla steerii)	Male Mikado pheasant (Syrmaticus mikado)

Female Mikado pheasant (Syrmaticus mikado)	Taiwan whistling thrush (Myophonus insularis)	White-eared sibia (Heterophasia auricularis)	Male yellow tit (Parus holsti)	Female yellow tit (Parus holsti)
Male Taiwan firecrest (Regulus goodfellowi)	Female Taiwan firecrest (Regulus goodfellowi)	Male collared bush robin (Tarsiger johnstoniae)	Female collared bush robin (Tarsiger johnstoniae)	Male Swinhoe's pheasant (Lophura swinhoii)
Female Swinhoe's pheasant (Lophura swinhoii)	Taiwan bush warbler (Locustella alishanensis)	Taiwan laughing thrush (Garrulax morrisonianus)	Taiwan yuhina (Yuhina brunneiceps)	Taiwan Bulbul (Pycnonotus taivanus)

Current research on Taiwanese endemic animal and plant species have focused on conservation, habitual behaviors, and their ecological environment. In particular, most books on Taiwanese endemic bird species are illustrated handbooks. These books order their content based on *The Checklist of Birds of Taiwan* (Bird Record Committee, Chinese Wild Bird Federation, 2017) and *Clements Checklist of Birds of the World* (Cornell Lab of Ornithology, 2017). However, those who do not understand the sorting system, especially those who know little about birds, find it difficult to retrieve the desired information from these books. The detailed knowledge contained in those books also cannot be properly absorbed and used by these readers. In biological species–related graphic design, the aim is to deepen the readers' understanding and make their learning more efficient by enabling the visualization of information. Despite size constraints and the need to balance between visual fatigue and visual aesthetics, digital-media graphics are typically semi-figurative and abstract, typically presented as graphic renderings, graphic symbology, and abstract symbology. This study focused on simplified digital-media graphic designs of Taiwanese endemic bird species, investigating how features can be better retained and recognizability can be better enhanced.

3. Methods

3.1 Visual features of Taiwanese endemic bird species

Expert interviews were conducted to understand the key visual features of Taiwanese endemic bird species. The interviewees were four professionals in the field of visual design with more than five years of experience. Interviewees were interviewed on the key features, the rationale behind visual identification, and the focus of the visual design. Interviewees were also asked to rank the importance of each feature and element in the graphic design of Taiwanese endemic bird species. As for the interview results, the key features identified were divided into three categories of color, contour and style, and personified characters. And the foci of visual design from most to least principal were (1) color of the individual body parts, (2) overall tone, (3) conformation of the individual body parts, (4) overall contour and style, (5) color of wings, (6) style and length of tail feathers, (7) size and length of the body, (8) color of tail feathers, (9) color of beak, and (10) color of feet.

3.2 Graphic design of Taiwanese endemic bird species

The graphical representations of the Taiwanese endemic bird species were designed based on the interview results of expert interviews. The first five of the aforementioned features were used as the focus of design: (1) color of individual body parts, (2) overall tone, (3) conformation of individual body parts, (4) overall contour/style, and (5) color of wings. In total, 20 graphic designs were made for 15 Taiwanese endemic bird species (both male and female). The method of overall-conformation extraction was used for graphical simplification. Graphic rendering, commonly seen in digital media, was adopted to retain the shape and contour details of birds within the hierarchy of stylization. Three sets of graphics of Taiwanese endemic bird species with different stylization levels were produced to examine differences with respect to degrees of matching. Each set comprised 20 graphics of Taiwanese endemic bird species of both genders, for a total of 60 graphics (see Tables 3). The different levels of stylized design are as follows.

- 2D design and color block, where the color and texture of the bird's appearance is transformed into color blocks in the 2D design style.
- 2D design and gradation, where the texture of the bird's appearance is transformed into color blocks and gradation is used to detail the bird's feathers; the 2D design style is adopted.
- Stereoscopic effect and gradation, where the texture of the bird's appearance is ignored and gradation and shadow are used instead to detail the stereoscopic effects of color and contour.

Table 3 Graphic designs of Taiwanese endemic bird species

Hierarchy of stylization	2D design and color block	2D design and gradation	Stereoscopic effect and gradation
Taiwan hill partridge (Arborophila crudigularis)			
Taiwan blue magpie (Urocissa caerulea)			
Taiwan barwing (Actinodura morrisoniana)			
Taiwan Liocichla (Liocichla steerii)			
Male Mikado pheasant (Syrmaticus mikado)			
Female Mikado pheasant (Syrmaticus mikado)			
Taiwan whistling thrush (Myophonus insularis)			
White-eared sibia (Heterophasia auricularis)			
Male yellow tit (Parus holsti)			
Female yellow tit (Parus holsti)			
Male Taiwan firecrest (Regulus goodfellowi)			

Female Taiwan firecrest (Regulus goodfellowi)			
Male collared bush robin (Tarsiger johnstoniae)			
Female collared bush robin (Tarsiger johnstoniae)			
Male Swinhoe's pheasant (Lophura swinhoii)			
Female Swinhoe's pheasant (Lophura swinhoii)			
Taiwan bush warbler (Locustella alishanensis)			
Taiwan laughing thrush (Garrulax morrisonianus)			
Taiwan yuhina (Yuhina brunneiceps)			
Taiwan Bulbul (Pycnonotus taivanus)			

3.3 Test of degrees of similarity

The degree of similarity was tested using a between-subjects design. The test was issued in the form of an electronic questionnaire, so the participant had to use a digital media such as computer or smartphone to complete the test. Specifically, participants were asked to match the bird's graphical representation with its photographic image. A five-point Likert scale was used. Participants were asked to judge the similarity between the graphical and photographic images and to state the rationale behind their visual identification. Because some participants may have knowledge on birds, the names of birds were not shown during the whole test. Only the graphical and photographic images were provided. Participants were aged 20–45 and were familiar with the use of mobile applications. Besides, to enable

the conduct of follow-up studies, the anticipatory scenario was not limited to indoor use. The graphics could be quickly retrieved and compared with the birds observed during bird watching activities. The photos of birds in the test were also taken from books on other birds and not limited to those of birds in the Taiwanese endemic bird species. Photographs of the sibling species of Taiwanese endemic bird species were also given to participants to examine whether they could correctly distinguish between the graphically represented birds and their similar-looking counterparts. Table 4 lists those birds that have a similar appearance with their counterparts in the Taiwanese endemic bird species.

Table 4 Sibling species of Taiwanese endemic bird species (Liao, 2017) (provided by this study)

Brown-flanked bush warbler (Horornis fortipes)	Light-vented Bulbul (Pycnonotus sinensis)	White-browed bush robin (Tarsiger indicus)	Streak-throated Fulvetta (Alcippe cinereicps)	Eurasian magpie (Pica pica)
Goldcrest (Regulus regulus)	Red-billed blue magpie (Urocissa erythroryncha)	Green-backed tit (Parus monticolus)	Blue whistling thrush (Myophonus caeruleus)	Blue rock thrush (Monticola solitarius)

4. Result

In total, 239 valid questionnaires were collected. Among them, 80, 79, and 80 participants were tested for the 2D design and color block, 2D design and gradation, and stereoscopic effect and gradation, respectively. According to the results, the graphics of Taiwanese endemic bird species that were designed using the 2D design and color block approach yielded the highest overall degree of similarity (86.5%), followed by those designed using the stereoscopic effect and gradation (85.81%) and 2D design and gradation (84.49%) approach. The results for the degrees of similarity and visual similarity are detailed in Table 5 and 6. And the result for total number of rationale of visual identification is in Table 7.

Table 5 Degree of similarity results

	Degree of similarity		
	2D design and color block	**2D design and gradation**	**Stereoscopic effect and gradation**
Taiwan Bulbul (Pycnonotus taivanus)	96.25%	100%	97.5%
White-eared sibia (Heterophasia auricularis)	58.75%	54.43%	73.75%
Taiwan whistling thrush (Myophonus insularis)	96.25%	96.2%	95%
Taiwan hill partridge (Arborophila crudigularis)	95%	92.41%	92.5%
Taiwan Liocichla (Liocichla steerii)	96.25%	91.14%	88.75%
Taiwan laughing thrush (Garrulax morrisonianus)	47.5%	27.85%	50%
Taiwan yuhina (Yuhina brunneiceps)	97.5%	100%	97.5%
Taiwan barwing (Actinodura morrisoniana)	88.75%	88.61%	87.5%
Taiwan blue magpie (Urocissa caerulea)	92.5%	88.61%	91.25%
Taiwan bush warbler (Locustella alishanensis)	63.75%	41.77%	47.5%
Male Taiwan firecrest (Regulus goodfellowi)	83.75%	96.2%	91.25%
Female Taiwan firecrest (Regulus goodfellowi)	80%	70.89%	75%
Male Mikado pheasant (Syrmaticus mikado)	80%	79.75%	72.5%
Female Mikado pheasant (Syrmaticus mikado)	91.25%	93.67%	91.25%
Male collared bush robin (Tarsiger johnstoniae)	92.5%	93.67%	92.5%
Female collared bush robin (Tarsiger johnstoniae)	96.25%	98.73%	96.25%
Male Swinhoe's pheasant (Lophura swinhoii)	90%	89.87%	88.75%
Female Swinhoe's pheasant (Lophura swinhoii)	86.25%	93.67%	92.5%
Male yellow tit (Parus holsti)	98.75%	98.73%	98.75%
Female yellow tit (Parus holsti)	98.75%	93.67%	96.25%
Total/average	86.5%	84.49%	85.81%

Table 6 Visual similarity results

	Visual similarity		
	2D design and color block	**2D design and gradation**	**Stereoscopic effect and gradation**
Taiwan Bulbul (Pycnonotus taivanus)	89%	92.41%	89.75%
White-eared sibia (Heterophasia auricularis)	72%	74.94%	77.25%
Taiwan whistling thrush (Myophonus insularis)	73.5%	78.73%	78.25%
Taiwan hill partridge (Arborophila crudigularis)	79%	84.56%	84.5%
Taiwan Liocichla (Liocichla steerii)	71.5%	73.42%	73.5%
Taiwan laughing thrush (Garrulax morrisonianus)	57.75%	62.03%	58.5%
Taiwan yuhina (Yuhina brunneiceps)	89%	89.87%	87.75%
Taiwan barwing (Actinodura morrisoniana)	77.75%	80%	79.25%
Taiwan blue magpie (Urocissa caerulea)	82%	82.28%	80%

Taiwan bush warbler (Locustella alishanensis)	54.5%	54.43%	55.25%
Male Taiwan firecrest (Regulus goodfellowi)	79%	87.09%	82.75%
Female Taiwan firecrest (Regulus goodfellowi)	70%	70.63%	70.25%
Male Mikado pheasant (Syrmaticus mikado)	76%	72.91%	72%
Female Mikado pheasant (Syrmaticus mikado)	73%	76.96%	78%
Male collared bush robin (Tarsiger johnstoniae)	83.25%	81.01%	78%
Female collared bush robin (Tarsiger johnstoniae)	83.75%	86.58%	83.25%
Male Swinhoe's pheasant (Lophura swinhoii)	79.75%	82.78%	78.25%
Female Swinhoe's pheasant (Lophura swinhoii)	79.25%	81.01%	79%
Male yellow tit (Parus holsti)	88.75%	91.9%	88.75%
Female yellow tit (Parus holsti)	81.5%	80.51%	80.5%
Total/average	77%	79.2%	77.74%

Table 7 Total number of rationale of visual identification (number of people)

	2D design and color block	**2D design and gradation**	**Stereoscopic effect and gradation**
Color of individual parts	1026	1055	1025
Overall tone	680	726	737
Conformation of individual parts	809	906	844
Overall contour/style	661	663	817
Color of the wings	329	373	313
Others/no similarity	14	9	11

Because the 2D design and color block approach had the highest overall degree of similarity (86.5%), this study further investigated it concerning visual identification. The degrees of similarity for 17 out of 20 birds were higher than 80%. Among them, the degrees of similarity for eight birds were over 95%. The degrees of similarity for both male and female yellow tits (*Parus holsti*) were 98.75%. The degree of similarity for the Taiwan yuhina *Yuhina brunneiceps* was 97.5%. The degrees of similarity for the following birds were 96.25%: Taiwan Bulbul *Pycnonotus taivanus*, Taiwan whistling thrush *Myophonus insularis*, Taiwan Liocichla *Liocichla steerii*, and female collared bush robin *Tarsiger johnstoniae*. And the degree of similarity for the Taiwan hill partridge *Arborophila crudigularis* was 95%.

Thus, the results demonstrated that based on most of the graphics of birds designed by this study, participants could clearly distinguish between birds of similar appearance. The degrees of similarity of the following three birds were lower than 80%: Taiwan bush warbler *Locustella alishanensis* (63.75%), white-eared sibia *Heterophasia auricularis* (58.75%), and Taiwan laughing thrush *Garrulax morrisonianus* (47.5%). The results indicated unclarity in the participant rationales underlying visual identification, thus indicating their limited usefulness. According to participants, the gradation of feathers of some birds was crucial for identification. Thus, the sole use of color blocks potentially

impedes identification. Moreover, when viewing many birds that are similar in appearance and overall tone, the participant rationales underlying visual identification as follows: (1) color of individual body parts, (2) conformation of individual body parts, (3) overall tone, (4) overall contour/style, and (5) color of wings, similar to the expert interview results. Notably, the conformation of individual body parts were, however, more critical for participants than for experts, indicating that more considerable attention should be paid to this element in the design of bird graphics.

5. Conclusion

Taiwanese endemic bird species are essential in Taiwanese culture. The comprehensive understanding of their visual features and the use of such features in the design of teaching materials on ecology can deepen not only the impressions of users regarding these birds but also aid the in-depth investigation of the ecology and culture of Taiwan. This study explored the aptness of the digital-media visual representations of Taiwan's endemic bird species. The methods of graphic rendering and overall-conformation extraction were adopted. Three levels of stylization were adopted in the graphic design: the 2D design and color block, 2D design and gradation, and stereoscopic effect and gradation approach. Degrees of similarity were tested to understand how accurately the graphical representations depicted the actual birds. According to the results, when participants used digital media, such as computer or smartphone, to viewed birds with similar appearances, the graphic designs using the 2D design and color block approach yielded the highest degree of similarity (86.5%), followed by stereoscopic effect and gradation (85.81%) and 2D design and gradation (84.49%) approaches. The study's findings are as follows.

1. The expert interviews and test of degree of similarity demonstrated that when designing the graphical representation of birds, the visual foci are as follows, from least to most important: (1) color of individual body parts; (2) overall tone; (3) conformation of individual body parts; (4) overall contour/style; and (5) color of wings.
2. The 2D design and color block approach yielded the highest degree of similarity. The gradation of the feathers of some birds, however, was crucial for identification and must be retained in the graphic design.
3. The color contrast of single-colored birds constitutes their most noticeable feature and thus aids identification.
4. The conformation of individual body parts aids the distinguish of birds from their similar-looking counterparts. Therefore, such conformation must be retained in bird-related graphic design for better visual representations and recognizability.

Taiwanese endemic bird species are not only a natural wonder but also crucial for the development of culture and aesthetic education in Taiwan. Through investigating the aptness of digital-media visual representations of Taiwanese endemic bird species, we understand how graphical representations of birds on digital media balance between visual fatigue

and visual aesthetics as well as between features of appearance and their recognizability. In general, this study can contribute to graphic design, information design, design process, visual communication, and education. However, the screen sizes of current digital media are different. By issuing the electronic questionnaires, we are not able to know precisely which kind of digital media participants used to fill in the answers. Furthermore, when the different levels of stylized design showed on a small-screen digital device, the graphics might look very similar, which could result in the similarity score were closed. Bird graphics that had a low degree of similarity should be further discussed and improved. Moreover, through interactive information design, more variety in the test material, such as an animated version or film recording, could be conducted and lead to clearer differentiation. The representation and interaction on digital media applications, such as smartphones and tablet computers, to visualized bioinformatics should be further investigated.

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About the Authors:

Chia-yin Yu got her ph.D. in Design from the National Taiwan University of Science and Technology (NTUST). Now she is an assistant professor at the Department of Applied Arts, Fu Jen Catholic University. She is skilled in visual communication, user-centered design, and consumer emotion.

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The effect of digital design representation on designers' visual attention

Rongrong YU[a]*, John GERO[b]

[a] Griffith University, Australia
[b] University of North Carolina at Charlotte, USA
*Corresponding author e-mail: r.yu@griffith.edu.au
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Abstract: This paper presents the results of an exploratory study on the effect of observing different digital design representations on designers' visual attention. Forty-five third-year and fourth-year architecture students participated in an experiment, in which they were asked to view a floorplan, a computer-generated hidden-line perspective, and a digital photograph of the same space in varying orders. Their eye-tracking data was recorded using a Tobii eye-tracker. The results indicate that complex spaces receive more attention and foreground areas attract designers' visual attention more quickly than other spaces.

Keywords: digital representation; eye tracking; visual attention

1. Introduction

Design representation is a core issue in most design domains including product design, architecture and engineering. It is considered as an essential tool to support design thinking (Visser, 2006), reflection in action (Schön & Wiggins, 1992), facilitate dialogues of the designer with him/herself (Schön & Wiggins, 1992), and to communicate design intent to design team or clients (Cross, 2000). Past studies suggest that visual representations during the design process assist designers with their concept development (Schön, 1992). By exploiting the information of the design representation, the experienced designer can explore an infinite world of ideas and concepts (Akin, 2001). With the growing application of computational design tools, digital design representations are increasingly being used in the design process. One of the methods that can be used to explore the effects of different representations is to look into designers' physiological response such as eye movement, when they view different digital design representations. For example, Park et al. (2019) has explored the role of digital design representation in the architecture design process using eye tracking technology. The results of their study suggest that line drawings both attract and deflect visual attention, and practical drawing techniques have direct effects on visual

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perception. Using eye tracking technology to follow designers' visual attention, it is possible infer some of their design intentions. For example, Yu and Gero (2018) explored how a computer-aided tool is used by designers when they are carrying out architectural design tasks, by studying designers' eye movements. Their results suggest that designers spend more effort focusing on façades and relatively less on edges and corners, and that their eye gazes are focused primarily on the model, with only a few eye gazes at the menu of the user interface.

Despite the earlier research on the topic, currently there is a lack of knowledge regarding designers' physiological responses as they view different digital design representations of an architectural space. Also, given that architecture students view images of multiple designs and multiple images of the same design, what is not known is whether the order in which images are viewed affects their responses. We conducted a study utilizing eye tracking to collect physiological data, comparing responses to different digital design representations in varying orders. Researchers have been interested in how designers look at scenes (Rensink, 2000). Experiments typically present the scene on a computer screen, allowing for a high level of control over variables of the scene. The aim of this research is to determine the effects of different representation modalities and order of viewing images on the physiological response of architecture students as measured by eye-tracking. From the analysis of the relationship between designers' eye tracking data and different modalities of representation, designers' responses to digital design representation in varying order will be measured and compared. The remaining sections of the paper will describe the research background, experiment setting, analysis of the eye tracking data, and conclusions.

2. Research Background

2.1 Visual attention studies based on eye tracking

Early research into visual attention based on eye movement can be traced to Buswell (1935), who focused on the aesthetic impact of photographs of artwork, patterns and sculpture, particularly the layout patterns of advertisements. Kaufman and Richard (1969) measured eye fixation times in several pre-defined parts of figures. They identified that the centre of gravity is an attractor, as are the edges and corners.

Torralba et al. (2006) proposed visual attentional guidance through an experimental search task. Results of their study suggest that contextual information plays an important role in object detection and observation, and some parts of the scene attract more attention than others. While the relationship between eye movement and perception of artworks has been investigated, there has been very little study on the role of eye movement in the perception of three-dimensional architectural space. One of the few studies on this topic was conducted by Weber, Choi, and Stark (2002) in which they collected eye tracking data as participants were asked to look at three-dimensional models, or photographs of models, of architectural space. These models were constructed to collect data on the perception

of the following architectural issues: empty space; symmetry vs. asymmetry; left and right reversed; obliquely-oriented elements; vista; and foreground. The research focused on comparing different arrangements of objects within a space, rather than different methods of representing the same spatial configuration. Their results showed that, the attention would fixate at the center; while the foreground was common for initial fixations, the eye did not typically scan the edges of interior space or rectilinearly-oriented contours; the objects on the left attract more attentions than the ones on the right. This confirmed the results by Arnheim (1985), who also claimed that fixations did not vary significantly when viewing the three-dimensional model compared with a photograph of the model, with the exception of the foreground, which attracted greater attention in the 3D model.

To explore the correlation of designers' visual attention with their design thinking process, Guan et al. (2006) studied the validity and reliability of the retrospective think-aloud method, based on design experiments in which participants' eye movements were recorded and then they thought aloud as they viewed their eye tracked activity. Results of the study show that the recounting of what went on in the exercise was consistent to the sequence of objects in the same order, and that the differing level of complexity did not interfere with the validity of the retrospective think-aloud method. Eye movement can also be used to measure the emotional response of visual stimulation. For example, Tuszyńska-Bogucka et al. (2020) conducted an eye tracking experiment to measure respondents' reactions while looking at visualisations of various interiors, with the aim of verifying whether certain parameters of an interior are related to emotional reactions in terms of positive stimulation, and the sense of security and comfort. The authors concluded that architectural spaces can have a diverse emotional significance and impact on an individual's emotional state.

2.2 Digital design representation

Design representations are made before, during and after the process of designing. External design representation is particularly necessary for the purpose of communication in a design collaboration setting, as well as a means of conversation with themselves for individual design processes (Goldschmidt & Porter, 2004). Design representation serves both as a tool for design thinking and communication (Self, Lee, & Bang, 2015). Traditionally designers use sketching as their main design representations, since sketching is an effective way of amplifying and extending mental imagery, not only a document for ideas but also generating them (Do, Gross, Neiman, & Zimring, 2000; Fish & Scrivener, 1990). Sketching as a design representation plays an important role during conceptual design, because of its ambiguous nature, semantic density and ability for transformations between and among design ideas.

With the development of computational modelling, digital design representation becomes possible during the design process, which assists designers in both off-loading cognition and providing the possibility to interact with their external representations (Schön & Wiggins, 1992). For example, BIM technology enables 3D (model check, design view, enhanced reality) and 4D visualization (plus time) (Eastman, 2008). Virtual reality (VR) can provide realistic virtual environments which enable navigational possibilities (Wang & Dunston,

2013). Augmented reality (AR) can enhance the user's perception by complementing the real world with 3D virtual objects in the same space (Morrison et al., 2011). These computational design tools allow designers to more readily explore design ideas and assist with the concept development of their designs. Digital design representation serves a similar purpose as traditional design representation such as sketching, in terms of facilitating design thinking and communication. However, to date there is insufficient knowledge about the physiological effects of digital representations on designers.

3. Experiment setting

To address this knowledge gap, we conducted an exploratory eye tracking experiment to examine the effect of digital design representation on designers' visual attention. In this study, 45 third-year and fourth-year architecture students at Harbin Institute of Technology (HIT) in China participated. The students were divided into three groups of 15 students per group. During the experiment participants were asked to complete demographic questions regarding their age, gender and native language. They were required to look at three images shown on a screen, Figure 1: Image 1 was a computer-generated floorplan, Image 2 was a computer-generated perspective drawing, and Image 3 was a digitised photograph of the same space when fully built.

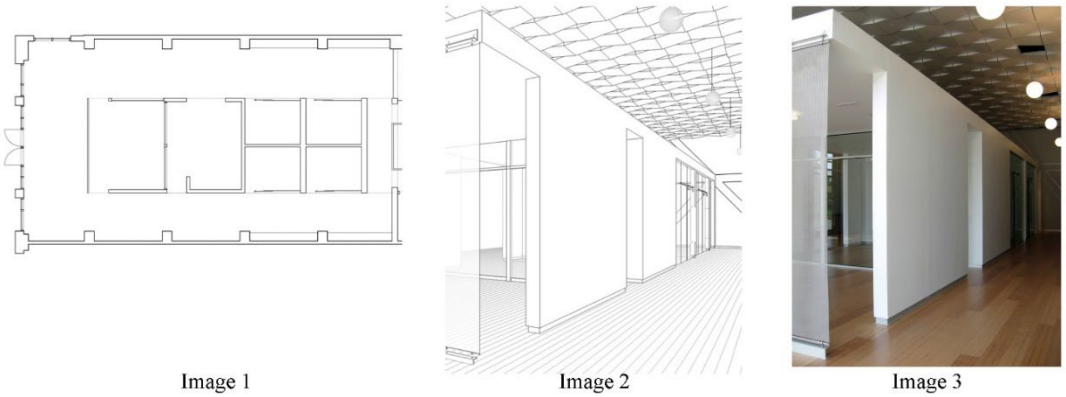

Figure Images 1, 2 and 3

When the participants looked at the images, their eye tracking data was recorded by an eye tracking system (Tobii studio). Each of the images were displayed for 20 seconds, with a few seconds for recalibration in-between them. The images were shown in a different order to each group: the first group of participants were first shown Image 1 then Image 2. The second group was first shown Image 1 then Image 3, and the third group was shown Image 2 and then Image 3. Figure 2 shows the experiment setting.

Figure 2 Experiment setting

Data collected during each session included eye fixations and saccades. For Images 2 and 3, we identified seven Areas of Interest (AOIs) in the visual scene presented, Figure 3. Each AOI defines an area where we wanted to gather data. AOIs defined the three doorways, the two wall surfaces between them, the terminus of the corridor and the ceiling.

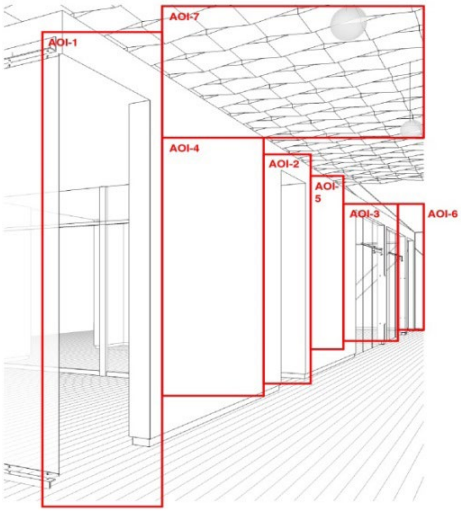

Figure 3 The seven Areas of Interest labelled AOI 1 through AOI 7 in Image 2, they occupy the same positions in Image 3.

4. Results

Figures 4 to 6 are the heatmaps of designers' viewing of the images in three of the different orders. Heatmaps represents the cumulative focus of visual attention of participants.

From a heatmap we can qualitatively observe that the participants' eyes focus area are similar regardless of the order of viewing of the images. This suggests that differences related to the viewing order are minor. For both Image 2 and Image 3, regardless of viewing order participants tended to focus on the complex spaces, such as AOI 3 and AOI 1. While for Image 1 which shows the floorplan, participant's eye gaze was located in the middle of the image, with a focus on spaces rather than edges.

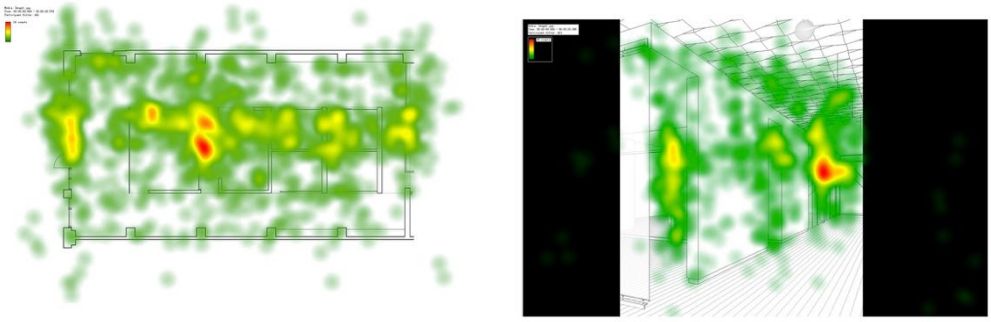

Figure 4 *Heatmap for Image 2 (right) after viewing Image 1: experiment 1-2.*

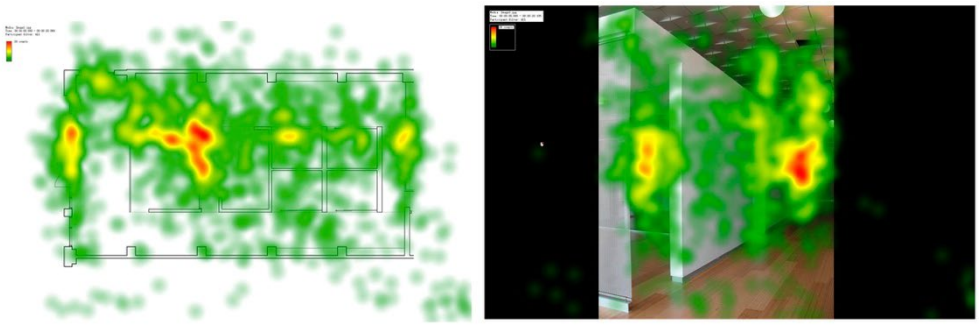

Figure 5 *Heatmap for Image 3 (right) after viewing Image 1: experiment 1-3.*

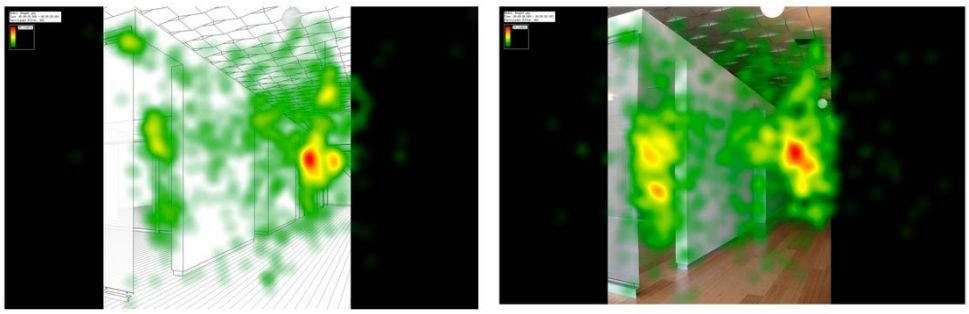

Figure 6 *Heatmap for Image 3 (right) after viewing Image 2: experiment 2-3.*

Tables 1 and 2 present the results of eye-tracking data for Images 2 and 3 in the three viewing orders. Four metrics for eye movement data were measured during the experiment: Time to First View (secs), Time Viewed (%), Fixations and Average Revisits. Time to First View measures how long it takes before a participant fixates on an active AOI for the first time. Time Viewed (%) is the percentage of time viewed within an active AOI of the total viewing time (total viewing time was 20 seconds in this experiment). Fixations measure the number of times the participant fixates on an AOI. The Average Revisits measures the number of visits within an active AOI. A visit is defined as the time interval between the first fixation on

the active AOI and the end of the last fixation within the same active AOI where there have been no fixations outside the AOI.

From Table 1 we can see that in the experiments where eye tracking was measured related to Image 2, AOI 3 is the first area of interest viewed irrespective of the order of viewing that participants looked at. AOI 1 is an opening with a complex space behind it, so would be expected that it would be a primary visual attractor. This is not the case here. Participants were initially attracted to AOI 3, which in Image 2 is a visually complex opening where the space behind it is unclear. AOI 3 was more attractive, presumably because the opening and the space behind required more cognitive effort to understand. AOI 6 is the last area to be viewed in both cases. It is the back wall of the hallway and has no distinguishing characteristics, so this result is to be expected. In experiment 2-3, AOI 3 has the longest time viewed, while in experiment 1-2, AOI 1 has the longest time viewed. These two AOIs have similar architectural features, i.e., they both are openings with spaces behind them. For both experiments, AOI 1 receives the most fixations. This may be because AOI 1 is in the front or the space through the door is relatively complex. The AOI with least fixation and time viewed is AOI 5 in both experiments, which may be due to the simplicity of the space of AOI 5. For both experiments, AOI 1 and AOI 3 show high revisit numbers presumably due to the complexity of the space behind them.

Table 1 Average eye-tracking data of participants – Image 2

Experiment	AOI name	Time to First View (secs)	Time Viewed (%)	Fixations	Revisits
Image 2 followed by Image 3; experiment 2-3	AOI-1	1.80	19.28	15.40	6.20
	AOI-2	2.45	6.94	5.27	4.00
	AOI-3	0.76	23.65	12.80	8.13
	AOI-4	1.28	5.37	5.27	3.87
	AOI-5	2.63	2.60	2.27	1.93
	AOI-6	6.27	7.42	5.73	3.27
	AOI-7	3.45	11.53	9.40	4.33
Image 1 followed by Image 2; experiment 1-2	AOI-1	1.03	26.76	21.53	6.80
	AOI-2	3.92	7.15	6.47	4.07
	AOI-3	1.14	19.22	10.87	6.07
	AOI-4	1.59	6.71	7.33	4.93
	AOI-5	2.95	1.59	1.40	1.33
	AOI-6	5.58	5.82	4.20	2.67
	AOI-7	1.55	12.67	10.00	4.27

From Table 2, we can see that for Image 3, unlike for Image 2, AOI 1 was the first to be viewed in one case, while AOI 4 was the first viewed in the other case, indicating that the sequence on viewing affects the how an image is viewed. AOI 6 was the last AOI that participants looked at in one case, while AOI 2 was the last viewed in the other case. In

both experiments, AOI 1 received longest time viewed, highest number of fixations and the highest number of revisits. This indicates that AOI 1 attracted the visual attention of the participants more than any other area. AOI 1 is an opening with a complex set of spaces behind it that requires more cognitive effort to read. This higher cognitive effort is reflected in these results.

Table 2 Average eye-tracking data of participants – Image 3

Experiment	AOI name	Time to First View (secs)	Time Viewed (%)	Fixations	Revisits
Image 2 followed by image 3; experiment 2-3	AOI-1	1.03	32.79	35.87	9.13
	AOI-2	5.52	4.62	6.00	4.00
	AOI-3	1.51	14.33	13.40	7.87
	AOI-4	0.43	7.27	9.73	5.47
	AOI-5	4.85	2.47	3.93	3.27
	AOI-6	4.92	4.76	5.07	3.67
	AOI-7	3.94	8.79	8.33	4.20
Image 1 followed by image 3; experiment 1-3	AOI-1	0.52	25.99	23.67	9.00
	AOI-2	3.74	7.02	5.87	3.60
	AOI-3	3.18	14.62	10.93	5.67
	AOI-4	1.09	5.88	7.20	5.07
	AOI-5	2.56	3.68	3.73	3.33
	AOI-6	9.63	3.65	2.87	2.00
	AOI-7	5.78	9.18	9.20	3.67

To further explore the effect of viewing order on designers' visual attention, we conducted paired t-tests to determine statistically whether the eye-tracking measurements of the same images when shown in different order are significantly different.

Table 3 shows the paired t-test comparison of Image 2, when viewing Image 1 to Image 2 and Image 2 to Image 3. From the table, we can see that time to first view only for AOI 7 is significantly different between the two experiments. Showing the floorplan before the computer-generated perspective, has a small effect on how Image 2 is read. There is a significant difference in revisits only for AOI 3. There are no other statistically significant differences.

Table 3 *Paired t-test comparison of Image 2 when viewing Image 1 then Image 2 and viewing Image 2 then Image 3*

	Sig. (2-tailed)						
	AOI 1	AOI 2	AOI 3	AOI 4	AOI 5	AOI 6	AOI 7
Time to First View	.423	.403	.163	.742	.869	.761	.015*
Time Viewed (%)	.136	.917	.256	.451	.386	.566	.672
Fixations	.352	.507	.223	.129	.309	.447	.833
Revisits	.843	.946	.011*	.316	.379	.461	.939

*p<0.05

Table 4 shows paired t-test comparison of Image 3, when viewing Image 1 before Image 3 and viewing Image 2 before Image 3. From the table, we can see that there are no significant differences in the eye tracking measurements, except for time to first view of AOI 6. The difference in AOI 6 means that designers who view the floorplan first, will look at AOI 6 much later. This may due to the understanding provided by the floorplan reducing curiosity about the complex space.

Table 4 *Paired t-test comparison of Image 3 when viewing Image 1 then 3 and viewing Image 2 then 3*

	Sig. (2-tailed)						
	AOI 1	AOI 2	AOI 3	AOI 4	AOI 5	AOI 6	AOI 7
Time to First View	.772	.343	.151	.068	.230	.026*	.367
Time Viewed (%)	.185	.547	.913	.576	.267	.397	.888
Fixations	.090	.184	.564	.304	.905	.186	.784
Revisits	.904	.624	.163	.754	.957	.139	.613

*p<0.05

5. Conclusion

This paper presents the results of an exploratory study, aiming to examine the effect of digital representations on designers' visual attention. From analysing eye tracking data of participants, the following conclusions can be drawn:

Firstly, when designers are viewing images, complex spaces usually receive more visual attention, for both perspective drawing and photographic images. This finding aligns with Gero, Sheilds, and Yu (2016), who suggested that eye fixation is focused on complex spaces. Certain features are more likely to attract the eye focus, for example on a face image the eye focus is usually on "eye" and "mouth" (Gould & Peeples, 1970). In architecture, past studies suggest that architects pay more attention to the spatial arrangement of various architectural elements (Weber et al., 2002).

Secondly, complex spaces in the front of an image are likely to attract attention faster, for

both perspective drawing and the photographic image. This complies with Weber et al. (2002)'s study which showed that the foreground was common for initial fixations. Gould and Peeples (1970) suggest that a subject's interpretation of a figure does not affect eye movements, which means that only "physical attributes" have influence on the eye movements. This means the foreground space which attracts more attention may not be affected by the interpretation of designers.

Thirdly, the order of displaying images had only a minor effect on designers' attention. For most of the areas, designers' visual attention did not change based on varying the order of images shown. However, differences were found in two AOIs, suggesting that displaying the floorplan first affects their later reading of the 3D space. This may possibly also be a result of all participants being architectural students who understand floorplans and have enhanced capabilities to imagine such spaces.

The findings of this research have provided a preliminary understanding of designers' visual attention for different digital representations. Digital representation plays an important role in designers' design processes. This study has measured designers' visual attention on various types of digital representations and examined the effect of different viewing orders for the digital representations shown to the designers. The results of this paper add to our understanding of designer's visual attention, providing insights for design cognition studies.

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About the Authors:

Dr Rongrong Yu is a lecturer in Architecture & Design at Griffith University. She has published broadly in international journals and conferences, within research fields including design cognition, computational analysis and parametric design.

Dr John Gero is a Research Professor in Computer Science and Architecture at the University of North Carolina at Charlotte. His research covers design theory, design computing, design cognition and design neurocognition. His research publications have received over 23,000 citations.

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A Theoretical Model of Similarity Judgment based on Ideas of Form and Spirit

Yifeng WEN[a]*, Ding-Bang LUH[a], Chi-Hua WU[a]

[a] Guangdong University of Technology, China, People's Republic of
*Corresponding author e-mail: yifengwen0912@163.com
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Abstract: Similarity is demonstrably important across many areas of cognition. At present, the main idea is that the similarity of a pair of objects increase with its commonalities and decrease with its difference. However, it's difficult to reasonably explain some counterintuitive situations that often occur. For example, people might find that someone looks similar with a dog, even though most shared features are dissimilar. Inspired by the ideas of form and spirit, we speculate that some key features of objects may have a greater impact on similarity judgment than the others. Therefore, this paper proposed a theoretical model of similarity judgment to illustrate the counterintuitive situation, indicating hierarchical or primary-secondary relationship among shared features between objects, expanding the scope of existing similarity theories. This model has potential applications in many aspects such as the development and protection of intellectual property, product design, game and film industries and so on.

Keywords: the ideas of form and spirit; similarity measurement; similarity judgment models

1. Introduction

Similarity is a basic and important concept in cognitive psychology. Assessment of similarity has great impact on human cognitive behaviours ranging from problem solving to memory retrieval to problem solving (Goldstone et al., 1997). The research of similarity comparison process can help us gain insight into other cognitive processes that involve similarity. The Feature-based model (Tversky, 1977), which is considered as one of the most representative models, assumed that people can recognize and list the features of the objects to be compared and comparing the list for overlap. After comparison, the matching features of two objects are called commonalities, while the mismatching features are called differences. The similarity of two objects increases with its commonalities and decrease with its difference, and the positive contribution of commonalities is greater than the negative contribution of difference. The maximum similarity between objects is reached when they are identical, no

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matter how much commonality they share (Lin, 1998).

Generally speaking, the more similar the matching features of objects, the more likely people are to judge that they are similar. But similarity is based not only on external properties of the stimulus, but also on one's internal representation (Roads & Mozer, 2017). In daily life, we often encounter some situation that against intuitions. For example, animals like cats or dogs have less commonalities with humans obviously, but we can often see comparison pictures of human and animals that are extremely similar on the internet. The other opposite example is that although some fake products can be very similar to the genuine products in shapes, they still can't replace the genuine products in people's mind.

Inspired by the ideas of forms and spirit, this study refers to this phenomenon as "similar in spirit" and "similar in form". The ideas of form and spirit is a philosophical debate that has lasted for thousands of years since ancient China. It can be traced back to the discussion of Taoism in early Pre-Qin Period, which advocates "form" as the external shape of things, and "Spirit" as the spiritual connotation of things. The concept of Zhuang Zi on form and Spirit extends it to the field of art and literature with human mind as the focus, and is widely used in the fields of painting, music, poetry and so on. However, due to the shifts on language connotation and epistemology, the ideas of form and spirit is worthy of in-depth discussion from a contemporary perspective. Gu Kaizhi, a famous painter in the Eastern Jin Dynasty, put forward the idea of "express spirit by depicting form", and believed that the spirit of characters should be reproduced in paintings by depicting the forms. However, Sikong Tu, a poet of Tang Dynasty, put forward the concept of "a sense of similarity regardless of its form", emphasizing the independence of "spirit" from "form". Though it is not completely separated "spirit" from "form", but advocating not being bound by "form", breaking the fetter of "form". The concept of "a sense of similarity regardless of its form" divides "form" and "spirit" into two dimensions, and there is a process of similarity comparison between things. "Similar in form" is the similarity of external shape of things, "similar in spirit" is the similarity of spiritual connotation of things. Intersecting these two dimensions, we can get a matrix containing four kinds of relations between "form" and "spirit": "Similar both in form and in spirit", "Similar neither in form nor in spirit", "Similar in form but not in spirit" and "Similar in spirit but not in form".

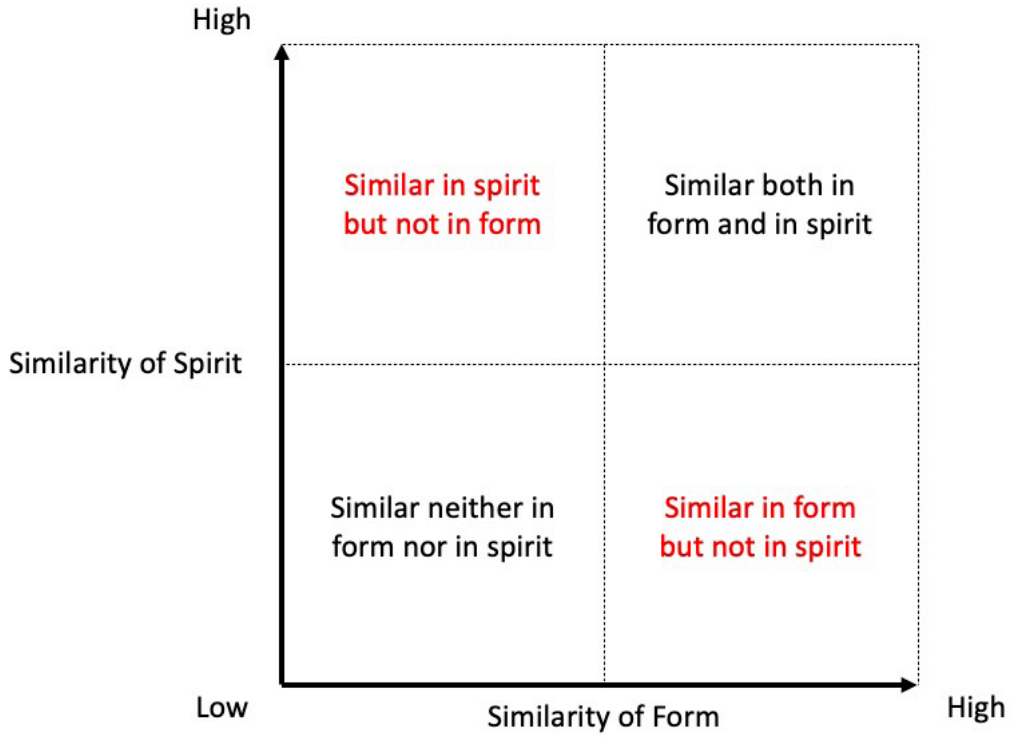

Figure 1 Four kinds of relation between "form" and "spirit".

At present, there are many researches on similarity judgment. By comparing the physical values of the external attributes of objects or similarity measurement functions, it may be possible to judge whether the objects are similar in shapes or not, but the phenomena of "similar in form but not in spirit" and "similar in spirit but not in form" has not been reasonably explained.

If these two phenomena can be explained rationally and scientifically, we may master the method to create them, which is of great value to the development and protection of intellectual property. With the continuous development of the new generation of digital technology, the creative industry is facing problems such as insufficient intellectual property development and transformation, and weak intellectual property protection, which also directly or indirectly leads to constant intellectual property disputes and disputes (S. Sun et al., 2019). In 2011, Apple and Samsung's intellectual property dispute case officially started. After an eight-year lawsuit, Samsung was judged to pay Apple 538.6 million dollars in infringement costs, of which only 5.3 million dollars were due to infringement of two Apple Utility patents, and the remaining 533.3 million dollars was due to infringement of three Apple design patents (Horwitz, 2018). Because utility model patents can determine the number of infringements through the split of technology, the design patent part cannot be split and quantitatively evaluated for similarity, so it can only be compensated as an entirety. Looking at the patent laws of various countries in the world, there are three main procedures as follows, which are Patent Application Examination, Invalidation Application and Patent

Infringement Determination, need to judge the similarity of patents.

Table 1 Comparison of design patent similarity judgment in different countries or region.

Country	Subject of judgment	Judgment premise	Judgment method	Judgment steps
China	Average consumer	The patent involved in the case is the same or similar categories to the infringed patent or product	Overall observation and comprehensive judgment	1. Determine the scope of protection for design patent rights; 2. Compare the patent involved with the patent infringed.
Japan	General demander		"Corrected the ambiguity"	
USA	Ordinary observer	Comparative patents are not restricted to the same or similar categories	"The two-step test"	
EU	Knowledgeable people		Judging by the overall impression	

At present, the intellectual property rights of different countries have different judgment methods in judicial practice. Although there are restrictions on the subject of judgment to reduce the subjective factors of similarity judgment, it is still not a complete objective assessment. If the cognitive processes of "similar in form" and "similar in spirit" can be describes, it is possible to develop methods to quantify the similarity of things, thereby improving the objectivity of similarity judgment and providing more effective protection for intellectual property rights. In addition, "similar in spirit but not in form" designs can be created, providing ideas for the development of intellectual property. All possible applications are based on the cognitive processes of similarity and judgment mechanisms, especially the similarity of spirit.

The purpose of this research is to try to propose a more complete similarity model based on existing similarity studies, to explain the principle of "similar in spirit" which against intuitions, expand the scope of similarity theories, and briefly discuss its potential application directions.

2. Literature Review

In the field of cognitive psychology, similarity seem to be important for a variety of cognitive

acts. There are currently four mainstream theoretical models for evaluating similarity (Goldstone & Son, 2012):

- Geometric Model (Shepard, 1962) assumes that mental representation can be seen as a kind of mental space, and concepts can be represented as points in the space. Those concepts represented by neighboring points are more similar psychologically than those with far distance;
- Feature-based Model (Tversky, 1977) pointed out the limitations of Geometric Model, and thought that people represented concepts by describing various feature lists of things. Similarity comparison is to compare these attribute lists for overlap. The matching features of two objects are called commonalities, while the mismatching features are called differences;
- Structural-mapping Model (Gentner & Markman, 1997) pointed out further elaborated that comparing only the lists of matching features is not enough to judge the similarity of things, structural alignment or mapping relations of these features are also necessary to be considered. In addition, those differences that are linked to commonalities (matching features) are called alignable differences, which have great impact on similarity judgment. For example, both Car and motorcycle have wheels, but car have 4 wheels and motorcycle have 2 wheels. In contrast, the difference brought by mismatching features is called nonalignable difference. Another study has also found that the impact of alignable difference on similarity is more pronounced than the impact of nonalignable difference (Markman & Gentner, 1996);
- Transformational Model (Hahn et al., 2003) proposes that the similarity is determined by the transformation distance between entities. The fewer the number of transformations, the more similar the two entities are.

With the rise of cognitive science, similarity has been used to explain the nature of concept development and object categorization in the field of psychology. Rosch (1973) proposed the Prototype Theory of categorization, which holds that there is a typical member in a category, that is, prototype. Categorization is to judge whether a thing belongs to this category by comparing the similarity between the thing and the prototype in the category. Once the similarity reaches a threshold, it can be categorized into this category. Medin & Schaffer (1978) first put forward the Context Theory of categorization, which holds that there are examples in a category, and examples are the real members of the category. In the process of categorization, people compare things with examples in the category to determine whether they belong to this category. Some researchers conclude that both Prototype Theory and Context Theory play a role in categorization. In the initial understanding of a category, people will average the features of things in the category to form a prototype. With the accumulation of experience, they will produce the most representative examples (Keri et al., 2002; Malt, 1989). Some other research results show that Prototype Theory plays a more prominent role in judging large categories and Context Theory plays a more prominent role in judging small categories (Minda & Smith, 2001).

From the literature on the definition of object similarity, we can find that judging similarity by matching and comparing the features is a relatively influential theory, it also explains the reason why the Prototype Theory and the Context Theory emerge in categorization theory based on similarity. At present, the research of judging similarity based on the features of things mainly focuses on the comparison of commonalities or differences between the matching features of things, and there are also some quantitative studies of corresponding similarity calculations like the Contrast Model (Tversky, 1977). However, the phenomena of "similar in spirit" indicate that the matching features of things may have a hierarchical or primary and secondary relation. Some primary features may have greater impact on similarity judgment than other secondary features, and even if we ignore the similarity of some secondary features, a consistent similarity judgment results can be obtained. But in current research, few mentions about the matching features of things themselves and their effect on similarity. Therefore, the theory of similarity may be further improved. One possible way is to improve the mechanism of similarity judgment to cover the principle of the phenomenon of "similar in spirit". The other possible way is to judge whether there are unknown factors affecting the judgment of similarity, leading to the occurrence of the phenomenon of " similar in spirit", or the two ways are parallel.

3. Theoretical Model and Hypothesis

According to the theories of Feature-based and Structural mapping Model, combined with the concepts of "similar in form" and "similar in spirit" proposed in the Ideas of Form and Spirit, this study points out that the theoretical prerequisite that there are some key features in the shared features. When the similarity of these key features is higher than a certain threshold, people will consider these two things similar or categorize them into the same category. In this situation, the similarity of other non-key features has little influence on the judgment of whether objects are similar or not. On the contrary, when the similarity of these key features does not reach a certain threshold, even if the similarity of other non-key features is very high, people may not think that these two things are similar.

In this context, how to determine the key features of things is an important premise to judge whether things are similar. The process of Similarity judgment will be influenced by the context and objects of comparison (Goldstone et al., 1997). The context of a comparison may influence the weights assigned to the features, and different compared objects may create or recruit a new context, which in turn influences the salient of the specific features. This suggests that the key features of a thing may be change dynamically with the compared context and objects. Besides, the process of similarity judgment is also affected by the theoretical knowledge related to the objects. In the absence of theoretical knowledge, individuals mainly make appearance-based similarity judgment, while individuals will make knowledge-based similarity judgment after mastering theoretical knowledge (H. Sun & Yin, 2019). The results of a bird naming experiment show that bird experts use more specific names to name bird image, while non experts use more general names (Tanaka & Taylor, 1991). It suggests that knowledge and experience have a significant impact on object

categorization, and people with different knowledge and experience may have significant differences in the determination of key features.

According to the prior studies, the processes of comparison can be divided into two situations, one is that two objects of comparison exist at the same time, the other is that only one object appears and compare to the object in people's mind. Based on Selective Attention Theory (Treisman, 1969) and Categorization Theory (Rosch, 1973; Medin & Schaffer, 1978), we can reasonably suggest that when two objects exist at the same time, people are more inclined to judge the similarity by comparing the features of perceptual attention; when only one entity appears, people are more likely to carry out the categorization process of prototype or context based on similarity. The phenomenon of "Similar in spirit" often occurs in different categorization of objects, for example, the similarity between human and animals. Therefore, the objects of comparison can be divided into the same category and the different categories.

According to the theoretical prerequisite and prior studies, this study defines "similar in form" and "similar in spirit" as follows: under the certain knowledge experience and a certain cognitive situation, when two things exist in the shared features that can be recognized, if the similarity of non-key feature is higher than a certain threshold, the two things are considered to be "similar in form" to each other; and if the similarity of key feature is higher than a certain threshold, the two things are considered to be "similar in spirit" to each other.

Based on the above theoretical prerequisite and definitions, a theoretical model can be established to describe the results of the similarity comparison between two things as Figure 2, assuming that the compared things are A and B, the X-axis represents the set of shared features of A and B. In the comparison of A and B, the Y-axis represents the degree of similarity of a shared feature, 0% means that the features are completely different, and 100% means that the features are completely the same. Theoretically speaking, comparing any two things according to the similarity of features will be presented as a curve on the chart.

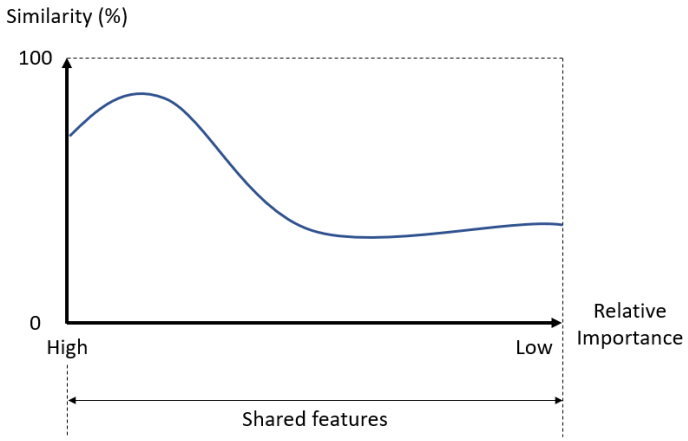

Figure 2 Feature similarity curve in two things comparison.

In Figure 3, the shared features (X-axis) can be ranked in order of relative importance. Those

features, which the relative importance is higher than a certain threshold, can be known as "key features". x_1 represents the number of key features of the shared features between A and B, and features with relative importance less than x_1 are non-key features. Considering the cognitive ability restriction of human being, x_2 represents the number of shared features that humans can recognize under the limitation of physiological conditions. Those features outside the x_0-x_2 interval mean that they can't be perceived by humans and are of lowest relative importance. Therefore, x_0-x_2 interval is the shared features to be compared, where x_0-x_1 interval is the key features and x_1-x_2 interval is the non-key features.

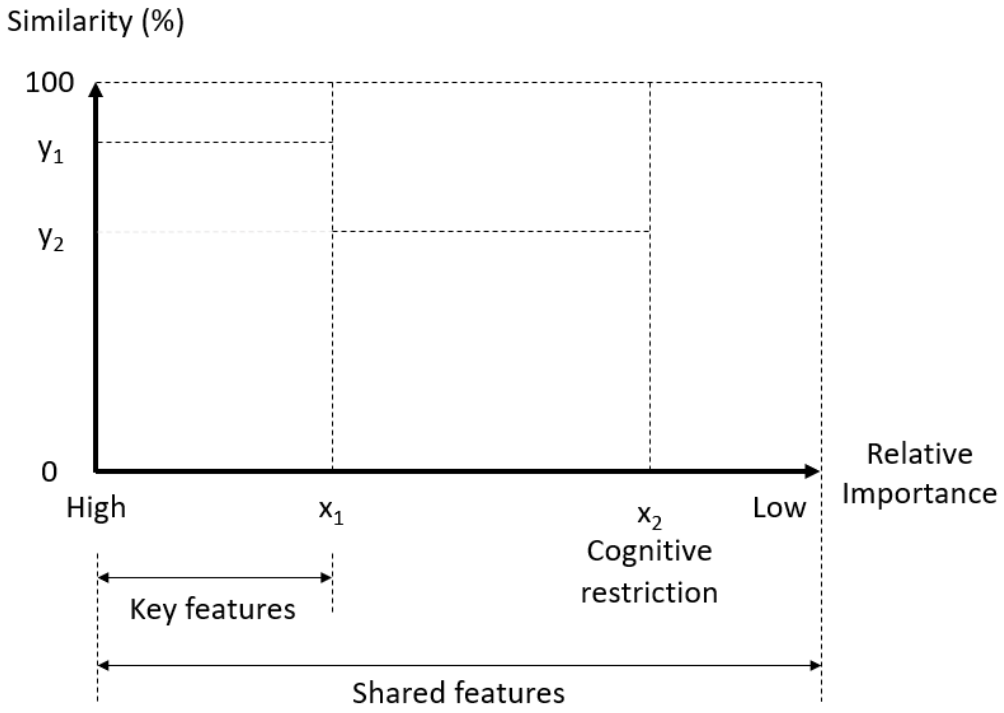

Figure 3 Feature similarity curve in two things comparison.

If individuals want to judge whether two things are similar to each other, the similarity degree of features needs to reach a certain threshold. The threshold required for similarity between key and non-key features is different, y_1 represents the threshold of key features required for similarity judgment, and y_2 represents the threshold of non-key features required for similarity judgment. When the similarity of key features (x_0-x_1) reaches y_1, the compared objects are "similar in spirit" to each other, and at this time, it is considered that A and B are similar whether the similarity of non-key features reaches y_2 or not. When the similarity of non-key features (x_1-x_2) reaches y_2, the compared objects are "similar in form" to each other, but whether people think that A and B are similar or not may depends on whether the similarity of key features reaches y_1 threshold. The four relations between "form" and "spirit" described in Figure 1 can be further described by the following four curves in Figure 4 by using this chart:

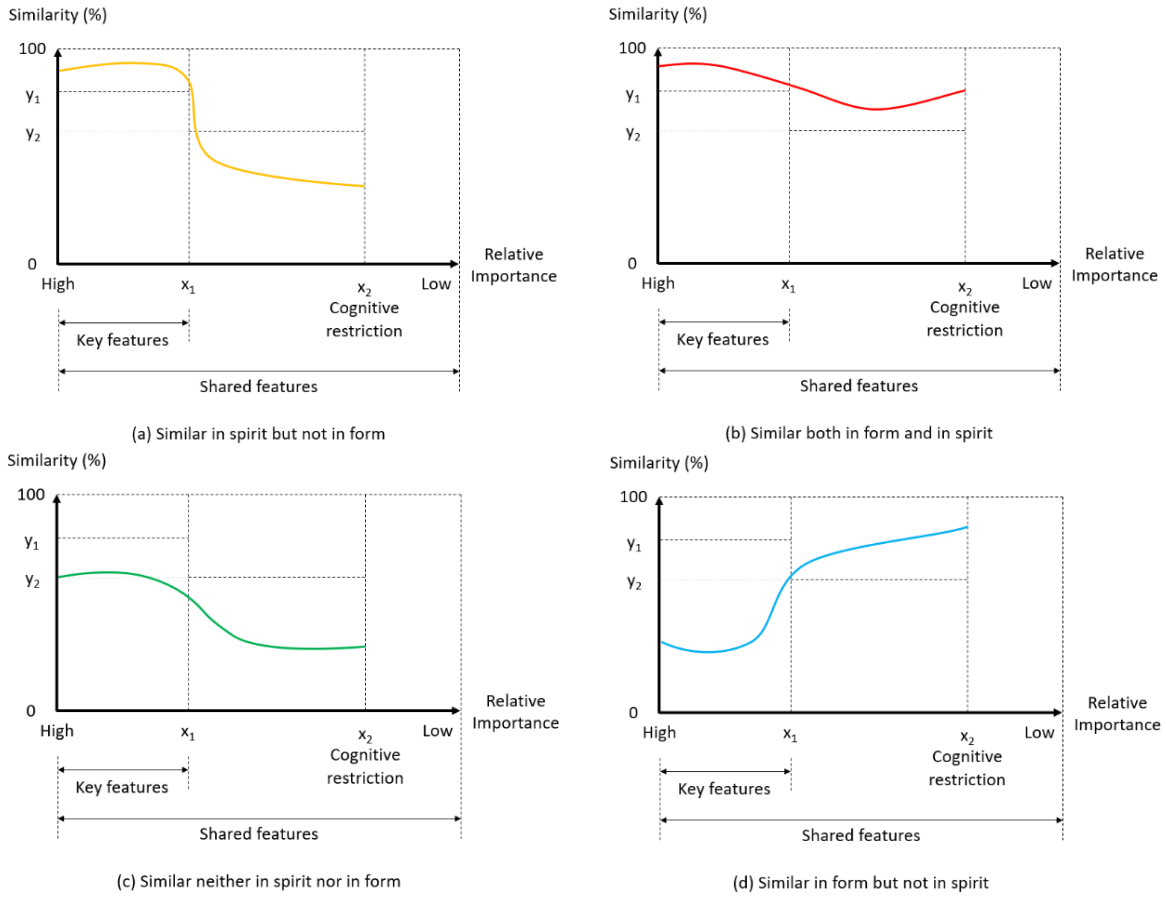

Figure 4 The four relations between "form" and "spirit" described by theoretical model.

The feature similarity of any two things can be roughly divided into the above four situations: (a) when the similarity of each key feature in the shared feature is higher than or equal to y_1, but the similarity of other features is lower than y_2, it is considered that the two things are "similar in spirit but not in form"; (b) when the similarity of each key feature in the shared feature is higher than or equal to y_1, and the similarity of other features is higher than or equal to y_2, it is considered that the two things are "similar both in form and in spirit"; (c) when the similarity of each key feature in the shared feature is lower than y_1, and the similarity of other features is lower than y_2, it is considered that the two things are "similar both in form and in spirit"; (d) when the similarity of each key feature in the shared feature is lower than y_1, but the similarity of other features is higher than or equal to y_2, it is considered that the two things are "similar both in form and in spirit".

In the (b) situation of "similar both in form and spirit" or (c) situation of "similar neither in form nor in spirit", people probably can easily judge whether the two things are similar or not. But whether people will not consider the two things are similar in the (d) situation of "similar in form but not in spirit", or whether people will consider they are similar in the (a) situation of "similar in spirit but not in form", needs to be verified by survey and research.

In the previous theoretical prerequisite, judging "similar in spirit" needs to satisfy that the similarity of all key features between two things to be compared has to reach the certain

threshold (y_1). Judging “similar in form” needs to satisfy that the similarity of other features has to reach the certain threshold (y_2). Taking the judgment of “similar in spirit” as an example, when only part of the key features between two things reach the threshold y_1 of similarity, whether people will consider that they are similar at this situation, needs further research.

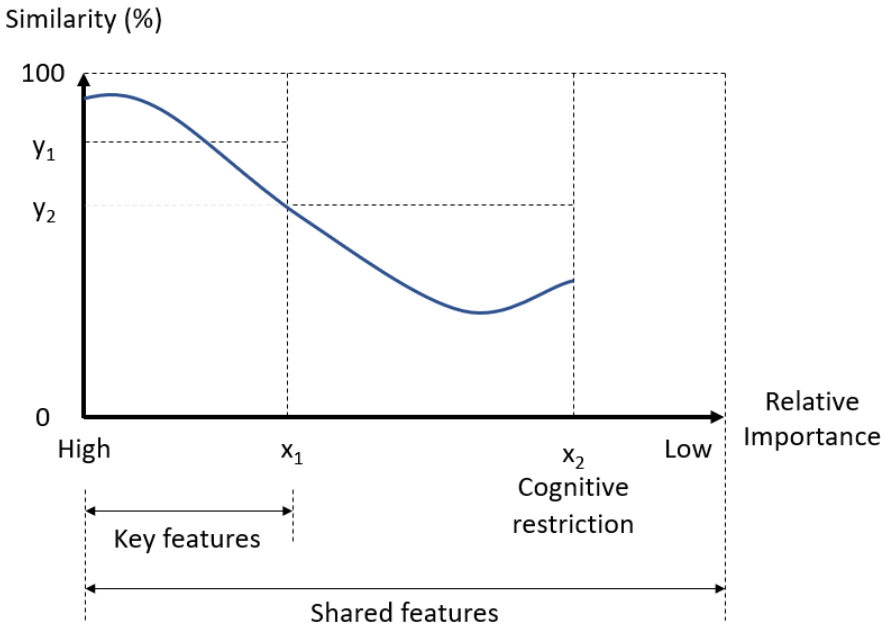

Figure 5 Part of the key features reach the threshold.

In this situation, there are two possible solutions. One shows in Figure 6 is to adjust the threshold of the relative importance of key features, and move those features that can’t reach the feature similarity threshold (y_1) into other features to ensure that each remaining key feature meets the similarity threshold (y_1), and then the remaining key features should be investigated again to confirm whether it is enough to judge “similar in spirit”.

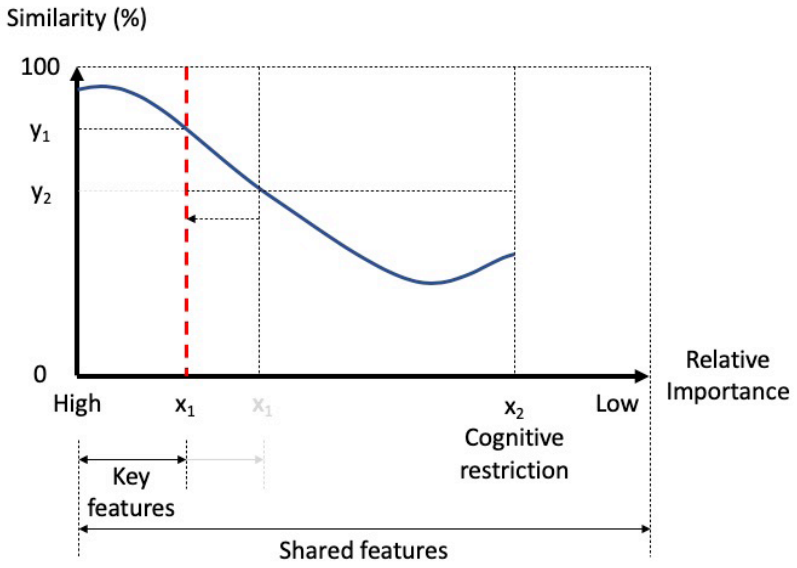

Figure 6 The relative importance threshold adjustment of key features.

The other method shows in Figure 7 is to calculate the area S_1 formed by the curve of the similarity degree of the shared features and the number of key features (x_1), and compare it with the area S formed by the similarity threshold (y_1) of the number of key features (x_1). When $S_1 \geq S$, people may judge the two as "similar in spirit"; when $S_1 < S$, they may not be judged as "similar" to each other.

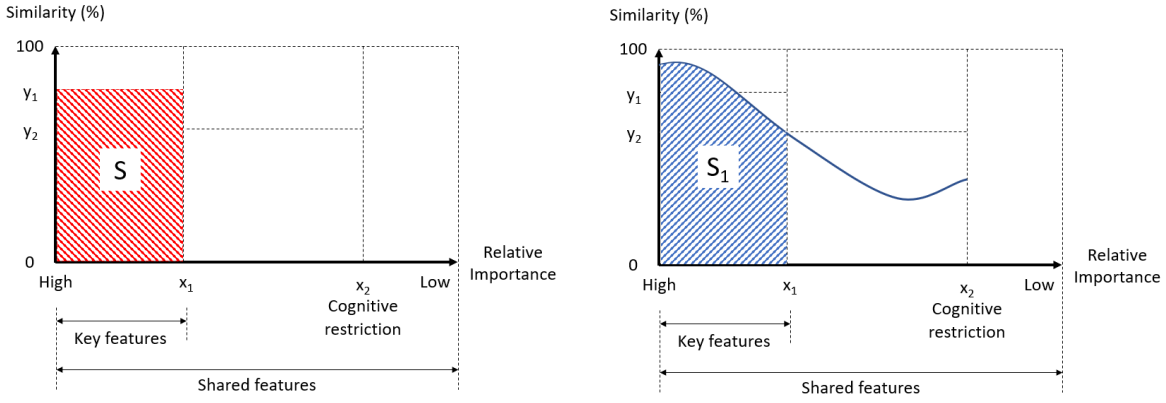

Figure 7 The comparing area S and S_1.

4. Summary and discussion

4.1 Theoretical inference

Based on the ancient Chinese theory of form and spirit and related theories of cognitive psychology, this research proposes a theoretical prerequisite that the relative importance of features will affect the similarity judgment process based on the comparison of shared

features of objects. There are some key features in the shared features of compared objects. When the similarity of key features reaches a threshold, the influence of the similarity of non-key features on the judgment will be reduced.

To verify this model in Figure 3, there are multiple thresholds that need to be clearly defined.

1. The first is the threshold (x_1) of the number of key features of things. Because the key features of a thing will be influenced by the compared context and objects, so the key features of a thing are changing dynamically. Therefore, when making similarity judgment, the first thing to do is to determine the shared key features of things;
2. The second is the similarity threshold of key features (y_1) and non-key features (y_2). When the similarity of non-key features is higher than the threshold y_2, people may consider that two objects are "similar in form". When the similarity of key features is higher than the threshold y_1, people can judge similarity directly from the key features, even ignoring the similarity of other features;
3. The third is the percentage of features (Y-axis). One physical way is to measure the similarity of features through the ratio of physical properties of the objects, such as length and volume. The other psychological way is to measure the similarity of features through the psychological scale score by doing survey. The attributes of the shared features are the decisive factors in determining which way to use to measure similarity.

4.2 Related Potential Applications

The core of this model is to determine the similarity in a quantitative way, and there are many potential application directions:

1. This model can provide quantitative standard for the protection of intellectual property rights (IPR). Similarity is one of the most important standards for examining IPR, especially the design patents. There are three main procedures, which are Patent Application Examination, Invalidation Application and Patent Infringement Determination, need to judge the similarity of patents. In current judicial practice, it is mainly judged whether IPR have been infringed by subjective and qualitative way, lack of quantitative evaluation.
2. After determining the key features of things, it is assumed that as long as the similarity of key features reaches the threshold (y_1), then the impact of other non-key features is relatively insignificant at this time. In other words, the non-key features can be created freely without worrying about changing the essence. For example, when we try to create a series of products with consistent brand image, we can grasp the "spirit" of brand characteristics to create a novel "forms", while ensuring the diversity of product shape, but also to maintain a consistent brand image.
3. The model of this may provide ideas for bionic design. The core of bionic design

is to imitate the special ability, shape or structure of biological principles to design products. How to extract the biological "spirit" to design the "form" of products is one of the possible applications that this model can explore.

4. In addition to traditional product design, relate applications may also be obtained in the movie, game and animation industries. For example, in common character modelling and special effects processing, it is necessary to process people's appearance into different forms to meet the needs of games or movies. If the model of this study is established, we can maintain the character's "spirit" to create corresponding "forms" that required, or even algorithms can be developed to automatically generate various different effects.

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About the Authors:

Yi-Feng Wen Master of School of Art and Design, Guangdong University of Technology.

Ding-Bang Luh Distinguished professor of Guangdong University of Technology. Graduated from Illinois Institute of Technology. The second person in the United States to obtain a Ph.D. in Design. The inventor of the Mirror Theory.

Chi-Hua Wu Distinguished Associate Professor of Guangdong University of Technology. Ph.D., Master of Industrial Design Institute, Cheng Kung University. Visiting scholar and guest lecturer of Royal Melbourne Institute of Technology.

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Using FCE and FAHP to Explore the multirotor drone appearance preference

Shih-Wen Hsiao[a*], Po-Hsiang Peng[b]

[a] Department of Industrial Design, National Cheng Kung University
[b] Department of Industrial Design, National Cheng Kung University
Corresponding author e-mail: 8008075@gs.ncku.edu.tw [a], p38081075@gs.ncku.edu.tw [b]
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Abstract: Every year there are new products on the market for drones prompting designers to spend a lot of time collecting data and analyzing product style trends in the market. However, it takes more time for new designers to understand consumers' evolving preferences. Therefore, this study proposes an evaluation model for DRONE appearance design. The method uses Morphological Analysis to extract product appearance characteristics, and uses fuzzy comprehensive evaluation (FCE) and fuzzy analytic hierarchy process (FAHP) to establish DRONE appearance in addition to preference analysis. It obtained the degree of importance that consumers attach to each component; the result weights that consumers attach were then analyzed to determine that the overall preference for the appearance of DRONEs is objective. In this way, the researchers or designers subsequently executing procedure can establish a modelling database and apply it to the process of rapid design.

Keywords: Drone; Morphological Analysis; Fuzzy Analytic Hierarchy Process, FAHP; Fuzzy Comprehensive Evaluation, FCE

1. Introduction

With the intensification of economic globalization, it is very important to make rational use of global design resources. For such a background, as the design goes deep into all aspects of the enterprise, the designer's job in the enterprise is not only to execute the design of modelling style, but also to cooperate with engineers, marketing personnel and others. However, today's market emphasizes cooperation efficiency and the rapid generation of innovative ideas. It is very important to determine whether the style trend accurately matches the preferences of consumers at the market end. Traditional design has thus entered a brand-new era of design management. On the one hand, it can save time for product development; on the other hand, it can enable new designers to understand market preferences more quickly and create designs that conform to the market. In 1922, large-

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scale drones were in the testing stage until the prototype of the four-axis drones began to appear in the United States in the 1950s. Up to now, drones have a 90-year history of development, and their early use was mainly military. In recent years, due to the influence of the Internet of Things and the integration of communication and network technologies, DRONEs have been combined with at least six technologies. From consumer recreational toys to high-value applications in the fields of climate, commerce, agriculture, urban planning and national defense, drones have become a new product just around the corner. Basson et al. (2019) proposed using the instrument technology evaluation method to evaluate drone performance, and to use in-flight measuring instruments to ensure stable flight. The design elements and performance standards are discussed in terms of mechanical design, electromechanical design, flight control optimization and drone performance standards for the three basic models of drones. Saha et al. (2018) proposed the idea of using Raspberry PI for drone development; it can be used in drones with cameras to identify organisms during flight. It is very useful for military operations and surveillance in remote areas. Mahamud et al. (2016) proposed a new algorithm for drones to make it easier for drones to move across the sky, land and water. Strengthening automatic identification can reduce the complexity of interaction with the database and optimize the relationship between drones' AI and database. All the researchers mentioned above have conducted research related to the design and development of drones. This study discusses the weight and preference of each evaluation item that comprise the overall appearance of the drones, so there is no further discussion on the functional aspect.

2. Theoretical Background

2.1 Morphological analysis

Zwicky, the founder of morphological analysis, argued in 1957 that morphological analysts should eschew prejudice and remain objective. This method is used to decompose the design target into a plurality of different design elements and generate new shapes or creative ideas through arrangement and combination. During the implementation, the external structure is first analyzed, and then disassembled and the parts combined with each other. The analysis method is divided into four steps:

1. Strive to complete the description of the subject;
2. Disassemble the independent factors of the subject;
3. List the multiple elements in each independent factor;
4. Combine different elements with each other to create many new ideas.

Dragomir et al. (2016) proposed the application of morphological charts in order to ensure the best match between product characteristics and customer requirements as well as to shorten the development time for greater flexibility. Azammi et al. (2018) proposed that the application of morphological charts to vehicle engines is an effective solution to improve the classification efficiency of module components. Hsiao et al. (2016) proposed applying the

morphological charts to the design of hair dryers, an approach which can also generate new product ideas quickly.

2.2 Fuzzy Comprehensive Evaluation, FCE

Fuzzy theory is a scientific method for studying and dealing with fuzzy phenomena; it was first put forward in 1965 by Zadeh (1965, 1975), a control theorist at the University of California. This process is used to process imprecise and fuzzy data to solve decision-making problems in fuzzy environments by strict mathematical methods. The fuzzy comprehensive evaluation method is a widely used method in the field of fuzzy mathematics. Its purpose is to effectively solve fuzzy and difficult-to-quantify problems, and is suitable for solving various uncertainty problems. Hsiao (2013) proposed using the FCE method to study bicycle preferences in the market and solve the problem of bicycle stocking. Hsiao (1995, 1998) used the fuzzy theory and analytic hierarchy process to make product decisions in the automobile design stage; fuzzy theory made relevant evaluations on monochrome schemes. In addition, Hsiao et al. (1997) used fuzzy linguistics to make product decisions for automobile exterior design. The following are the implementation steps of FCE, which are divided into 6 points:

1. Give the object set of the evaluation factor target $u = \{u_1, u_2, \ldots\ldots, u_n\}$;
2. Determine the indicator set $V = \{V_1, V_2, \ldots\ldots, V_m\}$;
3. Establish the weight set: Since the importance of each indicator in the indicator set differs, it is necessary to assign corresponding weights to the first-level indicator and the second-level indicator, respectively. The weight set of the first level $\omega_i = \{a_{1i}, a_{2i}, \ldots\ldots, a_{ni}\}, i = 1, 2, \ldots\ldots, n_i$, the weight set of the second level $\omega_k = \{a_{1k}, a_{2k}, \ldots\ldots, a_{mo}\}, \quad k = 1, 2, \ldots\ldots, m_o$. Factor analysis will be used here to determine the weight: $\sum_{i=1}^{f} \omega_i = 1$;
4. Determine the comment set: We set the evaluation set to v={very important, slightly important, neutral, slightly unimportant, very unimportant}
5. Find out the evaluation matrix: $R_i = (r_{ijk})$; first determine the membership function of U to v, and then calculate the membership degree of drone evaluation indicators for each level. R_i;
6. Obtain the fuzzy comprehensive evaluation set $B_i = \omega_i \circ R_i = (b_{i1}, b_{i2}, \ldots\ldots, b_{in})$ i.e., the general matrix multiplication; the final evaluation result is obtained according to the evaluation set.

2.3 Analytic Hierarchy Process, AHP

Analytic Hierarchy Process (AHP), developed by Saaty in 1971, is mainly employed to provide a quick way to reduce complicated decisions. Ulloa et al. (2018) proposed applying AHP to the appearance design of PV-T module of DRONEs. Finally, Arduino was used as a model to verify and test the experimental data. Lei (2014) proposed reducing the accident rate of electric vehicle fires through AHP, strengthening the fire safety management of electric

vehicles, and assisting in the development of management systems. The following are the five steps of the implementation process, as shown in Figure 1:

- Step 1 is decomposition, which divides the complex decision-making elements into several components, subdivides these components into multiple solutions, and organizes them into a tree-like hierarchical structure diagram.
- Step 2 is weighting, giving weight to the relative importance of each part, and then analyzing the priority of each part.
- Step 3 is evaluation. For decision makers, a pair comparison matrix is created in a hierarchical structure. Table 1 presents the definition of the AHP evaluation index and score.
- Step 4 is selection. AHP can help to confirm subjective and objective evaluation measures. The consistency ratio of evaluation should be checked eventually, which is also referred to as C.R. C.I. is the consistency index; RI is a random index; λ is the maximum eigenvalue of the matrix; n is the matrix order or the number of parameters; the calculation is shown in the following formula (1). With the alternatives suggested by the team to reduce the team's decision-making mistakes, such as out of focus, no plans, no participation, etc., Hosseini et al. (2016) proposed AHP subdivides the whole problem into several less important evaluations, but still maintains the overall decision-making method.

Table 1 Evaluation score and definition of AHP

Evaluation measurement	**Definition**
1	Equal importance
3	Slight importance
5	Essential importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate value

Only when C.R. <0.1 is satisfied and shown in the following formula (2);

$$\mathrm{C.I.} = \frac{\lambda_{\max} - n}{-1} \qquad (1)$$

$$C.R. = \frac{\mathrm{C.I.}}{\mathrm{R.I}}$$

$$C.R. < 0.1 \Rightarrow \mathrm{OK} \qquad (2)$$

$$\mathrm{C.R.} = \mathrm{Consisency} \circ \mathrm{Ratio}$$

$$\mathrm{C.I.} = \mathrm{Consisency} \circ \mathrm{index}$$

$$\mathrm{R.I.} = \mathrm{Randan} \circ \mathrm{index}$$

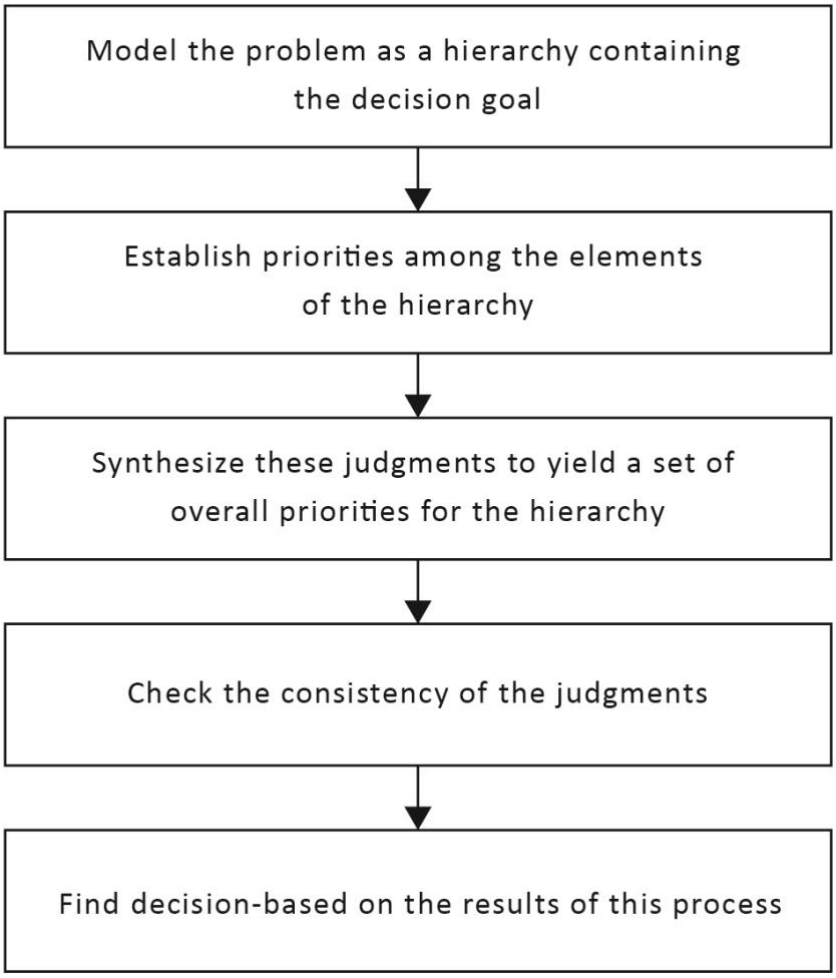

Figure 1 Process of AHP

2.4 Fuzzy Analytic Hierarchy Process, FAHP

In this study, fuzzy theory and the analytic hierarchy process are combined to establish the implementation of the Fuzzy Analytic Hierarchy Process (FAHP), which can effectively deal with fuzzy problems and accurately achieve the purpose of decision-making. Grann (1980) was the first scholar to add fuzzy theory to AHP. He proposed using triangular fuzzy numbers to express the importance of elements and then calculate the fuzzy weight of decision criteria. Shen et al. (2018) used FAHP to discuss the influence of watch product elements on gender orientation. The aim is to quantify five elements and their relative importance in terms of gender orientation. Moayyedian et al. (2018) proposed multi-objective optimization for injection molding. The purpose of their study is to determine the best alternative for the best formability index and the best alternative close to the best alternative for injection molded parts in injection molding technology. Through consideration of Taguchi, FAHP and the ideal solution, Kubler et al. (2016) proposed creating statistics on the existing research papers. FAHP is mostly used in the papers on manufacturing, industry and government departments. Among them, 57% still leave much room for research and discussion, which also represents that FAHP is widely used. In this study, triangular fuzzy numbers are used to

represent the weight values; the total weight is obtained by first calculating the interviewee results and then processing them. The calculation process is as follows:

1. Establish the fuzzy pairwise comparison matrix; according to the results of the questionnaire survey, the trapezoidal fuzzy number is used to represent the comparison matrix of two fuzzy sets. $\widetilde{A}$, where, $\widetilde{A} = \left[\widetilde{a_y}\right]$, $\widetilde{a_y} = \left[a_y , b_y , c_y , d_y\right]$.
2. Fuzzy weight of fuzzy positive-negative matrix; $W_i = \frac{\sum_{j=1}^{n} a_{ij} + \frac{n}{2} - 1}{n(n-1)}$
3. Consistency testing; $I(A, W) \leq A, A \leq 0.1$;
4. Level cascading and factor ordering; $W = (W_1, W_2, \cdots W_n)$

3. Case Study

This chapter includes six steps. First, identify the appearance feature components. Second, create a shape analysis diagram. The third step is to generate new combinations through the AHP questionnaire. The fourth step is then to compare the differences between FCE and FAHP. The fifth step is consistency verification. The sixth step is consistency verification. The seventh step is to create options from the morphology map. The eighth step is to verify the evaluation results obtained through the options. The ninth step is to compare the results of FAHP and FCE. If the results are equal, continue to the next step; if the results are different, the modeling questionnaire needs to be modified. The tenth step is the design and three views. The eleventh step is product performance and effect diagram. The process of the case study is shown in Figure 2.

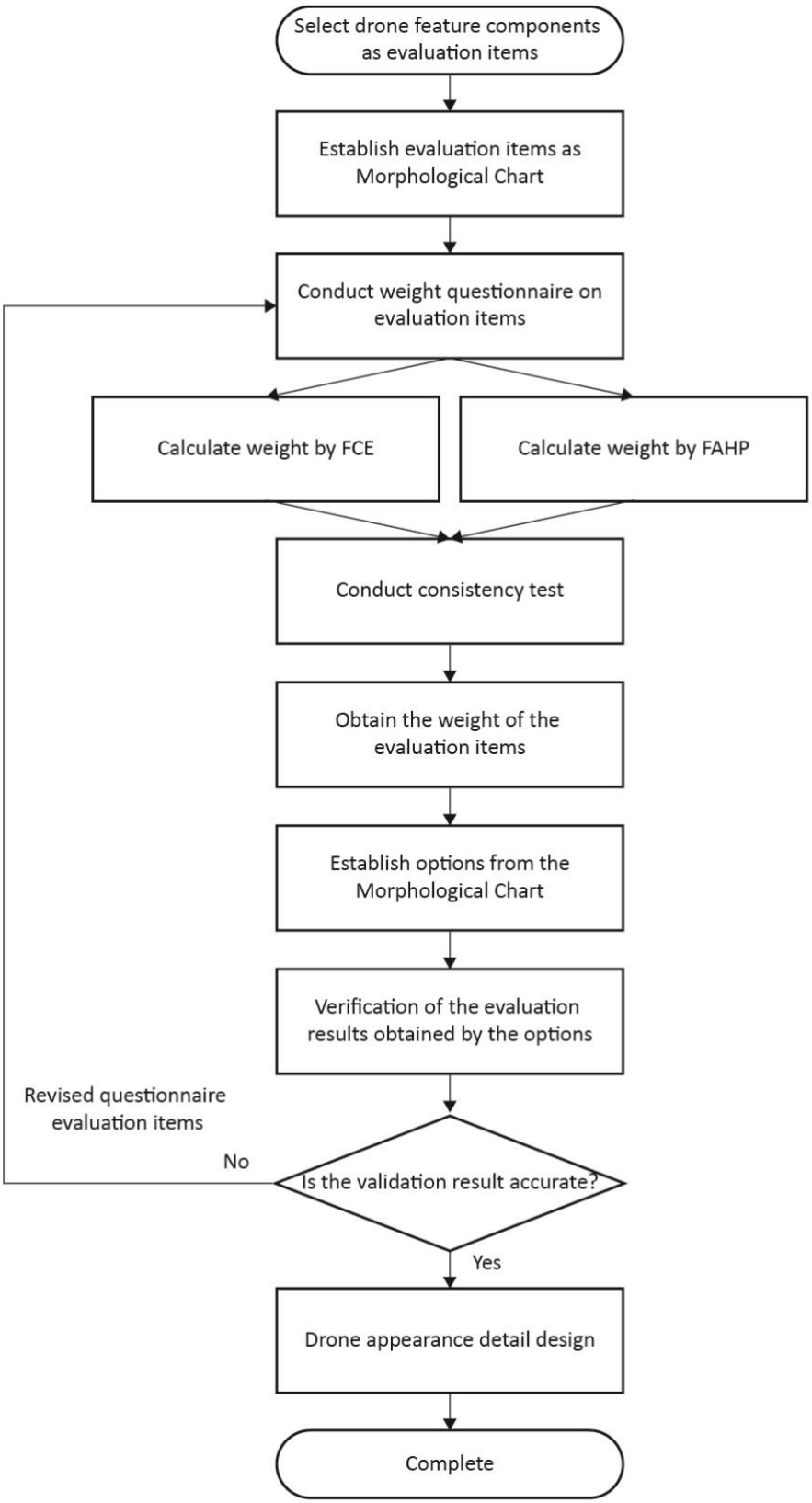

Figure 2 Process of case study

3.1 Identify components of appearance feature

First, the overall appearance of the DRONE was functionally disassembled; it could be divided into three parts: outer frame, propeller and lifting stand. Eventually, a description table of the appearance features was established, as shown in Table 2.

Table 2 Basic menu of drone.

	Description
Frame	The outer frame of the drone covers 95% of the mechanism and is the main component of the product.
Propeller	Drone take-off parts, the shape will affect flight efficiency.
Heighten landing skid gear leg	Drone lifting and grounding components need a combination of style and function.

3.2 Establish morphological analysis chart

After the DRONE was disassembled, it could be divided into 7 outer frames, 6 propellers and 6 lifting stands. Its components are visualized here, and are shown in Table 3. In addition, an Analytic hierarchy diagram was established, as shown in Figure 3:

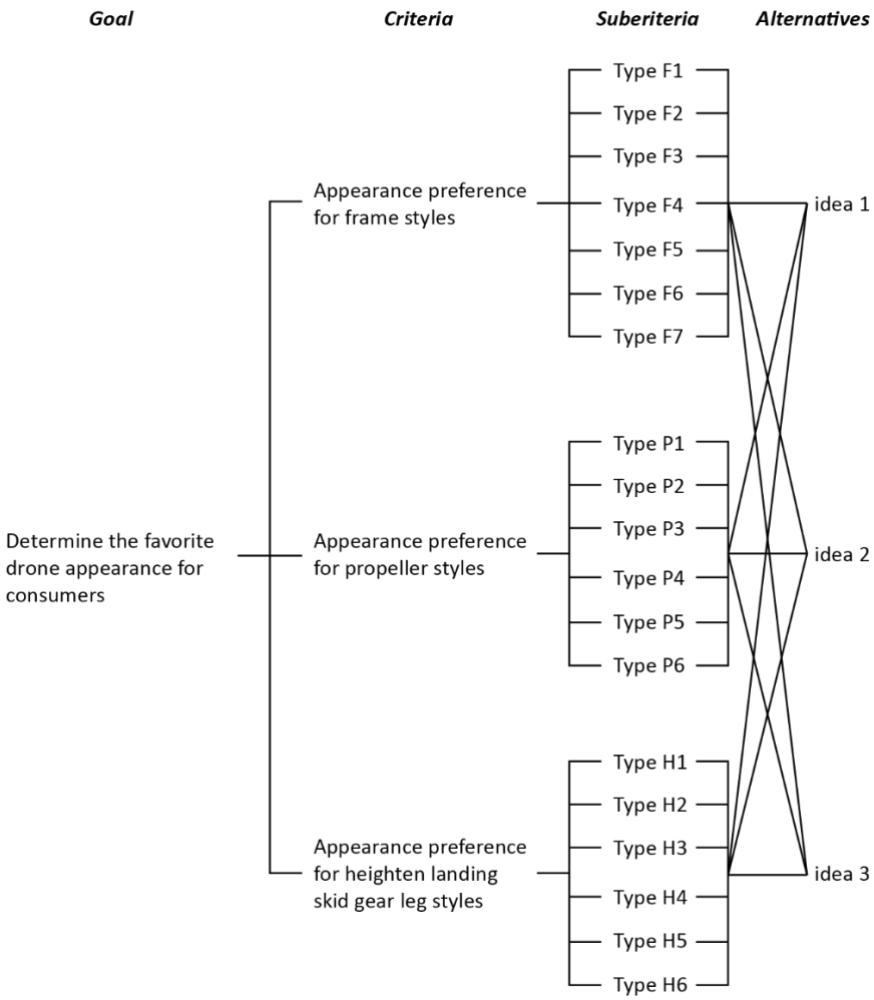

Figure 3 Analytic hierarchy diagram

Table 3 Basic menu of drone

	type 1	type 2	type 3	type 4	type 5	type 6	type 7
Frame							
Propeller							
Heighten Landing Skid Gear Leg							

3.3 The decision steps produce new combinations

Fuzzy comprehensive evaluation can quantify fuzzy indices of evaluation objects by establishing fuzzy subsets of grades. The fuzzy variable principle was then used to integrate each index to better solve fuzzy problems, such as the clear features of different attributes. After the final morphological chart was established, FAHP and the fuzzy comprehensive evaluation method were used to evaluate and select excellent combination programs. After the morphological chart was formed, FCE and FAHP were used to evaluate and select an excellent combination program. The results are as follows:

- Establish the factor set.
- Calculate the weight of each component.

The weight of the outer frame was 0.558, that of the propeller was 0.122, and that of the lifting stand was 0.319. Its weight ranking was outer frame > lifting stand > propeller, as shown in Table 4.

Table 4 Building a pairwise comparison matrix

	Frame	**Propeller**	**Heighten landing skid gear leg**	**Weight**
Frame	1	4	2	0.558
Propeller	0.25	1	0.33	0.122
Heighten landing skid gear leg	0.5	3	1	0.319

From the above table, it can be seen that the evaluation of external appearance is valued sequentially as follows: outer frame > lifting stand > propeller.

- Consistency verification of the weight of each component

$$\lambda_max=3.018$$

$$C.I.=\left(\frac{\lambda_max-n}{n-1}\right)=\left(\frac{3.018-3}{2}\right)=0.009$$

$$R.I=0.58$$

$$C.R.=0.017<0.1\rightarrow OK \quad (3)$$

The consistency score was 0.017, less than 0.1, which means that each weight is consistent and shown in the following formula (3); for each factor, the consistency score was summarized into a weight set:

- Establish a fuzzy evaluation matrix

Based on the factor set, evaluation set and weight set, a comprehensive evaluation questionnaire was designed, as shown in Figure 4 below. The questionnaire involved a total of 31 respondents, including college students and professional users. Following a statistical

analysis, the fuzzy membership relation of each part is shown in Table 5. Designers and manufacturers can use Table 6 to inquire about the general consumer's appearance preference for the final drone product.

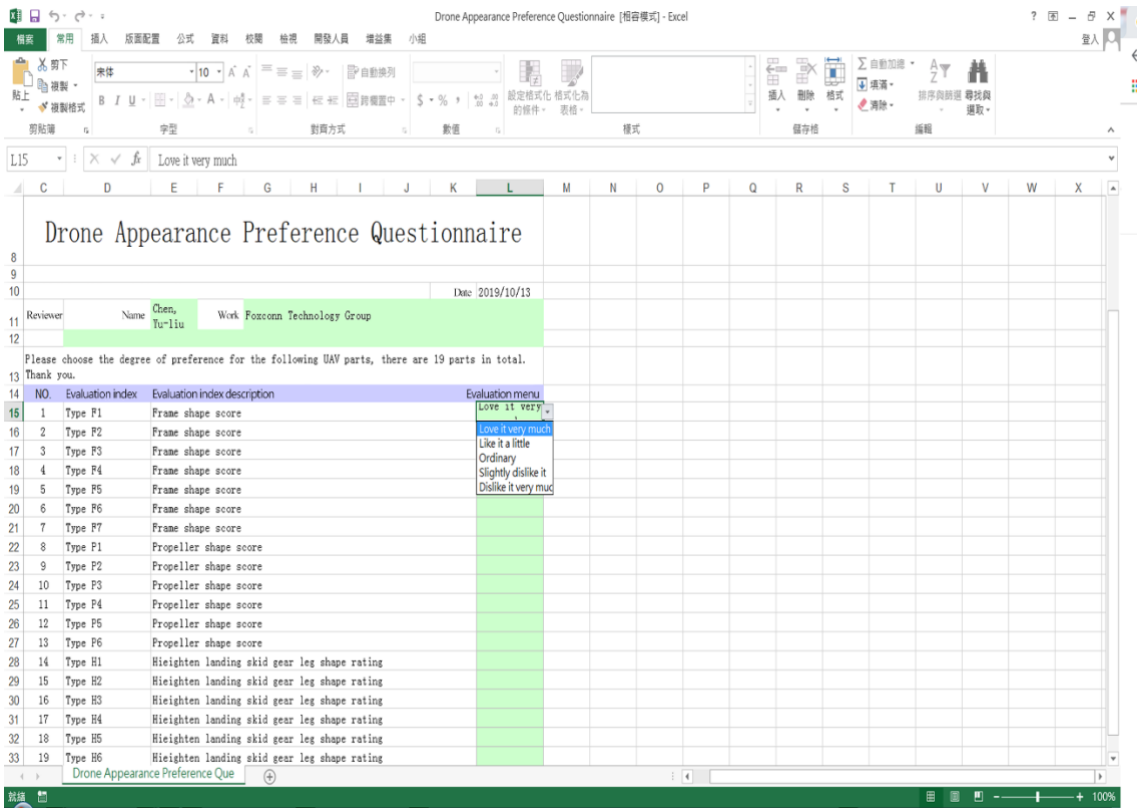

Figure 4 Establish a fuzzy evaluation questionnaire

Table 5 Building Fuzzy Membership Table

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Frame	0.104	0.248	0.149	0.255	0.227	0.219	0.186
Propeller	0.139	0.201	0.055	0.103	0.265	0.257	
Heighten landing skid gear leg	0.182	0.155	0.243	0.072	0.069	0.022	

Table 6 Morphological chart for IDEA 1-3

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Frame	0.104	0.248	0.149	0.255	0.227	0.219	0.186
Propeller	0.139	0.201	0.055	0.103	0.265	0.257	
Heighten landing skid gear leg	0.182	0.155	0.243	0.072	0.069	0.022	

IDEA 2 IDEA 1 IDEA 3

In order to further study the credibility of the research results, the first two parts with the highest fuzzy membership degree were selected from Table 6: concept 1 and concept 3 respectively. Concept 1 consisted of F4, P5 and H3. Concept 3 consisted of F1, P3 and H6. The part with the lowest fuzzy membership was IDEA 2, which consisted of F2, P6 and H1, so as to form the following three different DRONE exterior designs, as shown in Figures 5-7.

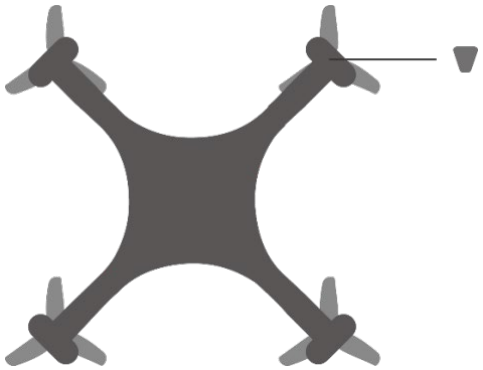

Figure 5 IDEA 1

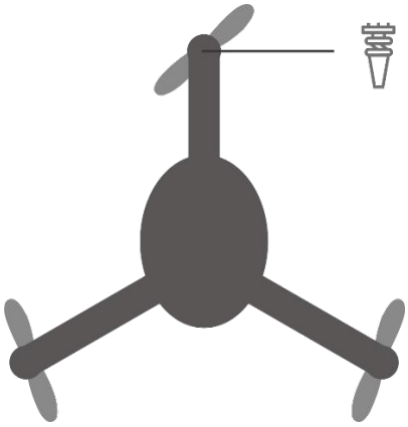

Figure 6 IDEA 2

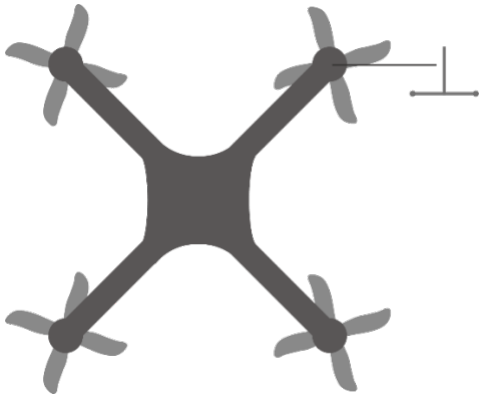

Figure 7 IDEA 3

- The weight matrix of primary index is

$$A=[0.558\ \ 0.122\ \ 0.319]$$

- The weight matrix of secondary index respectively can be written as

$$w_1=[0.104\ \ 0.248\ \ 0.149\ \ 0.255\ \ 0.227\ \ 0.219\ \ 0.186]$$

$$w_2=[0.139\ \ 0.201\ \ 0.055\ \ 0.103\ \ 0.265\ \ 0.257\ ]$$

$$w_3=[0.182\ \ 0.155\ \ 0.243\ \ 0.072\ \ 0.069\ \ 0.022\ ]$$

- The secondary fuzzy comprehensive evaluation matrixes are as follows

$$R_1=[0.104\ \ 0.103\ \ 0.022]$$

$$R_2=[0.248\ \ 0.257\ \ 0.243]$$

$$R_3=[0.149\ 0.139\ \ 0.069]$$

- Finally the Fuzzy comprehensive evaluation matrixes set is as below.

$$\underset{\sim}{R}=\begin{bmatrix}0.255 & 0.104 & 0.248\\ 0.267 & 0.103 & 0.257\\ 0.243 & 0.022 & 0.182\end{bmatrix}$$

- Comprehensively evaluate the fuzzy evaluation matrix which is built according to Table 5; the evaluation results are:

$$\underset{\sim}{B}=\underset{\sim}{W}\circ\underset{\sim}{R}=(0.426\ 0.027\ 0.219)$$

Based on this evaluation result, the order of priorities should be IDEA 1, IDEA 3, and IDEA 2. Generate new combinations with FAHP decision steps, as shown in Table 7. Applying normalization to the above vectors, the final vector could be obtained as follows: IDEA 1 equaled 0.449, IDEA 2 equaled 0.203, and IDEA 3 equaled 0.347. Based on these evaluation results, the priority order should be IDEA 1, IDEA 3 and IDEA 2, sequentially.

$$w=(0.449\quad 0.203\quad 0.347)$$

Table 7 FAHP Relation Table for Three Ideas

	IDEA 1	**IDEA 2**	**IDEA 3**
Frame	0.472	0.19	0.338
Propeller	0.516	0.175	0.308
Heighten landing skid gear leg	0.393	0.188	0.42

3.4 Verification results

This step was to compare the results of the fuzzy comprehensive evaluation with the preference statistics of the actual interviewees. It can be seen from the results in Tables 5 and 6 that the results were the same: IDEA 1 > IDEA 3 > IDEA 2; this shows that designers can use the hierarchical evaluation item weights (Table 7) and the fuzzy membership weight statistics (Table 5) in this study to reorganize different new options and obtain preference scores for each appearance combination, so that designers can also obtain pre-reference instructions on consumer appearance preferences.

3.5 Appearance design and three views

The conclusions drawn in the previous section can be used by designers to design and create three views, as shown in Figure 8.

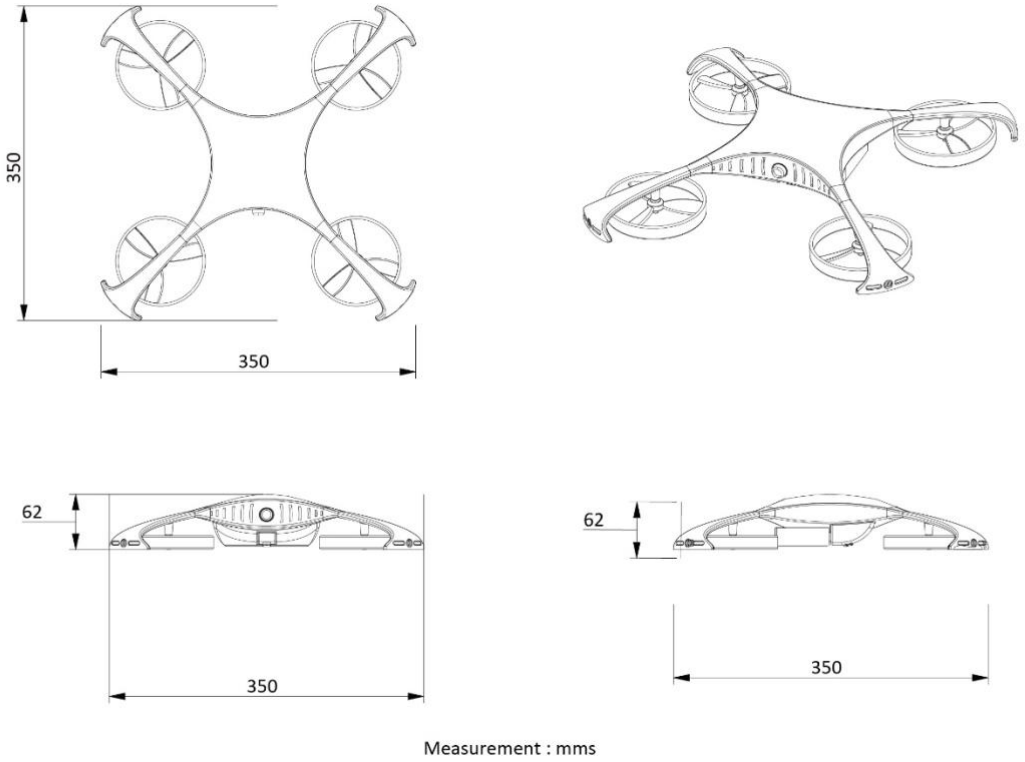

Figure 8 Design of IDEA 3

3.6 Product performance and rendering diagram

The ideation design IDEA 3 obtained in the previous section can use three-dimensional software and rendering software KeyShot, which can be subsequently used as a product proposal, as shown in Figure 9.

Figure 9 IDEA 3 product rendering proposal

4. Results and Recommendations

The results of this study show that among the three evaluation items (outer frame, propeller and lifting stand), the first choice for general consumers who chose drones according to appearance was the appearance of "outer frame", which had the evaluation result of 0.426 among all the evaluation items. The conclusion is that the results of this study using FCE and FAHP are all IDEA1, IDEA3, and IDEA2, so this result is reliable. Secondly, they considered the appearance of the "lifting stand" and expressed it with the evaluation result of 0.219. Thirdly, the evaluation result of the "propeller" was 0.027. Among these items, there are many accessories that can be added to the lifting stand on the market. For example, amphibious drones can add sponges to the lifting stand to enhance the buoyancy on the water surface. Therefore, the lifting stand will have new shapes and functions according to different purposes. The appearance of drones affects consumers' purchasing behavior. Even in daily life, the outer frames of drones with different numbers of axes seen by general consumers are very limited, mainly with four axes. With more and more drones of different purposes, they have evolved from three-axis drones to six-axis drones. For example, six-axis drones that carry goods to remote areas or high mountains, pesticide spraying drones or amphibious military drones reflect all the preferences and needs that can be further explored in the future. The weights of the evaluation items and the fuzzy membership degree of the parts in this study provide an objective reference for designers and manufacturers to determine the priority of different appearance designs or parts selection in the drone design stage. These three evaluation items cover 95% of the visual area of the drone's overall appearance; the application of this research method can overcome the

shortcomings of evaluating individual items instead of the overall appearance, as in the past. Since drones with new appearances are introduced every year, it is suggested to collect various appearances from time to time and increase the number of styles in each evaluation item, so as to observe the trends of the consumer market.

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About the Authors:

Shih-Wen Hsiao His major research include application of fuzzy theory on product design, concurrent engineering in product design, CAD, applying neural network, GA, and gray theory to product design, color planning, heat transfer analysis, and application of reverse engineering in product design.

Po-Hsiang Peng He is a Ph. D student in industrial design at National Cheng Kung University (NCKU). I am specialized in packaging design and industrial design, mainly studying Convolutional Neural Network, fuzzy theory apply to bicycle design and color apply to product design.

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Morphological Exploration of the Turkish Tea Glass for Engaging Design Solutions

Naz Ayşe Güzide Zehra BÖREKÇI[a]*, Fatma KORKUT[a]*

[a] Middle East Technical University, Turkey
*Corresponding author e-mail: nborekci@metu.edu.tr
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Abstract: This paper discusses the pedagogical approach followed for an educational project focusing on engaging design solutions for tea glass sets in the Turkish context. The project aimed at incorporating local values, usage patterns and rituals to enhance user experience and user-product interaction, reinforce product value, meaning and longevity, and develop more engaging and sustainable solutions. The project was conducted in collaboration with a major glass manufacturing company and involved 28 junior year industrial design students. Eighty preliminary and final design solutions for tea glass sets were analysed. The approaches that students adopted for addressing engaging practices and sustainability were gathered under tea drinking practices, tea serving practices, and marketing of the tea glass sets. The strategies followed by the students to differentiate their designs included analogies and historic precedents, body proportions, contour lines, differing inner and outer walls, axial asymmetry, visual and tactile patterns, and atypical typologies.

Keywords: turkish tea glass; engaging design; morphological analysis; design ideation

1. Introduction

Since the late 1960s, there has been a significant increase in the use of single-use throw-away items for packaging, as well as for serving hot and cold drinks and beverages, substituting glass with paper or plastic alternatives (Lamagna, 2019). Throw-away cups are used more and more in many public places such as restaurants, bakeries, tea and coffee shops, as well as institutional canteens, vending machines and workplace kitchenettes (Wright, Gregory & Kalaian, 2011). They are preferred for being lighter, taking less space in storage, and eliminating the burden of cleaning and storing after usage in high numbers, as they can be simply thrown away. But, alongside the health-related concerns that come with these substitute materials for throw-away cups, their usage also ends with large quantities of waste, leading to disastrous environmental consequences (The Guardian, 2018). They also lead to changes in the daily practices and rituals of serving and consuming foods and

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beverages, affecting the local and cultural values associated with them.

Today, drinking tea in slim-waisted glasses is a widespread daily practice in Turkey, and tea is a favourite hot drink at any time of the day. Turkish society has been introduced to the samovar and tea farming in the late 19th century through Russian economic relations (Sözenler, 2018). The Turkish Republic started tea farming in the 1940s in the Eastern Black Sea region. Whereas the society was mostly familiar with the Turkish coffee consumed in homes as well as in coffee houses (Birsel, 2017), it did not take long for the 20th-century Turkish society to embrace tea brewed in samovars and drunk in the typical small tulip-shaped glasses. Today, the average tea consumption per person is about 1300 glasses in a year (Akyıldız, 2019), and 400 million tea glasses are sold within the local market each year (Radikal, 2009), making this tiny bulbous glass the most popular tableware item in the local market.

1.1 Preparing and Drinking Turkish Tea

The Turkish tea is typically brewed in a two-piece teapot (Figure 1). The bottom part is larger in volume and is used to boil water. The top part is smaller in volume and is used to brew the tea leaves. After placing the desired amount and batch of tea leaves, boiling water is added to the top pot and left to brew for around 15-20 minutes, while the bottom pot boils water on the stove keeping the top pot hot. When the leaves no longer float on the tea and sink into the pot, the tea is considered ready to be served.

Tea is served in bulbous thin-waisted tea glasses (Figure 1). The glass forms a wide-section bulb from the base upwards at the bottom part, then curves into a thinner section waist, and opens up conically for a wider rim in the top part. First, the brew is poured into the glass in a small amount (around one-fourth of volume), with the help of a strainer to collect the tea leaves. Then hot water is added until rim to lighten and thin the brew. The wide bottom part of the tea glass before the waist is used as a reference for the amount of brew to be poured. The amount of brew in reference to the amount of hot water changes the strength of the tea. A serendipitous functional benefit of the bowl curve turning into a narrower waist is to keep the tea leaves not caught by the strainer in the bowl section as the tea glass is tipped toward the mouth for a sip. Transparency of the tea glass is essential to be able to see while filling the glass with tea for an appreciated taste and colour. The sign of a well-brewed tea is its colour, a clear and bright reddish-brown, sometimes referred to as “rabbit’s blood.” Some prefer the tea glass full up to the brim, while others prefer an amount of the glass left empty, for the lip not to burn from contact with hot glass. This room is called the “lip margin.”

The tea glass is small in size and therefore accepts little volume. Generally, many glasses of tea are drunk one after the other, though, tea drinking is a slow process done in numerous sips, and the glass is never finished in one gobble. Taking sips while drinking tea is a repetitive action of placing and replacing the glass on its saucer. The tea glass typically pairs with its saucer, which can be made from porcelain, glass, metal, or plastics. The typical and culturally noteworthy saucer is the red and white petal formed porcelain saucer with

gold gilded flower patterns at the centre and on the white petals (Figure 1). According to Güneş (2012) the red of the petals on the saucer refers to the colour of the well-brewed tea, whereas the white colour matches with the brightness and transparency of the tea. Tea is served with sugar, which may be cubes, granules, or what is known as the sugar rocks, and can also be served with slices of lemon. Cubes and granules are stirred into the tea, while sugar rocks are bitten with each sip of tea. Therefore, the tea glass needs a saucer for the sugar cubes or rocks, lemon slice, and also to rest the teaspoon that will be used more than once.

The tea glass is never held while presenting it; it always comes with a saucer while transferring from host to guest. In a crowded group, tea is served on a tray, and when everyone finishes, the glasses are collected on the tray to be refilled with tea. A service concern is for the tea glasses not to get mixed up and return to their original drinkers. Some practices for ensuring this, include using tea glasses of different forms, patterns and colours, using different saucers and teaspoons, and using small distinguishable accessories attached to the glasses. When a guest no longer wants his/her glass to be refilled, s/he places the teaspoon on the rim of the glass as an indication. During an extended tea service, fresh tea is brewed every time the top pot finishes.

Figure 1. Turkish teapot, tea glass and saucer.

Although tea making, serving and drinking practices still maintain their distinct local character outlined above, intensifying after the 1980s, these practices have been altered and diversified with economic liberalization, rapid urbanization, and introduction of alternative paraphernalia including mugs, disposable cups, tea bags and locally designed Turkish tea machines particularly in office environments. “Tea universe” in today’s Turkey is a hybrid universe embodying global as well as local products and practices (Öğüt, 2009; Timur & Er, 2006).

1.2 Motivation for the Study

Based on the sustainability concerns mentioned earlier, and on the popularity of the Turkish tea glass in the local market, we decided to work on an educational project on the design of Turkish tea glass sets. The challenges for us were working with glass as the material, working on mono-body products (those with no components), and working on the design of a well-explored glass typology allowing limited design interventions. This paper describes

the design process of this educational project and discusses the methodological strategies followed for overcoming these challenges towards the delivery of diverse and engaging design solutions for tea glasses. First, the paper describes the methods and procedures offered by the design studio tutors for the generation of diverse design ideas. Secondly, the paper presents the design approaches and strategies followed by students in responding to the sustainability considerations, and in the diversification of their design ideas from those of their peers and from products available in the market. The paper concludes with the implications of the methodological approach in the exploration of engaging and sustainable design solutions on design divergence in industrial design education.

2. The Project

The project was carried out in the 2017-18 academic year, with 28 junior year industrial design students at Middle East Technical University in collaboration with LAV, a major Turkish glass manufacturer. The topic of the project was "Tea Serving as a Sustainable and Engaging Practice." Regarding the increasing usage of throw-away single-use paper or plastic cups in public facilities in Turkey, it was found necessary to reconsider tea serving and drinking practices along with the basic accessories involved: tea glass, saucer and sugar bowl. The project addressed design for sustainability considerations in terms of developing engaging design solutions. Design solutions incorporating local values, usage patterns and rituals enhance user experience and product-user interaction, reinforce product value, meaning and longevity, and lead to more engaging and thus sustainable solutions. Tea serving and drinking as a focal practice offer rich scenarios for envisioning engaging design solutions.

The target user group was local users, and the usage environment was households, offices, cafeterias, tea houses and outdoor vendors. The tea glass and saucer set, and the sugar bowl were expected to be marketed separately while being the members of the same product family. The main goal of the project was to rethink serving tea, and to develop engaging and thus sustainable design solutions incorporating local values, usage patterns and rituals. The project duration was a total of eight weeks. The project process included the stages of design research, idea generation, technical feedback, and design iteration, development and finalisation (Figure 2).

2.1 Design Research

For the design research phase, students were asked to form nine teams. Teams first carried out field observations and interviews about tea serving and drinking practices, and tea sets and accessories used in private and public spaces, with diverse users and in different use environments (Figure 3, Left). Each team prepared a poster presentation to share the outcomes with the class. Teams were also asked to conduct a literature search on different topics assigned to each, using print sources, online sources, the literature, and a field survey. The topics ranged over from glass manufacturing to tea culture. Again, teams prepared a poster presentation for the class (Figure 3, Right).

Following the discussions on insights gained as a result of the design research, the students continued working on their projects individually.

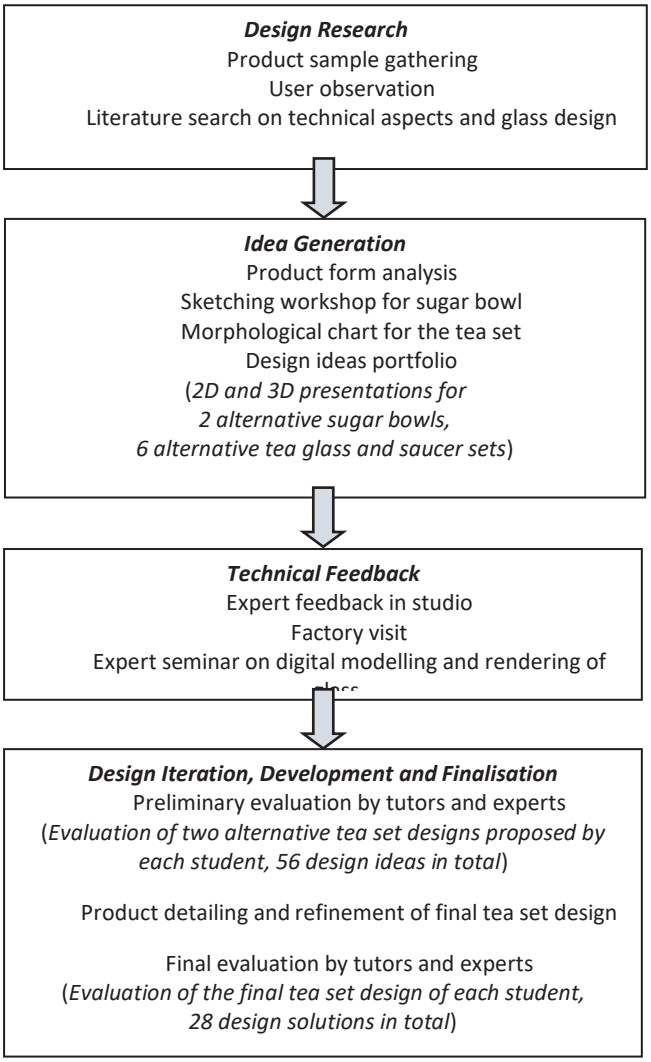

Figure 2 The design process followed for the project.

Figure 3 Left: User observation poster (Team 8). Right: Literature search poster (Team 4).

2.2 Design Ideas Portfolio

An intense idea generation stage was carried out for the development of diverse and numerous ideas. The project was primarily a search for form; therefore, it was important for the students to make 2D exploration with freehand sketching before making final design decisions (Tovey, 2012). The 2D exploration was supported with 3D prototyping (simple paper-based and clay-based models) to envisage the forms for spatial manipulation.

Product Form Analysis: Students were first asked to carry out a product form analysis to understand the morphology of the tea glass set items. They brought glassware samples to class to form a shared product library. From this pool each chose two examples of tea glasses, one saucer, and one sugar bowl, took their photographs, scaled these photographs to full scale, made print outs, then measuring both the actual glass and the printouts, they made 3:1 scaled technical drawings with half-sections for each item (Figure 4, Left). While transferring the curves of the glass items from 1:1 to 3:1 scale, the students had the chance to analyse the contours of the product and its sections, building awareness on the design decisions related to the production processes of glass, and also the usage of patterns on the form. On these technical drawings, they used tracing paper to variate the geometrical configurations including proportions of various parts, such as bowl, waist and rim, and the possible effects of changing curve radii.

Sketching and Prototyping Workshop for Sugar Bowls: The following session involved a one-day workshop for 2D freehand sketching and simple 3D prototyping. The particular focus was sugar bowls. The workshop was carried out by an invited lecturer. The task given to students was the making of numerous sketches on A6 size paper, exploring forms, and searching for proportions. The outcomes of the session were two sugar bowl design solutions and their mock-ups (Figure 4, Right).

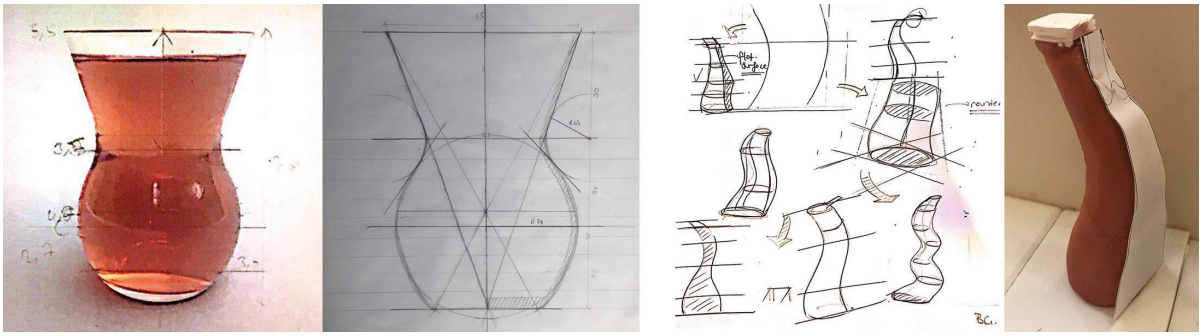

Figure 4 Left: Example of product form analysis. Right: Example of sketching workshop outcomes.

Morphological Chart: The following session was carried out for idea generation on tea glasses using the morphological chart method. The morphological chart is a table used for exploring various form alternatives for the components of a product (Roozenburg & Eekels, 1995; Wright, 1998; Smith, Richardson, Summers & Mocko, 2012). This exploration is done by first decomposing the product and identifying around 8 to 12 sub-functions. Then, these sub-functions are listed on the first column of the table. For each row representing a sub-function, six alternative sub-solution ideas are sketched. When the chart is complete, there will be many ideas of partial products or components. The final step is to combine the selected sub-solutions into an overall solution, adapting the sub-solutions to each other and to the overall design in terms of characteristic features, product usability and production processes. As the tea glass is a single piece object that does not have any obvious functional components, in deciding on the sub-functions, we looked at the form and determined the physical features. We gave the students a list of sub-functions for a tea glass for them to use in their morphological charts (Table 1). The expected outcome of the session was six alternative tea glass design solutions, together with their saucers, and mock-ups of two selected alternatives (Figure 5).

Table 1 List of sub-functions for tea glasses

A: Sub-function 1	Variations in form based on vertical proportions
B: Sub-function 2	Variations in form based on diameters of characteristic body sections
C: Sub-function	The contour of the body (vertical curvatures and lines)
D: Sub-function 4	The form of the rim
E: Sub-function 5	The form of the base
F: Sub-function 6	The form of the waist
G: Sub-function 7	Patterns as surface treatments (e.g., graphic applications, frosting, laser etching, engraving, sandblasting, gilding)
H: Sub-function 8	Patterns as form (relief designs)
I: Sub-function 9	Handles / glass holders
J: Sub-function 10	Stem / foot
K: Sub-function 11	Saucer: variations in top view
L: Sub-function 12	Saucer: variations in section incl. the way the tea glass meets the saucer

Figure 5 *Left: Example of a morphological chart. Right: Example of outcomes for the morphological chart exercise.*

2.3 Design Detailing and Finalisation

Visit from Firm and Expert Feedback: The design ideas portfolios prepared by the students in the idea generation stage of the project were evaluated in class by the experts from the collaborating firm. Distributing into four parallel critique tables, the experts gave design and technical feedback to students on their 2D and 3D prototypes (Figure 6, Left). Also, an expert on 3D digital modelling carried out a seminar with the students to help them with their glass modelling and rendering skills (Figure 6, Right).

Factory Visit to Firm: We also conducted a visit to LAV's manufacturing plant in Kütahya to get a first-hand look at the production processes. From then on, the students continued with the development of their design ideas.

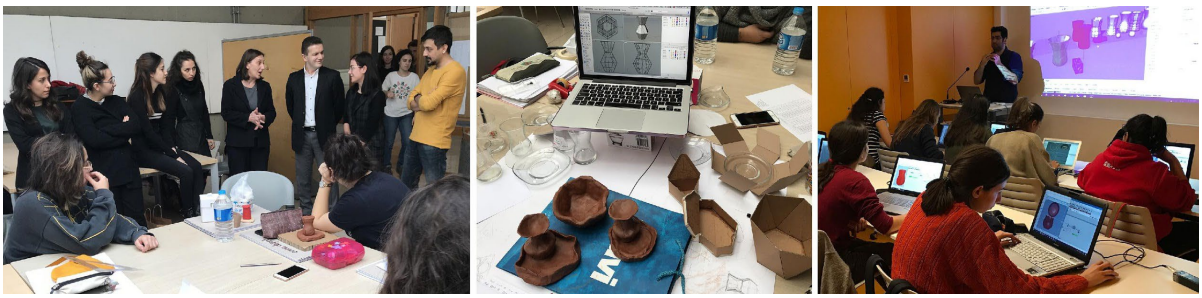

Figure 6 *Left: Expert feedback given in the studio. Right: Seminar on 3D digital modelling and rendering of glass.*

Preliminary Evaluation: The preliminary evaluation was carried out two weeks after the factory visit. Experts from LAV attended the evaluation session and provided feedback related to design, production and marketing (Figure 7, Left). For this evaluation, the students were expected to converge their design ideas and suggest two alternative tea glass sets. The submission of two alternative design solutions is a strategy we utilise in studio projects; rather than deciding on a final solution early in the process, we encourage *divergence* (Jones, 1980; Goldschmidt, 2016), and thus thinking in *parallel lines of thought* (Lawson, 2005),

which means thinking on more than one design idea at the same time. The benefits of this strategy are:

- to allow the flow of ideas and design synthesis to extend into the design process, for preventing early made premature design decisions.
- to crosscheck and evaluate significant ideas in reference to one another, and
- to have alternative ideas to transfer and combine from (Cross, 2000) during *convergence* (Jones, 1980; Goldschmidt, 2016), while the final design is being developed.

Design Finalisation and Final Evaluation: Three more weeks were allowed in the calendar for the students to carry out user-product trials, select from among their two design alternatives, work out the design details to finalise their designs, and prepare their final 2D and 3D presentations. For the final evaluation, the students were expected to submit one design solution for a tea glass and saucer set, and a sugar bowl, together with their packaging. The submission requirements for the final jury were presentation boards, technical drawings, and rapid-prototyped, paper-based or clay-based models of all items (Figure 7, Right).

Figure 7 Left: Preliminary evaluation. Right: Final evaluation.

2.4 Analysis of Tea Glass Set Design Solutions

We carried out a visual content analysis (van Leeuwen & Jewitt, 2001; Krippendorf, 2004) on the submissions that the students made both for the preliminary and final juries, to identify the approaches and strategies that they employed for their design solutions. We determined the particular focus as the tea glass designs, as this was the focal element of the product family, affecting the design approach adopted for the other members of the family, namely the saucer and the sugar bowl. Fifty-four (out of 56) preliminary and 26 (out of 28) final submissions for design ideas (80 design ideas in total) were analysed in terms of their formal qualities in combination with functional and tea culture-specific considerations. In our analysis we also took into consideration, when relevant, the names given to the designs, the project descriptions, and the ways in which the designs were presented within their context.

The findings were grouped into two major themes: *approaches to engaging practices and sustainability*, and *design strategies*.

3. Approaches to Engaging Practices and Sustainability

Looking at the design solutions offered and their project descriptions, we identified objectives that students adopted as their *approaches to engaging practices and sustainability* while responding to the design problem. We grouped these approaches as *tea drinking practices*, *tea serving practices*, and *marketing of the product sets*.

3.1 Tea Drinking Practices

Tea drinking was considered as a process from pouring tea into tea glass to comfortably and safely drinking tea with repetitive actions of holding, removing from the saucer, sipping, and replacing onto the saucer, all taking into account the typical local practices.

Guidance for adjusting tea strength: Solutions offered specialized patterns (e.g., rings and layers) for marking brew levels on the tea glass indicating the ratio between brew and hot water, for light and strong tea (Figure 8, Left).

Easy access to sugar bowl: Suggesting that sugar granules fall out during service, solutions included wide rims for sugar bowls for ease of access, and also tilted bowls that can be turned to serve in all directions (Figure 8, Right).

Figure 8 *Left: Adjusting brew levels with ribs on the glass. Right: Sugar bowl rotating in all directions.*

Stirring sugar in tea glass: Solutions considered a wide section for the bottom part of the tea glass to allow space for stirring in sugar with a teaspoon (Figure 9, Left).

Comfortable hold of tea glass: Solutions offered a comfortable hold of the tea glass by holding in one palm, holding within two palms, holding with two fingers from the rim, neck, waist and bowl, pinch holding from a handle, and support-holding from under handles at two sides (Figure 9, Right). Other solutions considered making the tea glass heatproof for the hand with a double-walled base section while slowing down the cooling of the tea.

Figure 9 *Left: Wide bowl section for ease of stirring. Right: Different ways of holding tea glass.*

Sipping the tea: For a comfortable drink of the hot liquid content, solutions defined a “lip margin” for the tea glass, as well as a specific lip contact area to always drink from the same side on the rim.

Accident-proofing: Solutions offered ribs and indents on various sections of the tea glass to prevent slipping from hand. Others provided a wide or thick sham (base) to prevent the tea glass from tipping over (Figure 10).

Easy replacement of tea glass on the saucer: Another objective addressed was the easy removal of the tea glass and its easy replacement back on the saucer, during the repetitive action required for drinking tea. Having a wide saucer diameter with a deep section, an outward extending conical or wavy skirt to catch the base of the glass, and using radial asymmetry for the form of the saucer, were among the solutions offered for a balanced service and usage (Figure 10).

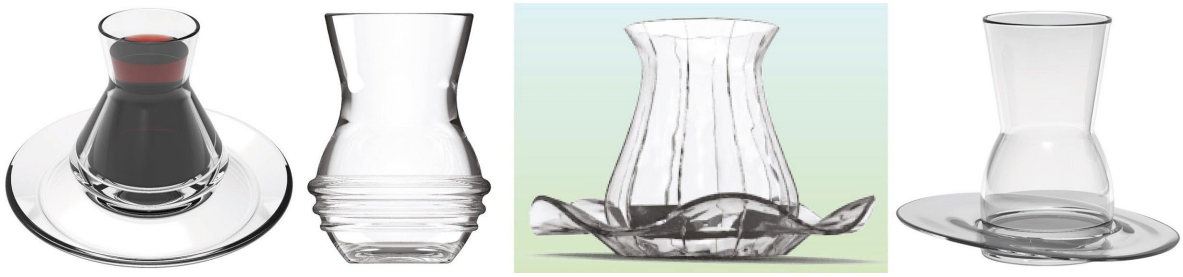

Figure 10 *From left to right: Glass with a wide base, glass with ribs; saucer with a high and wavy skirt; asymmetrical saucer.*

3.2 Tea Serving Practices

Tea serving was considered as a presentation medium of the tea glass set, also contributing to the tea drinking experience in terms of usage, visual appeal, and hosting rituals.

The set with a focal item: The tea glass sets had a focal item which mostly was the tea glass, but in some solutions, the sugar bowl or the saucer were offered as the focal item in the set (Figure 11). As a strategy, the items of the tea set were in harmony, sharing similar proportions and design features. Some solutions brought forth the tea glass in the set, giving

it more characteristic features, and a few examples emphasized the saucer with distinctive features.

Visual appeal: Solutions aimed for an attractive look to differentiate, surprise, and stand out among alternatives in the market, be displayed in home showcases, convey that the set is exclusive to guests, and provide a thematic visual identity for commercial environments. Solutions offered patterns for pleasing, dynamic and playful reflections; forms that provide variations in appearance from different angles (Figure 12, Left); forms that convey a stable and balanced look; forms that present a slim and elegant contour; and forms that convey generosity and luxury, achieved through their curves.

Figure 11 Left: Set with sugar bowl as the focal item. Centre: Tea glass and saucer sharing design features. Right: Design emphasis placed on the saucer.

Stackability: Solutions offered stackability for space-saving purposes, as well as for storing *in style*. Stackability was considered for the tea glasses as well as the saucers (Figure 12, Right).

Figure 12 Left: Visual appeal achieved with different optical effects. Right: Stackable saucers.

Comfortable hold of saucer: Another aspect was the ease of picking up the saucer from the service tray, table or counter, and handing it out for serving. Solutions considered easy lifting of the saucer from a flat surface with its wide and angled skirt, comfortable pinch hold for the saucer, and an appropriate diameter for the saucer for a comfortable two-finger grip from the rim. The tea serving solutions included asymmetrical saucers with one corner extending outwards for offering a lemon slice, cookie, sugar, or sweet on the side (Figure 13).

Figure 13 Tea serving solutions achieved with saucers.

3.3 Marketing of the Tea Glass Sets

The cultural significance and value laid on the tea glasses, namely, having widespread use in homes as well as in public places, being used daily as well as for special occasions, being historical as well as contemporary, and symbolising the care that the homemaker or host gives to his/her family or guests, were reflected in the marketing approaches adopted for the tea glass sets.

Sales channels for the tea glass sets: Affordability and wide accessibility of the tea set was observed to be a significant concern. The solutions suggested for the tea glass sets to be distributed through mass-market retailers. Solutions were shown on shelves displaying their convenient stackability, and that the packages of individual items belong to the same set.

Tea glass sets were also offered as a touristic gift pack with symbolic value to be sold in touristic shops and airport stores, and also as housewarming or wedding gifts to be sold in specialised shops.

Packaging of the product family items*:* The tea glass set solutions were offered as sets with all items packed together, only tea glasses and saucers packed together, and tea glasses, saucers, and sugar bowls packed separately.

In the Turkish market, tea glasses are generally sold in sets of six. The design solutions offered for tea glass and saucer sets included sets of two, three, and four (besides six). This strategy was offered for providing the consumers with the possibility of combining different models (e.g., three of each), buying in required amount (e.g., only two packs of four making 8 in total, instead of two packs of 6 making 12), and replacing the few broken items of larger sets (e.g., buying a set of two).

4. Design Strategies

We observed that students used several strategies while searching for origins for design ideas, generating diversified design ideas, and developing them into final design solutions. These strategies were identified from the idea content of the designs (e.g., theme, source of inspiration, the reason for a design feature), and from a morphological analysis of the designs.

4.1 Design Precedents

Employing analogies: Students employed analogies from nature, man-made things, and actions in their design ideas (Figure 14). Analogies from nature included honeycomb, leaf, water lily, tulip, pomegranate, magpie, shark fin, reptile scales, pinecone, water ripples, diamond and flame. Analogies from man-made things included the dome, minaret, and envelope vests. Analogies from actions included melting, knotting, pinching, posing, flaming, whirling, wrinkling and twisting. Using this group of analogies required effort in representing the dynamic qualities of actions in a stable product, making use of the optical qualities of glass, and exploring the limits of production constraints for this material.

Employing historic precedents: Although in a limited number, we observed references to precedents. One historical reference was used in the patterns to be applied on the tea glass set items (Seljukian geometrical patterns), and one cultural reference was used for form (oriental and central Asian bottles) (Figure 14).

Figure 14 *From left to right: analogies of twist, diamond and acorn; geometrical pattern and curvy form with references to precedents.*

4.2 Design Morphologies

Variations in body proportions: Form explorations of the tea glass were based on how they were divided into volumetric parts (base, bowl, waist/neck and rim). The general tendency was to signify the bowl and the rim as separate parts divided with the thin waist. The waist could be a curve defining a third body part on the glass contour, or an edge between the bowl and the rim. The bases and rims were mostly left plain with radial symmetry, complying with mass production constraints.

Variations in proportions were made both horizontally and vertically, affecting the volumetric sectioning of the tea glass (Figure 15). Explorations of horizontal variations in proportions refer to the ratio among the characteristic diameters of base, bowl, waist and rim. Variations in these diameters defined the inner and outer extremities of the characteristic curves of the tea glass. Explorations of vertical variations in proportions refer to the ratio of the heights of the base, bowl, waist and rim against each other and overall glass height.

Variations in the height proportions of each part affected the volume defined for each,

emphasized the distinction between the bowl and rim in particular, raised or lowered the centre of gravity of the tea glass, and overall affected the typology of the resulting tea glass.

Variations in contour lines: The tea glass contour is what characterises the tea glass typology; this contour is constituted by various curved and straight lines and the articulations between them. Characteristic contours were defined with single curves (the arc traveling from rim to base), two or more straight lines forming zigzags, two curves in opposing directions, combinations of three curves or more used in different directions, and combinations of multiple straight lines and curves (Figure 16). A general tendency was to use curves mostly on the contour of the bowl section, and straight lines for the contour of the rim section. Subtle contours followed the characteristic contour of the tea glass typology with smoother articulation between sections. Emphasized contours used more uneven articulation between sections, following strategies such as wide rim, wide base or wide bowl diameters, in combination with narrow diameters for the waist.

Figure 15 Variations in body proportions and contour lines.

Differing inner and outer walls: Differentiating the cross sections of inner and outer forms of the tea glass body was another strategy followed. Wall sections were offered as either full with glass, or as double-walled. In both cases, the optical effect would be fully revealed when the glass is full of tea (Figure 16, Left). A similar strategy was used for the base of the tea glass by making a thick sham filled with glass for a heavy appearance. This strategy resulted in tea glasses with smaller inner volumes. It was seen that this design strategy was explored for the preliminary ideas, and was quit altogether for the final design solutions.

Figure 16 Left, two: Inner and outer walls with different cross sections. Right, three: Axial asymmetry.

Axial asymmetry: Solutions exploring alternatives to a radial symmetry included tipping the axis in an angle, and breaking the vertical axis in an angle half-way through its height. Others included making the glass base wider on one side of the axis, making rim wider and extending to one side, using a flat surface on one side, and using parallel contour curves (instead of mirrored) on both sides of the central axis. There also were forms close to a soft square. Strategies for asymmetry were explored for the preliminary ideas and were mostly abandoned for the final design solutions (Figure 16, Right).

Variations in visual and tactile patterns: Pattern was used as a strategy for forming, emphasizing or softening the contour (Figure 17). In some solutions, the pattern was the geometrical form of the glass itself. Patterns were mostly applied as a texture on the bowl and waist sections. Patterns were used along the contour, and against the contour, contributing to the visual appeal of the tea glass. Subtle patterns used less depth and lower numbers of repetitions, resulting in optical effects. Emphasized patterns used more depth and higher numbers of repetitions, resulting in a more visible and tactile texture.

Figure 17 Patterns as form, as texture, and as optical effects.

Atypical typologies: Solutions explored ways for diverging from the typical tea glass (Figure 18). Solutions showing significant divergence from central tea glass typologies can be considered as extreme variations in body proportions or in contour lines, or a unique combination of them. These explorations resulted in *atypical* tea glass typologies referring to other product categories with their own typologies (e.g., vase, jug, tumbler, bowl).

Figure 18 Atypical tea glass typologies.

5. Discussion

Making a general overview of the process adopted for the project and the outcomes of each stage, we observed that the students were able to offer variety in their designs and bring novel solutions to the design of tea glasses, saucers and sugar bowls. We also observed that the design detailing and finalisation level of the projects were high. Many flaws in the preliminary designs making them inappropriate for industrial glass production were resolved for the final submissions. The quality of 2D and 3D presentation was mostly high, demonstrating that the technical aspects of the glass items were committed to production standards. The eight-week duration allocated to the project was a factor in this, but we observed that the strategies followed in the planning and carrying out of the design process have also contributed.

The research activities carried out in the early stages of the process supported the development of engaging and sustainable ideas. Students reflected on practices, habits and rituals, and were able to associate cultural values with them, and then transformed into engaging and sustainable themes.

The methodical design activities carried out with regular expert feedback supported a strong technical foundation. The project had many constraints related to material properties and production. The technical background set the project limits, but with more information, students were able to work around the constraints for variety in tea glass set design solutions. Regular expert feedback allowed students to test their designs, evaluate them and make timely critical decisions.

We observed that an in-depth 2D and 3D design exploration, and thinking with numerous alternatives supported the students in achieving diversity in their design solutions. A product form analysis combining technical drawings and freehand drawings worked well for understanding contour geometry, glassware sections, and consequently tooling considerations for the removability of glass items from the production mould. The morphological analysis helped identify the decomposition of a mono-body product in terms of its function as well as its production constraints. The product decomposition allowed the identification of various formal qualities that can be explored in terms of design and how they correspond to the functions and usage of the tea glass. Combining the partial design solutions for the decomposed features of the tea glass into alternative design solutions required a synthesis on the students' part, and in this stage of the process, students made use of the technical background they acquired.

The explicit focus of the project on local values, usage patterns and rituals offered a challenge to student designers to reinvent and reinterpret the local tea practices they were blindly familiar with, and develop engaging design solutions reinforcing product value, meaning and longevity. The collaboration with the industry, on the other hand, brought in the perspectives of external experts, and manufacturing and marketing concerns to form-giving process. These challenges coupled with the methodological approach adopted for the project resulted in i) highly specialized tea glass forms that, for example, afford precise

guidance for adjusting tea strength, comfortable pick through dimples on opposite sides, or safe sipping from a dedicated lip contact area, and ii) diverse tea glass typologies combining various strategies, for example, combining a variation in body proportions or a variation in contour lines with visual and tactile patterns.

As a final note, we need to address the complex relationships among the actors involved in the project. Kaygan (2016) posits the form-giving process as a material-semiotic practice. Reinforced with perspectives from science and technology studies and actor-network theory he offers a Foucauldian analysis of "the curve" (in the case of Turkish coffee pots) as "an idea and a guiding principle of design" mediating the design process "from beginning to end" in multiple ways, and for multiple actors. In a similar fashion, the form-giving practice experienced in this project was more than design students' engaging with affordances or typologies; the process involved a unique web of interactions, interventions, negotiations and compromises on the part of tutors, students, and experts.

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About the Authors:

Naz A.G.Z. Börekçi received her BID from METU Department of Industrial Design (1995); MFA from Bilkent University IAED (1997); PhD from University of Kent at Canterbury / KIAD (2003). She is currently Associate Professor at METU Department of Industrial Design.

Fatma Korkut is Associate Professor at METU Department of Industrial Design, Ankara, Turkey. Her research has ranged over design history, design education for sustainability, idea generation, sustainability scenarios, collaboration models with industry in design education, and design protection.

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Design Science Approach to Nature Inspired Product Forms: Studies on Processes and Products

Shiv Kumar VERMA[a]*, Ravi Mokashi PUNEKAR[a]*

[a] Department of Design, Indian Institute of Technology Guwahati, India
*Corresponding author e-mail: ecashiv@gmail.com
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Abstract: This paper follows a design science approach to inquire into the act of creation of nature-inspired product forms. Structured on Nigel Cross taxonomy, it considers three aspects for design research: Processes, Products, and People. In this paper, we discuss two aspects of the framework examining Processes & Methods by undertaking a comparative study of methods in the published literature on the generation of product forms inspired by nature. The second aspect, the study of Products is a qualitative study of visual elements of product form inspired by nature. The paper explores the possibilities of developing i) systematic design research and ii) systematic design practice in exploring nature-inspired product forms.

Keywords: nature-inspired design; design science; design research; design knowledge

1. Introduction

Nature has been a source of inspiration for man since time immemorial. Verma and Punekar (2017) in their review of published literature on Nature-Inspired Design (NID) focused on two professional groups' viz. Researchers/Scientists/Engineers and Designers/Architects/Painters/ Artists to examine terminologies, processes, and methods. The review also suggests that researchers have developed a few systematic frameworks/methods for the nature-inspired design that outline the different stages that are to be followed during the design process. Design as a discipline is often believed to be more application based and formal design guidelines for training the industrial designer to take inspiration from nature, seem poorly documented in published literature. Majority of the designers work is based on the creation and generation of product form based on intuition. Researchers, Scientists and Engineers often criticize Designers for being 'non-scientific' in their approach (Badarnah, and Kadri 2015) (El-Zeiny 2012) (Lepora et al. 2013). Motivated by such criticisms, the current research work intends to explore the possibilities of systematic design research and systematic design practice for the process of generating nature-inspired product forms. Specifically, we seek to answer the following research questions:

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- Can there be a systematic approach to inquire into the process of generating nature-inspired product forms?
- Can the process of generating a nature-inspired product form be systematised?

Our search for systematic design led us to the literature on Design Science.

Design science is defined to be a study of the design process that is - investigative (Gregory, 1966); scientific, logical, rational, systematic and organized (Johannesson and Perjons, 2014; Hubka and Eder, 1996; Cross, 2006). The research outcomes of design science are the artefacts like physical products, drawings, blueprints or they could take the form of knowledge e.g. guidelines, constructs, models, methods and instantiations (Johannesson and Perjons, 2014) (Borek et al., 2012). From the reviewed literature, design science could be summarised as 'investigation and accumulation of knowledge about the design processes' and it is also a 'systematic approach to design'. With these directions, this ***paper aims to study, investigate and accumulate knowledge about the process of designing nature-inspired product forms.***

2. Framework for research

Nigel Cross in his book 'Designerly Ways of Knowing' suggests that design research has to engage with the development, articulation, and communication of design knowledge that is embedded in three sources: people, processes, and products. It is therefore pertinent to investigate three aspects – the human ability to design; the processes and techniques that aid the designers; and the study of form and configuration of the products (Cross, 2006).

This taxonomy proposed by Nigel Cross forms the framework of inquiry for this research. It comprises of

- *Study 1 – A study of Processes and Methods:* It examines the methods proposed by designers and design educators to design nature-inspired product forms.
- *Study 2 – A study of Products:* It undertakes a three-dimensional visual analysis of product form of a selected range of products that are inspired by nature.
- *Study 3 – A study on People:* It examines the approaches followed by professional designers as they develop nature-inspired product forms.

The research follows a mixed-method approach involving qualitative and quantitative methods. The framework for the study undertaken is schematically represented (Figure 1). In this paper, we are presenting Study 1 on Processes and Study 2 on Products.

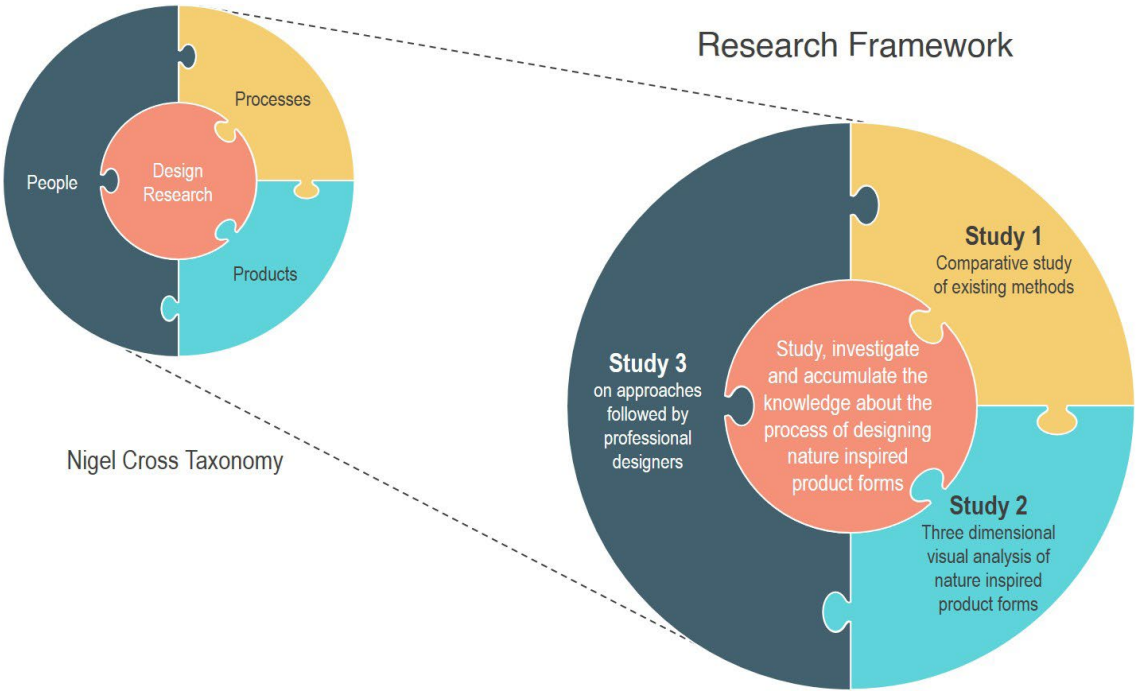

Figure 1 Research Framework adopted from Nigel Cross Taxonomy

3. Study 1 – A study of Processes and Methods

Drawing from sources of previous researches and tools developed by a few of the design schools in their pedagogic approaches, We draw a comparative summary of ten identified methods for product form generation that are inspired by nature.

Product Design from Nature (PDN) (Wen et al., 2008) and Generative product design (Huang and Li, 2014) are the methods based on CAD application. These methods integrate new technologies like 3D scanning, generative modelling, and rapid prototyping. In design education, there are some methods developed to aid novice designers in ideating new product forms. Diagram for Biomimetic Product Design (DBPD) is a nine-step process in which product semantics is the main approach in conceptual transformation (Hsiao and Chou, 2007). Applied aesthetics in biomimetic design – a guide, is a work of Technical University of Denmark (DTU), which proposes seven methods that can be used individually or complement each other in taking inspiration from nature's aesthetic attributes in a methodical way (Jorgensen, Kjeldsen and Lenau, 2013). Among the schools of Design in India, the processes followed include Elements of Form IV – Course series by Alexander Bosnjak (Bosnjak, 2007, IIT Guwahati), Abstraction in form generation (Sharma & Chakravarthy, 2009, IDC/IIT Bombay). Designing with analogy (Sinha and Chakravarthy, 2013) and 'Abstraction of animal, bird or insect', are research works and methods followed also at IDC, IIT Bombay. (http://www.dsource.in/course/form/form-and-abstraction).

Other methods were not specifically developed to take inspiration from nature but they, however, have included natural objects as inspiration in their process. Form generation

through styling cue synthesis is a method in which the styling cues from two different objects are merged together and abstracted for a new product form (Teubner, 2008). Hekkert and Cila (2015) in their research work, explains the process of applying metaphors to product forms to enhance the product experience. Table 1 summarizes these different methods.

Adopted from Pugh Matrix, a comparative study of the ten methods helped to identify the strengths and weaknesses of the different methods as illustrated in Table 2. The outcome of this study on Methods and Processes highlights the following five criteria's/requirements reflected in the process of designing. These are:

1. ***Integration of technology with the design process:*** Only two methods (method 1 & 2) integrate technology with the design process. New technologies used in these methods include CAD-based applications like 3D scanning, generative modelling, and rapid prototyping. Although employing CAD-based applications are very helpful in quick prototyping, they involve the use of expensive 3D digitizing tools and specialized knowledge to process their output data.
2. ***Observation of principles in nature and their application in the form generation process:*** In table 2, methods 2, 5 and 8 involve the observation of principles in nature. Natural form is analysed in second step of method 2. The method includes the application of observed principles in design process but is limited to the principles of aesthetic patterns only. In method 5, the observed principles related to structure, geometry, proportion, etc. are recorded in the form of graphic images like photographs and diagrams. The integration of information obtained by analysing natural form and development of three-dimensional form is not clear in this method. Method 8 involves the observation of four principles on unity of rhythm, variety, balance and form found in nature and their application in design.
3. ***Use of product semantics:*** Product semantics seeks to convey the meaning of product form. Designers often use natural forms as a metaphor to make their products more communicative. Method 3, 4, 7, 9 & 10 are the methods in the list that involved the use of product semantics. In method-3, product semantics is the main approach in conceptual transformation. Step 1 of method 4 helps to transfer the qualities of natural elements into design expressions by analysing natural element as a product. In method-7, direct analogy in nature act as a point of association with the desired emotion of food and helps in the initial stage of idea generation. Method 9 involves the use of a cue chart that has a list of terms that represent elements of visual semantics. Method-10 discusses eight metaphoric means or modes that a designer can use to transfer source cues to the target to enhance product experience. The method is more focused on selection of source and transfer of source cues to the target but does not discuss the transfer of selected features into form during form generation process.

Table 1 Methods for designing nature-inspired product form

S.No	Methods	Stages in Form Generation									Type
1	Product Design from Nature (PDN)	Capturing surface geometrical information	Building a 3D model	Manufacturing a prototype							CAD application based methods
2	Generative Product design	Identifying objective patterns in nature	Natural form analysis & development	Generative modeling							
3	Diagram for Biomimetic Product Design (DBPD) (Text)	0. Describe organism name & photo (Graphics)	1. Explain the features of organism (Graphics)	2. Depict unique feature that most represent the organism (Graphics)	3. Depict other features (Behaviour, habitat) (Graphics)	4. Describe various features obtained in step 3 (Text)	5. Categorize the keywords selected from step 4 into Noun, Adjectives & Verbs (Text)	6. Illustrate the meaning of three types of keywords in step 5 (Graphics)	7. Reproduce the graphic & objects from step 6 in grid (Graphic) (Objects)	8. formulate several conceptual solutions using graphics form step 2 & step 7 (Sketches)	9. Produce a detailed model	Design Education focused methods
4	Applied aesthetics in biomimetic design – a guide	Nature as product	Action reaction	Split feeling	Impressions on the spot	Inspiration boards	Pattern of inspiration	Inspiration wheel				
5	Elements of Form IV – Course series by Alexander Bosnjak	Analysing inspiration	Recording Observations	Compilation of result	Evolving three-dimensional form							
6	Abstraction in form generation	Perception	Conception	Visualization								
7	Designing with analogy	Expression depiction	Take an analogy from nature and source visuals	Identify attributes of the source analogy	Representation of analogy to target plate design and its form							
8	Abstraction of animal, bird or insect (D'source course)	Generic study	Develop a concept	Choice of material	Analyze material use	Final abstraction						
9	Form generation through styling cue synthesis	Understanding styling cues and visual language	Generating a configuration drawing	Choosing two objects	Analyzing and absorbing the styling cues	The Abstraction Scale	Applying the Process	The Final Synthesis				Methods not specific to nature-inspired design
10	Product metaphors	Source selection	Metaphoric means									

4. ***Focus on abstraction:*** In art, abstraction is the act of drawing out the essential qualities in a thing, a series of things or a situation (Hale, 1993). Instead of imitating exact natural form, designers prefer abstraction by removing extra visual cues from their designs. Method-5 makes use of photographic, allegorical, iconographic and diagrammatic representations to explore various possibilities for abstracting meaning and form. Method 6 & 8 consider abstraction as an important aspect of their form generation process. Method-6 is the adoption of Emiko Ohnuki's model with three levels of abstraction: perception, conception, and visualization, in which externalization happens at modified level 3. The authors explain the form generation process aided by abstraction through an example, which involves four stages. In Stage 1 of the process, the number of ways to capture stimulus in its abstraction is not well defined. Abstraction in Method-8 is more oriented towards exploration through a material. Authors describe it as a technique of capturing the essence in the limitation of medium. Method 9 uses an abstraction scale to control abstraction from literal depiction to abstract interpretation.
5. ***Approaches to help to generate more number of conceptual solutions:*** Creativity is a very significant element of a design method. A good design method supports creative idea development and helps designers to generate a large number of conceptual solutions (Shah, Vargas-hernandez, and Smith, 2003) (De Bono, 1992). Method 3 & 4 are the only methods that make use of ideation tools during form generation. Method-3 uses morphological analysis and Method-4 involves the use of inspiration wheel. Method-7 and Method-9 also support generation of alternative conceptual solutions, but they do not involve the use of any ideation tool. Method-7 uses an analogy from nature as a catalyst to trigger multiple thoughts. Method-9 merges the styling cues of two different objects to make a new one.

Considering the outcome of study 1 we can summarize that the above five considerations are essential requirements in the design process/method to generate product form inspired by nature. It is evident that no single method meets all the requirements of the form generation process. This is a research gap that can be explored for the development of tools and methods, which can cover all the five current requirements and the future requirements too. An in-depth study on people and products may help us to identify the factors that play an important role in the process of generating product forms inspired by nature. Combining those findings with the five essential requirements will help us in our attempt to theorize the phenomena, which can further support the development of tools and methods to help a designer in generating product forms inspired by nature.

Table 2 Comparison of ten methods based on five essential requirements.

S.No	Methods	Integration of technology with the design process	Observation of principles in nature and their application in the form generation process	Use of product semantics	Focus on abstraction	Help to generate more number of conceptual solutions
1	Product Design from Nature (PDN)	✓				
2	Generative Product design	✓	✓			
3	Diagram for Biomimetic Product Design (DBPD)			✓		✓
4	Applied aesthetics in biomimetic design – a guide			✓		✓
5	Elements of Form IV – Course series by Alexander Bosnjak		✓		✓	
6	Abstraction in form generation				✓	
7	Designing with analogy			✓		✓
8	Abstraction of animal, bird or insect (D'source course)		✓		✓	
9	Form generation through styling cue synthesis			✓	✓	✓
10	Product metaphors			✓		

4. Study 2 – A study of Products

Following the taxonomy proposed by Nigel Cross, we now study products as a basis for understanding the process of designing. The objective of the study is to conduct three-dimensional visual analysis of products that are inspired by natural forms. It, therefore, becomes pertinent to examine and develop a process to collect data on the perceptual similarity between product form and their respective natural inspirational form.

We will first consider the three levels of biomimicry that include: mimicking of natural form;

mimicking of natural process; and mimicking of natural ecosystems (Baumeister et al., 2013). For this study on artefacts (nature-inspired products) we draw upon the research work by Cila et al., who have discussed various past researches on analogy and metaphor and the role of two types of similarity between source and target (Cila, Hekkert and Valentijn, 2012) – i) perceptual similarity, which is the physical resemblance between two objects, and include appearance, movement, sound and interaction pattern; and ii) conceptual similarity, which represents the relation between two concepts and include function, working principle, emotions they evoke and environment/context.

In this study, we mainly examine the overall 'exterior visual form' of the selected products and focus on perceptual similarity between designed products and their inspiration source in nature – mainly appearance (Form, Size and Proportions).

4.1 Methodology

To undertake the study, a graphical data collection tool was developed drawing upon Rowena Reed's methodology of 'structure of visual relationships' (Hannah, 2002); Cheryl Akner-Koler's principles of three-dimensional visual analysis (Koler, 1994); Frank M. Young's methods of three-dimensional form analysis/manipulation (Young, 1985) and Maggie Macnab's methods on using universal form and principles in design (Macnab, 2012).

The graphical data collection tool contains twelve form attributes: Form category, Primary Geometric Volumes & Surfaces, Hierarchy of order, Type of axis, Conditions expressed by axes, Types of axial movements, Types of axial relationships, Types of curves, Transitional forms features, Type of organization of elements, Type of symmetries and Type of patterns (figure 2). This tool guides the respondent to compare and enter the visual information or visual cues of natural and man-made three-dimensional form.

Stratified sampling of 30 nature-inspired products was undertaken for the current study based on the following two criteria's:

1. Selected products are designed by leading designers/companies who are well known for designing nature-inspired products.
2. The inspirations for the selected products were very clear and mentioned by the designers/companies on their websites, interviews or magazines.

Following these two criteria, 15 products designed by professional Indian designers and 15 products designed by well-known professional international designers were selected for this study. Table 3 shows a detailed list of all the products with their respective designers/ company.

Figure 2 Graphical data collection tool.

Table 3 List of thirty nature-inspired products with their respective designers/company.

Products designed by International Designers	
Product	**Designer/Company**
Diatom Chair, Biophilia, Agaricon, Florensis, Cosmic Leaf.	Ross Lovegrove
Anyfix, Mega passenger, Tea Service “Drop”, Squirrel Colani Cup, Canon Frog.	Luigi Colani
Kastor, Parrot, Piccantino, Juicy Salif	Alessi
Daisy (Coat Stand)	James Irvine/Danese Milano
Products Designed by Indian Designers	
Product	**Designer/Company**
Jelly Fish (Floor standing lighting), Ant (Floor book holder), Twig (Fruit holder), Hammer head (Digital movie player), Slice (Fruit holder), Urchin (Tooth pick holder), Raptor (Bicycle), Sting-ray (Watch packaging), Leaf (Mixer grinder), Butler’s Mixer Grinder, Pure it	Neil Foley
Ground or Suspended lamp	Satish Gokhale
Tiltr – Fitness Device	Axiom Consulting
Water Purifier inspired by apple	i2r Design
Perfume Packaging inspired by lotus	Onio Design

Qualitative data gathered in the form of texts were subsequently coded into numbers for further analysis. The cluster analysis method was adopted to identify the patterns of similarity that exist in the product form and inspirational form.

The visual analysis of any object can involve a high level of subjectivity and very much depends on an individual's perception. To ensure the objectivity of the study, the experiment was conducted with three respondents and in two sessions. A detailed discussion on principles of visual analysis was held before the experiment to bring the three respondents on a common ground for analysis. Respondents performed the visual analysis in two sessions (Figure 3).

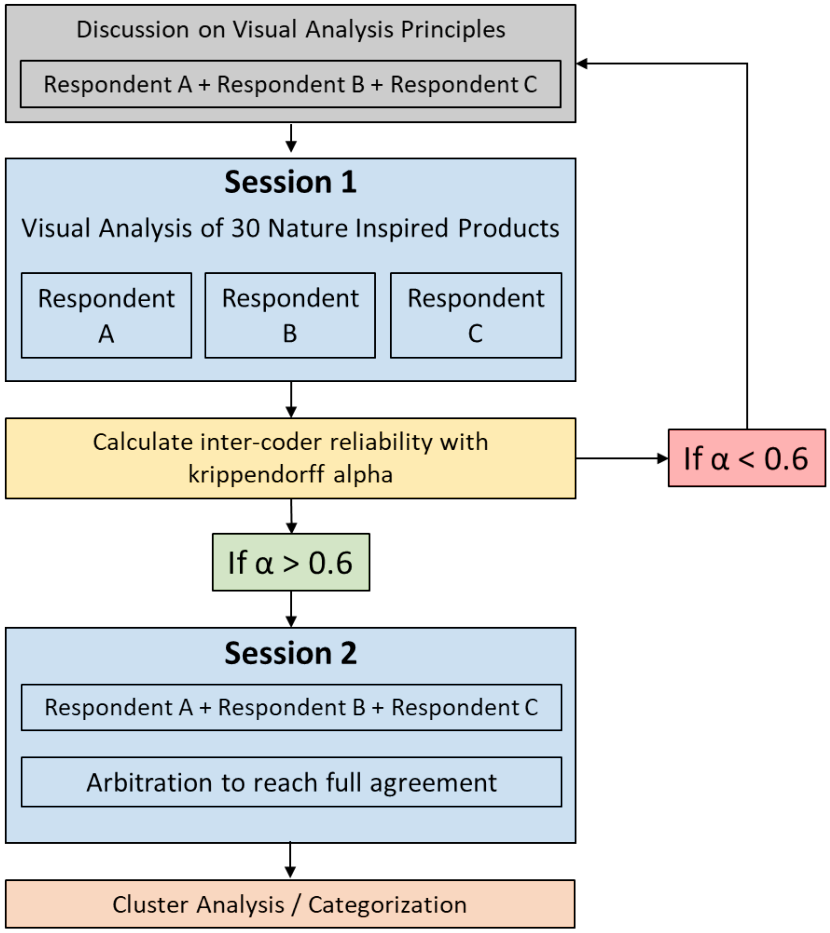

Figure 3 Experimental procedure for three-dimensional visual analysis

In session-1, respondents performed the visual analysis individually and separately. The inter-coder reliability for 12 items of the tool was checked using Krippendorff alpha (Hayes and Krippendorff, 2007) (Krippendorff, 2004). The values of Krippendorff alpha for twelve form attributes for the current experiment after session 1 are represented in Table 4. In session 2, respondents A, B, and C discussed all the differences in their data for arbitration to reach 100% agreement.

The data obtained after session-2 was then used as an input for hierarchical cluster analysis and analysed using the SPSS statistical software package. Cluster analysis was performed only for those form attributes that have more than three attributes of similarity. If the attributes of similarity were less than three, then the products were grouped under those attributes of similarity.

Table 4 Value of Krippendorff's alpha for Respondent A, B & C after session 1

S.No	Form attributes	Krippendorff's alpha For Respondents A, B & C
1	Similarity in the ***form category***	.9304
2	Similarity in ***Primary Geometric Volumes*** or ***Surfaces / Shapes***	.8490
3	Similarity in ***Dominant, Sub-dominant*** and ***Sub-ordinate*** elements	.9027
4	Similarity in ***types of Axis***	.8024
5	Similarity in the ***conditions expressed by axes***	.7606
6	Similarity in ***types of Axial movements***	.8202
7	Similarity in ***types of Axial relationships***	.8909
8	Similarity in ***types of curves***	.6263
9	Similarity in the ***transitional forms features***	.7694
10	Similarity in the ***type of organization of elements*** existing in the form	.7200
11	Similarity in ***type of patterns***	.7567
12	Similarity in ***types of symmetries***	.6365

Example – The cluster analysis result of similarity in the 'hierarchy of order' for thirty products reveals that there are four clusters when a cutting point is located at 7 scales as shown in figure 4.

Cluster 1: Cluster of products in which there is no similarity in the dominant, sub-dominant and sub-ordinate elements of the product and natural inspirational form.

Cluster 2: This cluster consists of products that have similarity in dominant and sub-dominant elements of the product and natural inspirational form.

Cluster 3: This cluster of products has similarity in dominant elements of the product and natural inspirational form.

Cluster 4: This cluster consists of five small clusters: Cluster of products having similar sub-ordinate elements, a cluster of products having similarity in dominant & sub-ordinate elements, Cluster of products with all three elements similar, cluster of products having similarity in sub-dominant & sub-ordinate elements and a cluster of products having similar sub-dominant elements.

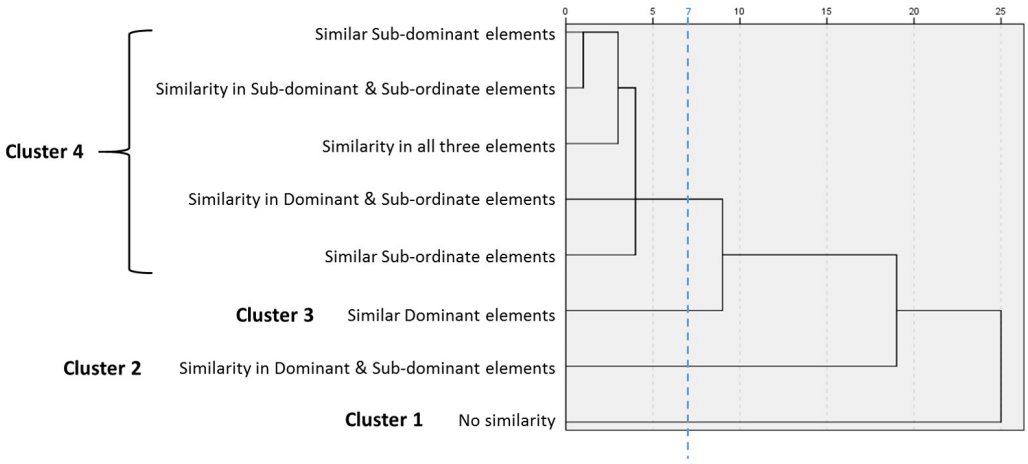

Figure 4 Dendrogram of similarity in the hierarchy of order for thirty products.

4.2 Results & Discussion

The visual analysis of thirty products for twelve form attributes indicates that similarity in certain visual cues and no similarity have emerged as the major clusters/groups in outcome analysed (Table 5). All twelve form attributes have clusters/groups of similarity with the majority of the products falling in those clusters/groups e.g. form category - cluster 1 and Primary Geometric Volumes & Surfaces – Cluster 1 & 3. These form attributes also have the clusters/groups of no similarity e.g. Hierarchy of order – cluster 1 and Conditions expressed by axes – group 2. This similarity and no similarity in visual elements could be an important parameter for resemblance and abstraction that designers seem to consider in their product forms inspired by nature. Consider similarity/more resemblance and No similarity/less resemblance/abstraction as two extremes of a spectrum. This spectrum when merged with attributes of similarity, can help a designer to control abstraction in new designs through a form attribute controller (Figure 5). It can also help to generate more number of design concepts following a generative approach of design. This study is focused on exterior forms of artefacts (Nature-inspired products) which helped to understand the relationship between perceptual similarity, form attributes, and abstraction in such products.

Table 5 Results of cluster analysis of thirty products

S.No	Form Attributes	Number of Clusters/ Groups	Classified clusters and Groups		Number of products in each variable
			Cluster/Group	Attributes of similarity	
1	Form category	4	Cluster 1	Both forms belong to the same form category	16
			Cluster 2	One form belongs to the central category and other belongs to main category or subcategory from the outer ring.	5
			Cluster 3	One form belongs to the main category & another one belongs to subcategory adjacent to main category	5
			Cluster 4	Both forms belong to two subcategories adjacent to main category.	3
				Two forms lie in opposite categories	1
				Both form belongs to two different main category	0
2	Primary Geometric Volumes & Surfaces	3	Cluster 1	Both forms have similar primary geometric volumes	18
			Cluster 2	No similarity of primary geometric volumes and surfaces in both forms	8
			Cluster 3	Both forms have similarity in primary geometric volumes as well as primary surfaces.	1
				Both forms have similar primary surfaces	3

3	Hierarchy of order	4	Cluster 1	No similarity in dominant, sub-dominant and sub-ordinate elements	10
			Cluster 2	Similarity in dominant & sub-dominant elements	8
			Cluster 3	Both forms have similar dominant elements	4
			Cluster 4	Both forms have similar sub-ordinate elements	2
				Similarity in Dominant & Sub-ordinate elements	2
				Both forms have similarity in all 3 elements (Dominant, Sub-dominant & Sub-ordinate)	2
				Similarity in Sub-dominant & Sub-ordinate elements	1
				Both forms have similar Sub-dominant elements	1
4	Type of axis	3	Cluster 1	Similarity in three types of axis exists in both forms	16
			Cluster 2	Similarity in one type of axis exists in both forms	7
			Cluster 3	No similarity in the type of axis among both forms	3
				Similarity in two types of axis exists in both forms	4
5	Conditions expressed by axes	2	Group 1	Both forms have a similarity in one type of condition expressed by axes.	20
			Group 2	No similarity in the type of conditions expressed by axes.	10
6	Types of axial movements	2	Cluster 1	Both forms have a similarity in one type of axial movements	16
			Cluster 2	No similarity in axial movements of forms	9
				Similarity in two types of axial movements	5

7	Types of axial relationships	2	Cluster 1	Both forms have a similarity in one type of axial relationship	17
			Cluster 2	No similarity in axial relationships among the two forms	7
				Similarity in two types of axial relationships between forms	6
8	Types of curves	3	Cluster 1	Both forms have a similarity in one type of curve	14
			Cluster 2	No similarity in the type of curves exist between forms	8
			Cluster 3	Similarity in three types of curves among forms	1
				Similarity in two types of curves in both forms	7
9	Transitional forms features	3	Cluster 1	Both forms have a similarity in one type of transitional form features	10
			Cluster 2	Both forms have a similarity in two types of transitional form features	9
			Cluster 3	No similarity in the type of transitional form features among two forms	9
				Similarity in three types of transitional form features	2
10	Type of organization of elements	2	Cluster 1	Similarity in one type of organization of elements	15
			Cluster 2	No similarity in the type of organization of elements	12
				Similarity in two types of organization of elements	3
11	Type of Symmetries	3	Cluster 1	Both forms have similar reflection symmetry	21
			Cluster 2	No similarity in the type of symmetries among two forms	5
				Similarity in rotation symmetry among two forms	4
12	Type of pattern	2	Group 1	Similarity in the type of patterns among two forms	10
			Group 2	Pattern doesn’t exist	20

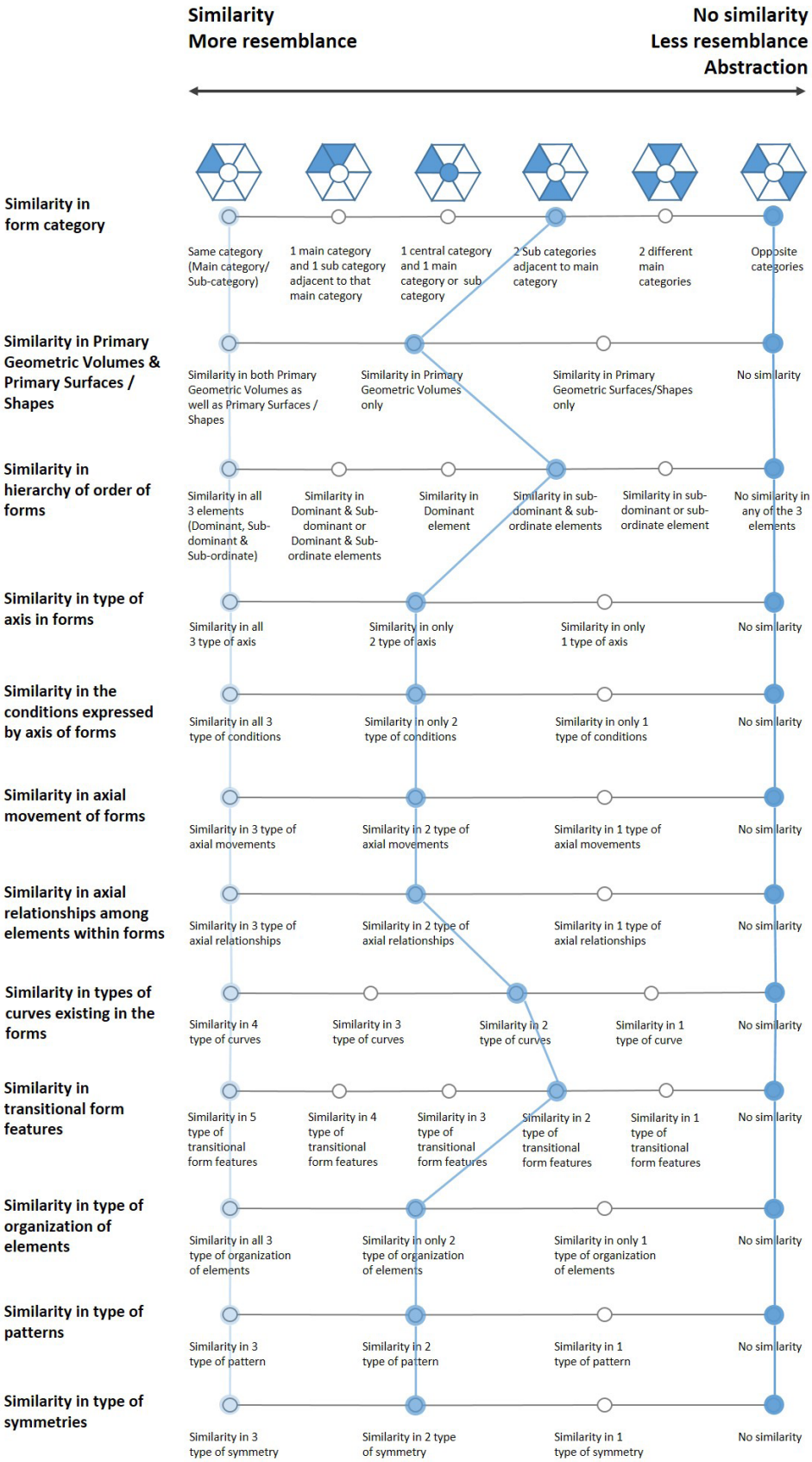

Figure 5 Proposed form attribute controller that can be used in a design tool

5. Discussion

Through a rigorous study of – processes, products, and people, Nigel Cross outlines a unique process in design research for knowledge generation. The focus of our research is to understand the process of nature-inspired approach in the generation of product form, we adopted the above taxonomy as the framework for driving our study. In this paper, we have attempted a systematic inquiry into two aspects of the research framework focused on two different modes of knowledge: Processes and Products. In this section, we discuss our observations and insights from these two considerations following a systematic mode of inquiry that is summarized below.

Under the study of Processes and Methods (Study 1), we identified five key requirements for a design process in the generation of product forms inspired by nature. These key requirements can be used as a guideline to develop a design process.

- ***Technology***: Can be integrated at various stages within the design process for the generation of conceptual and novel product forms.
- ***Observation:*** Different methods can be incorporated into the design process to observe natural form and their fine details.
- ***Semantics:*** Include semantic studies that seek to answer what natural forms mean to people and how that meaning can be conveyed through the product form.
- ***Abstraction:*** Identify new ways in the extraction of essential visual cues for manipulating them to achieve controlled abstraction in the product form.
- ***Creativity:*** Develop creative approaches to facilitate the generation of more conceptual design solutions for the product form drawing from the source in nature.

In the study of Products (Study 2), we were able to identify how the presence and absence of perceptual similarity is important in form generation; its relationship with form attributes; and how it can be controlled for abstraction.

The findings assimilated from these two different modes helped us to gain knowledge about the nature-inspired form generation process that we aimed for. It highlighted the scope for introducing a systematic approach to the study of nature-inspired design.

In the view of the authors, the significant contributions that the study was able to achieve are the following:

A research framework based on Nigel Cross taxonomy – In our study, we have followed a research framework based on Nigel Cross taxonomy. The strength of this framework lies in its holistic approach that can help a researcher to investigate an unexplored research area from three different perspectives: Processes, Products, and People.

Earlier attempts to understand the design approach of the nature-inspired design were more 'People' oriented. Lutchmansingh investigated Mackmurdo's approach of botanical designs (Lutchmansingh 1990). Chen and Sung examined the organic design style of Ross Lovegrove (Chen and Sung 2013). Wong studied the work of four architects: Frank Gehry, Zaha Hadid,

Daniel Libeskind and Thom Mayne (Wong 2010). We have demonstrated a successful application of this framework for our research work focused on 'Processes' and 'Products'.

To the best of our knowledge, such an approach to apply Nigel Cross taxonomy in conducting a study on nature-inspired product form has not been attempted earlier. This research framework provided a systematic mode of inquiry to understand the process of nature-inspired form generation, which answers our first research question.

The systematic inquiry leads to a systematic approach of design – Our systematic inquiry focused on processes, products, and people has helped us to gain knowledge from three different sources. Five essential criteria identified in the study of Processes and Methods (Study 1) form a core, around which a method can be developed for undertaking a nature-inspired form generation process in design.

Although abstraction is an important aspect among four methods (Method 5,6,8 & 9) covered under the study of Processes and Method (Study 1), there is no systematic way to control abstraction in these methods. Form generation through styling cue synthesis (Method 9) involves the use of an abstraction scale but the selection and manipulation of form elements with two variables on the scale (literal depiction and abstract interpretation) is not clear. The proposed form attribute controller in the study of products (Study 2) can be developed into a creative design tool that will systematise the form generation process and will help a designer to navigate through the form generation process in a systematic way. This offers interesting possibilities for design practice and design education in the future.

Methodology and experimental protocol for three-dimensional visual analysis – The third contribution of this research is the methodology and outline of the protocol for nature-inspired product analysis.

Graphical data collection tool for three-dimensional visual analysis – The graphical data collection tool has been specifically developed to collect visual information on perceptual similarities during this research and can be used in two different forms for future works.

- It can be used directly in research studies involving the study and assessment of three-dimensional visual analysis of the perceptual similarity between the source in nature and the target product form.
- In research studies related to the study of nature and form, the data collection tool can be modified suitably into an observation sheet to systematically collect visual information or visual cues of natural form under study.

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About the Authors:

Shiv Kumar Verma is a Ph.D. student at the Department of Design, Indian Institute of Technology Guwahati. Previously, He worked as a Project Research Associate at IDC, IIT Bombay on project E-Kalpa (D'source) with a Master in Industrial Design from IIITDM Jabalpur.

Professor Ravi Mokashi Punekar is a Product Designer and Professor at the Department of Design, IIT Guwahati. After an early stint in industry, he joined the Faculty of Industrial Design at the National Institute of Design in 1986. He is actively involved in Design Research and Product Design and Development activities.

Experiential Knowledge SIG

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Editorial: Synergy and experiential knowledge in collaboration – the Experiential Knowledge SIG

Nithikul NIMKULRAT[a*] Convener of the DRS Experiential Knowledge SIG (EkSIG)

[a] Faculty of Design, OCAD University, Canada
* nnimkulrat@faculty.ocadu.ca
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Introduction

The selected papers for the EKSIG section at the *DRS 2020: Synergy* present case studies that address tacit knowledge generated and communicated in the *processes* of making and designing that take place as collaborations, in one way or another, between the maker and the material, the maker and the designer, or the maker and the user. The papers relate to the fundamental issue of the DRS Special Interest Group on Experiential Knowledge (EKSIG) that is concerned with the understanding and role of knowledge in research and professional design practice. It is also linked to the trend that EKSIG is leading with regard to how joint experiential knowledge is accumulated and communicated in and through collaborations or collaborative processes, how synergy between collaborators is generated, and how such knowledge is embodied in the outputs and may be traced back to the origin of the practice.

EKSIG section: Selected papers

The paper 'Material connections in craft making: the case of felting' by Bilge Merve Aktaşa, Maarit Mäkelä and Tarja-Kaarina Laamanen (paper 216) describes a study that aimed to understand how the practice of felt makers developed in connection with wool (i.e. collaboration between the makers and the material). It was carried out by interviewing and observing felt makers in Turkey and its empirical data was analysed using Malafouris's (2013) theory of material engagement. The data demonstrates how felt makers' identities evolved in relation to things, people, space, and time. "Through their material interactions, felt makers design their artefacts, organise their workspace, and review their connections to other makers". The findings of the study elucidate a holistic and insightful understanding of the material's role in shaping felting practice.

Tacit knowledge generated and communicated in a collaboration between the maker and the

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designer can be seen in Estelle Berger's paper entitled 'Empowering artisans through design: a case study on the dynamics of collaborative projects' (paper 113). The paper examines collaborations between artisans and designers, aiming to address the gap between theory and practice by analysing the dynamics of co-design projects. The case study presented in the paper was conducted in France with immigrant artisans who were paired up with designers to work as co-design teams to design and prototype objects based on the expertise of the artisans including wickerwork, woodwork, sewing, jewellery, tapestry, and ceramics. This case study followed a guiding framework built from Ingold (2012) and Niedderer (2013) that consisted of the following three approaches: know-how driven; material driven; and concept driven approaches. The framework did not aim at generalizable findings, but rather at contribution to knowledge on the dynamics of collaborative projects that could potentially be used for future projects. The results of the case study led to the following recommendations to promote stable and rich collaborations: preparing the collaborative approach; projects' dynamics and management; and empowering artisans to play an active role in their professional path. Transversal competences and interactional expertise are key to success.

The study presented in Jessica Priemus's paper entitled 'Materialising weaving: embedding a narrative of construction time within experimental woven textiles' (paper 354) aims to illuminate a synergy between the maker and the user. The question asks in the paper is what methods and tools of design could be utilised to connect the user to textile making processes. It is to find ways in which woven textiles can narrate the weaver's traces of time involved in hand weaving to the user, serving as the site for user engagement. Priemus explored the question from a first-person perspective of a weaver who employed a practice-led research methodology, a weaving log to track her own actions, and Anni Albers' (1965) hierarchical 'three elements of weaving', which includes texture (weave), yarn and colour, to provoke haptic experiences to the potential user. The study followed Nimkulrat's (2012, p. 1) practice-led research methodology that places an emphasis on how research can "theoretically inform practice" in order to "develop the practitioner's aesthetic intelligence" in designing objects that can be interpreted more easily. The outcome of this research was the development of a "framework for textile designers and weavers that privileges cloth as a conduit for temporal connections between maker and user".

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About the Author:

Dr Nithikul Nimkulrat intertwines research with textile practice, focusing on experiential knowledge in craft processes in the context of design research. Her current research interest lies in the correlation between craft practice and mathematics as well as digital technology. She is the main editor of *Crafting Textiles in the Digital Age* (Bloomsbury, 2016).

For more information on the Experiential Knowledge SIG, please visit the SIG's webpage at http://drs.silkstart.com/cpages/experiential-knowledge-sig. To find out whether the SIG is organising a satellite event to the DRS2020 conference, or just to get in touch with members and see news on the SIG, please visit the SIG webpage.

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Material Connections in Craft Making: The case of felting

Bilge Merve AKTAŞ[a]*, Maarit MÄKELÄ[a], Tarja-Kaarina LAAMANEN[a]

[a] Aalto University, Finland
*Corresponding author e-mail: bilge.aktas@aalto.fi
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Abstract: This study examined a creative practice, namely felting, to explore the daily practices and encounters of felt makers. The study aimed at understanding the material connections of felt-making that are not limited to the making process. To examine how practices of felt makers emerge in connection to materials, we employed the material engagement theory as our perspective. The data was collected through interviews with eight felt makers and participant observation at two studios in Turkey. The analysis revealed how felt makers think between things, people, space and time and develop their practices accordingly. These findings illuminated a holistic and insightful understanding of the material's role in shaping the practice and field. A more holistic and insightful approach can also propose being open to constantly renewing creative practices and recognising how its material connections affect other things and people.

Keywords: felting; wool; creative practice; material engagement

1. Introduction

Philosopher Gilles Deleuze and psychoanalyst Felix Guattari (2019, p.553) described felt as an anti-textile that is "in principle infinite, open, and unlimited in every direction; it has neither top nor bottom nor centre; it does not assign fixed and mobile elements but rather distributes a continuous variation". Our previous study about felting in Turkey indicated that variation also continues in makers' approaches to felting (Aktaş & Mäkelä, 2017). These different approaches are not limited to differences in techniques of actualising an artefact but also includes various social and material encounters. This paper extends the previous analysis that examined designerly approaches in felt-making to understand how material affects the creative practice.

In this study we examine felting from the perspective of material engagement theory (MET). According to archaeologist Lambros Malafouris (2013, p.35), MET can illuminate interactions between mind and material to understand "the making of present and past ways of thinking". MET proposes that human thinking is situated in deep intra-actions between

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people and their surroundings, both human and nonhuman, and occurs between people, things, space and time (p.39). Similarly, a creative practice requires life span development and emerges out of an interaction between individual, field, and domain, which in our study is felting (Simonton, 2000; Csikszentmihalyi, 1990). Applying MET to examine craft making and its material connections can illuminate various ways of becoming a maker in connection to material things, other people, working spaces and the history of craft practice.

For this study, we examine ways of felting in relation to the material, namely wool, due to its central role in shaping creative practices. For instance, materials can affect thinking while making (Nimkulrat 2012; Aktaş & Mäkelä, 2019), experiences and communicating with the experiences (Karana, Pedgley & Rognoli, 2015; Pallasmaa 2009), and ideating design (Bolt 2007, Ingold 2010, Laamanen & Seitamaa-Hakkarainen, 2014). We contribute to these discussions by looking more holistically at the materiality of felting and its connections.

For this study, we interviewed eight felt makers from Turkey and conducted participant observation at two studios, five days at each. In the following section, we first unpack the concept of MET then present our empirical data and discuss it from the perspective of MET to gain a better understanding of the field. We conclude by studying our findings regarding people, things, space and time to present a more a holistic and insightful understanding of the material's role in shaping the practice and field.

2. Material Engagement Theory (MET) as an approach

Craft practice is a way of thinking while manipulating material (Nimkulrat, 2012). In this process, the maker builds a dialogue with his/her hand, mind, material, and material surrounding (Aktaş & Mäkelä, 2019; Mäkelä, 2016; Sennett 2013). This dialogue is extended to the situations, as social scientist Donald Schön (1988, p.183) argues, since creative practices either transform the situations or are transformed by the situations. Based on their personal experiences, makers generate various perspectives and knowledge types for similar creative practices (p.182). Accordingly, as sociologist Richard Sennett (2008, p.150) argues, the dialogical act of making and thinking can facilitate the gaining of knowledge. By thinking with materials and shaping them into forms, cultures are constructed (p.199). Therefore, creative fields emerge from the togetherness of interrelations between things, bodies, ideas, memories, and social formations (Fox & Alldred; 2017, p.88).

According to Malafouris (2013, p.44), we make sense of the world through our material engagement in which the mind is extended to the surrounding space, and we think between people, things, space, and time. He proposes that during constant material engagements, materials enact people to interact with them in different ways (p.118). Therefore, while engaging, materials actively shape how humans think and transform their intentions (p.148).

Similarly, sociologist Andrew Pickering (1993, p.571) argues that through time, human perceptions and material existence re-constitute each other, which results in new knowledge and experiences. By accommodating to constraints emerging from culture, materials, or practices, which are sometimes not even actively operating, we gain our agencies (p.583).

Therefore, as Malafouris (2014, p.150) proposes, things and humans *come to be* through mutual engagement with social encounters and interactions. During these processes, whether they are craft-making processes or other types of material engagement, various entities enable and constrain each other (Malafouris, 2008).

Accordingly, in this study, we follow the idea that material and immaterial things actively affect the way we think, make, and exist in the world. We examine felt-making in relation to the possibilities that the material provides to understand how felting emerges. According to political theorist Jane Bennett (2010), things embed no fixed or static identifications but rather their meanings can change in relation to the conditions and other participating entities. Similarly, craft fields have dynamic structures based on interrelations between people, materials, space and history. According to Schön (1988, p.182), knowledge of making is embedded in the "materials, artefacts made, the conditions under which they are made, and manner of making".

Drawing from these discussions, we study various practices that felt makers engage with to understand how they make felt not only through actualising an artefact but also through social and material encounters in the field. Thus, our discussion is not limited to the actual making process of felt but also includes other practices of the felt maker, such as obtaining the material, working with other people, and maintaining the practice. The MET perspective can extend the understanding of making and illuminate how the practice of felting operates on many levels and is connected to *things*, such as materials and tools, *people*, such as other felt makers and audience, *space*, such as making space, and *time*, such as evolvement of the practice through time. Next, we will present the setting of our study.

3. Studying the field of felting in Turkey

Felting is based on entangling wool fibres by applying friction, warm water and acidic soap to create nonwoven textile pieces (Burkett, 1979). Felting has a rich history in Turkey with an established design understanding both for making procedures and visual ideation for the practice (Burkett, 1979, p.77). Over time, new machines were introduced that quickened the production process by applying the friction power not with human physical effort but with machine power (Figure 1). New materials were also introduced, some of which were different types of wool and some are composite fibres with qualities resembling wool. Currently, felting is practised within a larger context that involves utilitarian and self-expressive artefacts (Atiş-Özhekim, 2009; Ovacık & Gümüşer, 2015).

Figure 1 *Felting machine. The two arms apply pressure from above while the tank in the bottom whirls the piece around itself. Photography: Aktaş, December 2016, Tire.*

To gain a general understanding of the field, we conducted a field trip to various cities in Turkey in December 2016. We interviewed felt makers working at eight studios that utilise felting for producing various kinds of artefacts, such as artworks, garments, carpets, and utilitarian intermediary products. These interviewees were selected after an extensive online search to map the field based on their use of felting as their main practice.

We interviewed felt makers in their workspace while they were working to observe and be in the real environment and position their opinions about their practice in context (Muratovski, 2016, p.64). The questions were mainly about making processes, raw material generation, the structure of the workspace and collaborations. Semi-structured interviews also provided insights into how they perceive their practice and the field. The interviews lasted between thirty minutes to two hours and they produced interview transcripts, videos of making processes, photos, and field notes (Table 1).

In August 2017, we organized another field trip to spend time at two studios, five days in each. On this field trip, we employed participant observation procedures to become more integrated into the field and observe the insider's knowledge (Bernard, 2006). The first author became a participating observer and helped craftspeople with their everyday activities, including preparing the wool, making the artefact and communicating with customers. This observational time produced interview audio-recordings, videos of making processes, photos, and field notes (Table 1). Also, in this period the first author was involved

in the production of eight small or medium-size carpets and one large carpet in the first studio and one large carpet and twenty small cushions in the second studio.

Table 1 Empirical data of the study.

Data	Audio-recordings of Interviews	Video data	Photographs	Field notes in A5 pages
First field trip (eight studios)	4.5-hour	3.5 hours	565	78
Second field trip (two studios)	6.5-hour	2.5 hours	358	56
Total	11 hours	6 hours	923	134

3.1 Analysing the data

To identify the everyday practices and social encounters of felt makers, we investigated the interview transcripts using thematic analysis and generated sixteen codes and eight overarching themes (Figure 2 presents codes in lower case letters and themes in upper case). Field notes and photographs supported contextualising the information. First, we employed the *cut and sort* method to find significant phrases in the texts (Ryan & Bernard, 2003, p.94-96). These phrases included descriptions, emotional expressions and informative reflections that helped us understand the field.

Then, we identified repeating patterns emerging from these phrases by focusing on repetitions, similarities and differences, and transitions between the information among different felt makers (Ryan & Bernard, 2003). We found sixteen codes that conveyed information about the practice, space, things, people, and time, categories which we adopted from MET. The codes were: *preparing the wool, the material (wool), additional materials, co-workers, the practice, products, the workspace, commercial activities, contact people, the identity of the maker, personal histories, other felt makers, definitions, the general situation of felting, problems/wishes*, and *plans for the future* (Figure 2).

We then grouped these codes and generated eight overarching themes that construct the practice and the field of felting (Ryan & Bernard, 2003). These themes were: *making, design, material, marketplace, economy, the maker's societal relations, attachment to the practice* and *collaboration* (Figure 2). The thematic analysis revealed the material's key role in the felt maker's practice as it appeared both as a code and a theme. Thereby, the material became the main frame of this paper to examine the practice and the field of felt-making.

When grouping the themes, some of the codes were shared by several themes. To show the overlaps of the codes within themes, we designed an image in which each theme is assigned a colour and a shape to group the codes it involves (Figure 2). The translucent colours emphasised the strong connections between various aspects and showed how most codes are relevant for multiple themes (Figure 2).

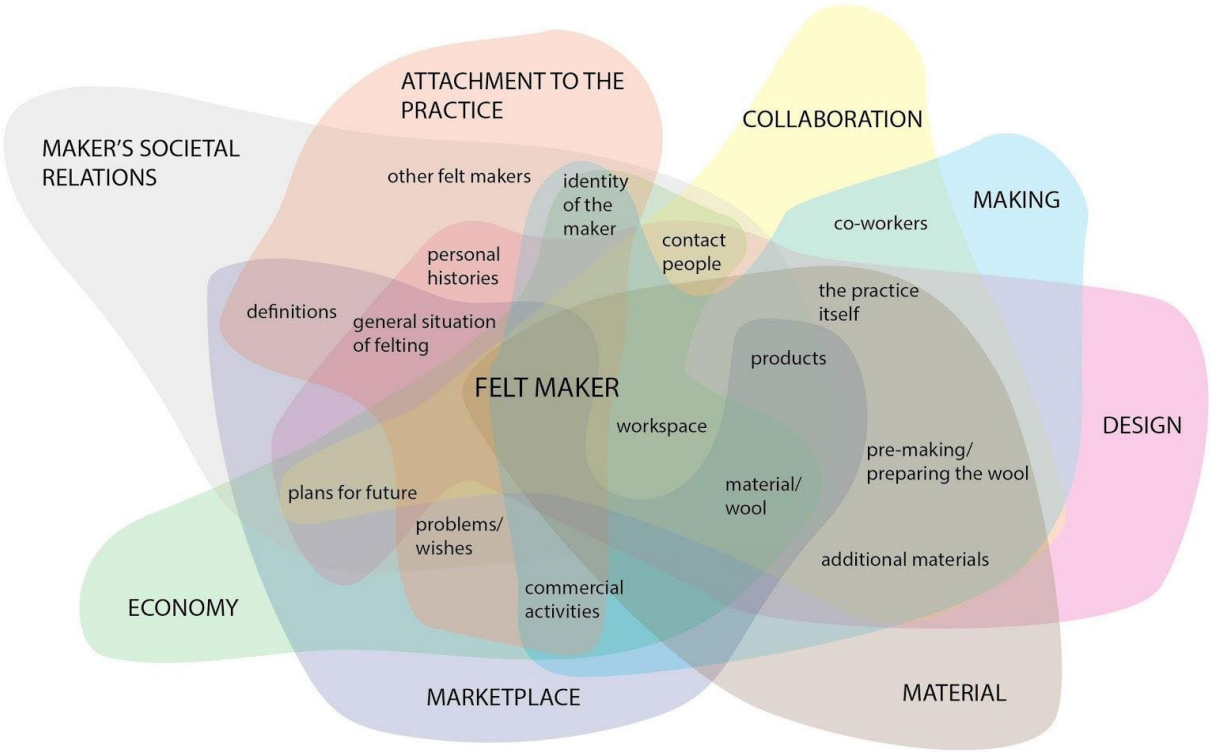

Figure 2 *The components of felt-making are strongly connected as they are affected by similar factors.*

Next, we will discuss how the practice of felting is connected to *things*, such as materials and tools, *people*, such as other felt makers and audience, *space*, such as making space, and *time*, such as evolvement of the practice through time.

4. Layers of felt-making

During the interviews, felt makers pointed at several issues that significantly shape their practice and the field. The material, namely wool, was one of the most significant components that affect the makers' practice, designs, workspace, and relations to people. In Turkey, sheep typically grow thick fibres, mixed with thin ones (Tüfekçi & Olfaz 2014, p.22). Although the thick fibres possess a fine felting ability, the sensory experiences may not be as nice. Therefore, felt makers stated that they can work with three types of wool in accordance with the needs. They can work with the local wool that comes from local sheep, they can re-treat the local wool and select only the thin fibres or they can purchase imported wool (Figure 3). In this section, the main themes from Figure 2 will be discussed in depth in connection with the types of material.

Figure 3 Local wool (left) and imported wool (right). Photography Aktaş.

4.1 Workspace

As Figure 2 indicates, workspace is a central element that affects most of the themes. Therefore, although it is not a theme, we included workspace in this section to discuss material connections. Different wool types require various practices, such as cleaning, carding or selecting the wool. Therefore, makers designed and structured their workspace according to the wool they were using. Thus, the workspaces are drastically different. When craftspeople prefer to employ local wool, either the villagers deliver their wool to the workspace or the felt makers collaborate with people living in the surrounding villages to collect wool (Figure 4).

Some felt makers use local wool as it is without cleansing it of the natural features and with mixed fibres. First, they separate the wool based on its cleanness and colours, as wool may naturally have ivory or dark colours. Then, with a machine that jumbles up the wool in a whirling tank, the dirt and natural pieces, such as hay pieces, are eliminated. Next, the wool is carded with a machine to disentangle the fibres and line them up in an orderly way (Figure 5). After this, the wool is ready to be felted. As this wool requires multiple steps before the actual felting, it requires a large workspace. Also, since this wool is utilised with all its natural qualities, the workspace is mostly messy.

Figure 4 Material delivery to the workspace. Photography: Aktaş, August 2017, Yalvaç.

When the wool is generated by selecting thin fibres from the local wool to improve sensory experiences, the maker needs a large space to carry out such a practice. After cleansing the wool of dirt, which is often done in collaboration with industries, the makers select the thin fibres by hand and do carding at their workspace. Since this work is done in large amounts, a storage space is often needed. This treatment requires time, labour and financial investment.

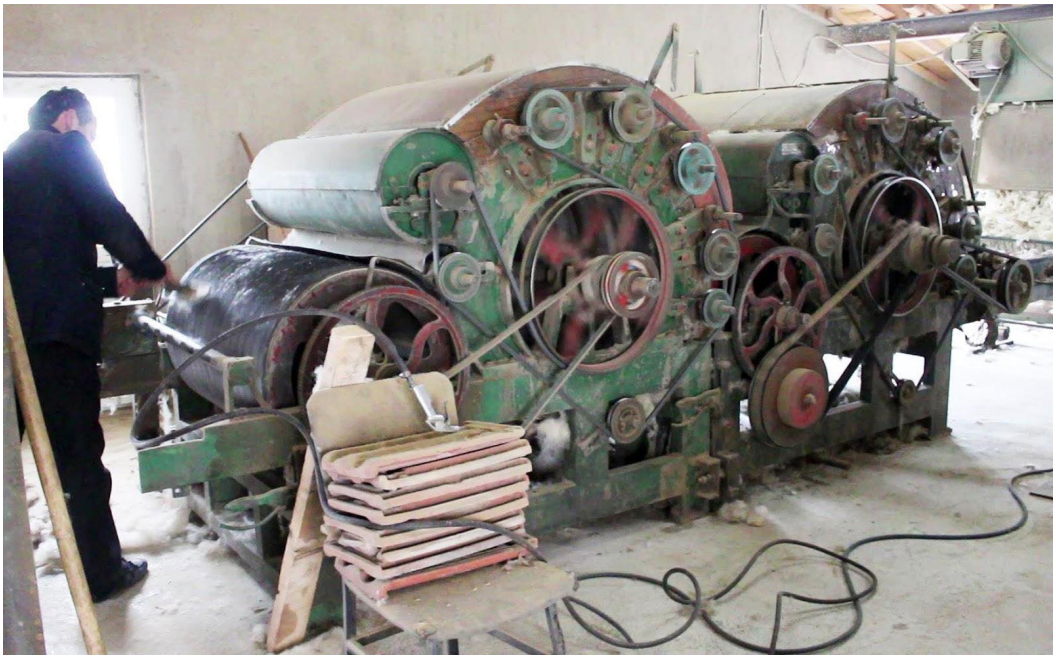

Figure 5 Carding machine in Gencer's workspace. Photography: Aktaş, December 2016, Yalvaç.

When felt makers use imported wool, they usually purchase it through intermediary

businesspeople from New Zealand; therefore, they need financial investment. When the wool arrives at the workspace, it is ready to be felted. In this case, the workspace is more sterile as only clean wool enters the space (Figure 6).

Figure 6 *Ayfer's workspace, she uses imported wool and often makes artistic felt works. Photography: Aktaş, December 2016, Seferihisar.*

Therefore, workspaces differ from each other with their size and cleanness. A common approach in organising the studios is to leave large enough empty space in the centre to locate the table or work on the floor when making large pieces (Figure 6). The empty space enables spreading the wool and creating a form before the actual felting begins. Accordingly, the machinery is usually placed around the walls to create such availability. Sometimes, workspaces also extend to public space in front of the studios, either because of the limited size or to benefit from fresh air.

4.2 Design

The thick wool fibres are typically firm and create an itchy sensory experience when in contact with human skin. Therefore, it is usually employed for everyday use artefacts with no direct contact, such as floor coverings, modest carpets and cushions, and utilitarian products, such as insulation sheets, saddle fabric and tents (Figure 7). In these carpets, the designs are similar to the ones from historical examples that Burkett (1979, p.78) presents.

Figure 7 *Traditional carpet and cushion examples from Ufuk's workspace. Photography: Aktaş, December 2016, Tire.*

The thin fibres generate softer sensorial experiences, and this wool is usually employed for fine products such as carpets and garments. The size can vary, yet due to the labour-intensive work or financial investment, it is typically employed for medium and small size artefacts. This wool is often employed for making fine designs and artefacts, such as artworks, garments or high-quality carpets (Figure 8).

Figure 8 *A tapestry by Ayfer, who has a background in painting. Photography: Aktaş, December 2016, Seferihisar.*

Products that are mostly garments can be found at several shops without their maker's signature. There are also unique designs, mostly carpet or tapestry, that carry traces of their maker. In developing new artefacts, felt makers find inspiration from each other's works but also follow iterative design processes. One felt maker pointed out the importance of having access to a large amount of material in order to experiment with it:

"It doesn't matter if the designs don't work out well. I can try several more times because I have the material and I am eager to try new things. Other felt makers may not be that experimental." (Gencer, 22 December, 2016, Yalvaç).

Gencer's iterative design process also refers to the importance of generating new design ideas by experimenting. As Malafouris (2014, p.144) proposes, makers *discover by creating*, and experimenting with materials can enhance their creativity.

4.3 Making

Felting techniques are essentially the same even when different wool types are employed. First, the wool is spread out on a surface according to the desired size. Hot water is then splashed over the wool, the piece is rolled around itself and placed in the machine. The machine whirls the wrapped piece around itself while applying pressure from above and the sides (Figure 1). The machine's work continues for several hours, depending on the thickness of the artefact. When felting is completed, the artefact produced is washed and cleansed of soap. If the artefact is asymmetrical, its form can still be changed by pulling and pushing from the sides (Aktaş & Mäkelä, 2019).

Although this process remains similar, various wool types might require different tools. For instance, usually the artefacts made with thick wool are large in size and to speed the process, a tool called a çırpı is employed so that the wool is spread more quickly as this tool enables the collecting of a larger portion of wool. With thin fibre wool, however, since the artefacts are more delicate, spreading the wool is usually done by hand. Since the artefacts made with this wool are usually small or thin, felting can be also done by hand on desktops. In this case, after splashing on the water, the piece is hand-rolled back and forth until the fibres are entangled completely.

All felt makers stated that they often make their artefacts without a prior planning process. Rather, they follow the material and decide the visual elements of the artefact as they create. This approach is similar to Ingold's (2010, p.10) discussion on designing while making and observing material transformations, rather than forcing a preconceived idea. Therefore, for the felt makers, the making process is also the designing process. For instance, one of the felt makers stated that although she thinks a lot before she makes, her mind is often free while making:

> "The material leads and fluxes you … as a method, I find staying in the moment very valuable. When the material starts moving, I take a step back … I leave the room, have a cup of coffee. When I'm back I know what to do". (Ayfer, 20 December, 2016, Seferihisar).

4.4 Marketplace and Economy

The analysis showed that the Marketplace and Economy as themes share most of their codes, therefore we discuss them together. The material types, designs and workspace create the audience. As Bennett (2010, p.56) argued, the creative materiality of artisans can generate various forms of encounters in relation to other things, such as makers or materials, that they are in close contact with. Similarly, as the wool type and wool generation technique creates various sensory experiences, users approach the product differently, such as for utilitarian or artistic purposes. The craftspeople we interviewed also noted that, regardless of the wool type, customers approach the felt artefacts with their preconceived assumptions, such as its ties to rural life. Since the thick fibre wool is often used for making utilitarian artefacts, its audience is often people living in rural areas or businesspeople who are looking for intermediary products. The artefacts, made of thin fibres, usually target domestic and international tourists as well as everyday users.

Felt makers frequently sell their artefacts within their workspace since they can benefit from tax-aid. Sometimes, makers also collaborate with other shop owners to exhibit their works in multiple locations. Although the financial conditions of the felt makers are in general quite diverse, there were no apparent complaints regarding this matter. However, it was obvious that maintaining an art or design-oriented practice with re-treated or imported wool requires financial stability. For instance, one felt maker that uses imported wool makes different artefacts to maintain her practice:

> "I wish … I could spend more time on design processes or making process. But if you want to maintain your work, sometimes you have to pay attention to the market demand. Now I have a few types of practices. I give what is asked from me to maintain the business, so I make things that are in demand. Then I have artistic works in which I make my own designs and enjoy the making process, with these works I open exhibitions. And the third type is the small-scale decorative accessories to keep the business alive". (Ayfer, 20 December. 2016, Seferihisar)

4.5 Maker's Societal Relations and Collaboration

Analysis revealed that the Maker's Societal Relations and Collaboration as themes share most of their codes; therefore, we discuss them together here. The activities of people who participate in a given field interfere with each other in unpredictable ways (Law and Mol, 2008: 70). Similarly, felt makers collaborate with several people in various ways. For instance, most felt makers work with their colleagues at their own workspaces. All the studios visited included at least two felt makers working together on most projects (Figure 9). Sometimes, felt makers collaborate with other felt makers who have their own studios but work in different ways. In this collaboration, the aim is often to unite different knowledge types to co-make an artefact. For instance, sometimes they collaborate to combine different wool types:

> "All artefact types require different material. It makes no sense to try to make something out of the material that I don't use. I have friends who already make them, so we share things". (Ayfer, 20 December 2016, Seferihisar).

Figure 9 *Co-design in progress at Tahsin's workspace. Photography: Aktaş, December 2016, Ödemiş.*

Felt makers also collaborate with other craftspeople, such as saddle makers, to co-produce artefacts in which the main aim is to make a profit. Most interviewees shared their experiences of participating in local and international fairs and exhibitions. Although these fairs are useful for maintaining their social existence, felt makers who work in remote locations also mentioned the challenges of participating in big events. Yet, participating in events and having an online existence, mostly on social networks, also bring collaborators such as artists and designers through maintaining social relationships (Kaya & Yagiz, 2011, p.59). Therefore, some felt makers work with visiting designers and artists to develop their products. One felt maker stated that he changed his style of making through an international collaboration he had ten years ago. Another felt maker also described how he develops new designs with other creatives:

> "We develop our artefacts with our collaborators … People bring their ideas to us and we experiment together. Then, if the designer allows us, we alter the designs and generate our own artefacts … We want to stay amateur. Otherwise, we are afraid that we wouldn't have dialogues with these designers". (Ufuk, 21 December, 2016 Tire)

Felt makers also participate in socially beneficial events, such as organizing vocational courses for underprivileged people or art events with kids. These initiatives often happen in collaboration with local governments, as most felt makers stated.

4.6 Attachment to the practice

Often the attachment comes from personal histories and how felt makers identify

themselves and is structured through time. Most of the interviewed felt makers learned this practice in their early lives from their family members. Since felting is part of their identity, they continue this practice even without a significant profit. For instance, one felt maker who works with his two brothers and two friends continues his job because of the joy he gets:

> "Sometimes my brother and I dislike each other's designs and argue, but we continue making because we love this job… To improve ourselves, we work in new ways all the time … We collaborate with other felt makers [and] do our best to create something nice for people. This makes us happy." (Tahsin, 21 December, 2016 Ödemiş).

Another felt maker referred to the history and making process of felting that builds an emotional tie not only between the maker and the practice but also between users and the artefacts:

> "Felt is the first textile … [and] it is still produced with the same techniques … [the material features are such that] hugging the wool is [almost] the same as hugging your mum". (Ayfer, 20 December, 2016, Seferihisar).

This study shows that the procedures to transform wool into felt remain similar for all felt makers since the material characteristics, such as its flexibility and elasticity, remain similar across various kinds of wool. However, the type of wool can generate significant differences before making starts and after making is finalised in terms of product type, workspace and collaborators. These significant differences dramatically affect the subsequent steps, which eventually affect the practices of the maker. Our findings suggest that through interactions with wool, felt makers have developed fluid identities that are co-constituted with other felt makers and through material interaction. Next, we will discuss these themes in relation to people, things, space and time, which we adopted from MET.

5. Understanding the Field of Felting from the Material Perspective

Our findings are in line with Malafouris's argument on thinking that takes place in between things, people, space and time. Although Malafouris (2008, 2013) discussed thinking in direct engagement processes, such as while throwing clay at a potter's wheel, we find it suitable for understanding material connections and how thinking emerges through participating in the field. The empirical data demonstrates that felt makers understand and explain their maker identities as being constituted between *things*, such as their materials, workspace, and artefacts, *people*, such as their fellow makers, collaborators, audiences, and users, *space*, such as workspace, marketplace, and economic space, and finally *time*, such as by reflecting on their previous experiences and personal attachment.

In felting, *things* often refers to materials and tools that affect how makers think and act. Through their material interactions, felt makers design their artefacts, organise their workspace, and review their connections to other makers. Thus, things mediate the co-emergence of the makers, artefacts, and the field. For instance, making felt by hand or with a machine can dramatically change designs, since while hand-making the design can still be altered, whereas in machine production making changes can be challenging.

Felt makers interact with many *people* when obtaining the material, making with colleagues, generating an audience and collaborating with other creative makers. These interactions are sometimes planned but often evolve more intuitively and require the felt makers communicate in different ways. This encourages felt makers to think in new ways to construct a multi-angled practice. For instance, although most felt makers concentrate on making a certain type of artefact, by collaborating with various people they develop their practices. Even the makers using local wool stated that they sometimes collaborate with art students to simplify their own designs.

The interaction between things and people affects the emergence of a *space* that felt makers participate in. The most significant engagement space for felt makers is their workspace with its own evolving ecologies. However, the participation space can extent both physically and virtually. For instance, some felt makers employ even public space as an extension of their workspace, both to make and exhibit their artefacts. Some felt makers use their workspace for teaching the practice, exhibiting and selling their works. Within this physical extension, felt makers also extend their minds, how they think and how they make. In this sense, the marketplace and economic environment also become spaces for felt makers to operate in. For instance, most felt makers started participating in *virtual space* by using online platforms to exhibit their works.

Through *time*, felt makers continue developing their unique ways of engaging with the material to evolve in their craft. Most felt makers mentioned the importance of staying sharp and fresh by constantly searching for something new. Thus, their practices and identities are changing continuously since the flux and emerging interactions generate new knowledge as well as new experiences (Pickering, 2005). For instance, most felt makers started their practice by making traditional products, as they learned from family members, and it was only later that they began making their own designs. Thus, the time that craftspeople have been making felt impacts their practice. Also, the time that is required for making a single piece impacts the outcome and thinking of the craftspeople as well. For instance, when making small artefacts with imported wool, the time spent with the material is shorter than making an artefact from the local wool, in which case the process starts with collecting and cleaning the material. Being with the material for an extended time while making an artefact also impacts the outcome and process.

Discussing how felt makers think between things, people, space and time shows how their maker identities have been evolving in connection with material interaction. If we make sense of the world through our experiences with the material world, as Malafouris (2013, p.44) argues, then we call for a deeper and more comprehensive understanding of the world. In this understanding, the question is not who does things but instead what is happening and will continue happening (Law & Mol, 2008, p.74). As Pickering (2010, p.18) argues, being open to what our surroundings can offer might propose renewed ways of material engagements both at the micro and macro level. At the micro-level, we might recognise how our creative practices and its surrounding constitute each other (Pickering, 1993). At the macro level, understanding the dynamic relationship between the human and the

nonhuman, such as materials, can present new directions for developing "new procedures, technologies, and regimes of perception" to understand the political ecologies to which we belong (Bennett, 2010, p.108).

In this paper, we mapped the field of felting from the material perspective and identified the themes of felt-making. Although previous craft and design studies have tackled similar issues (Nimkulrat, 2012; Tung, 2012), only recently have holistic approaches emerged (Laamanen, 2016; Chudasri & Saksrisathaporn, 2017). From a holistic perspective, our study showed that, for felting, the capacities of the material are almost as important as the maker's conscious decisions and intentions since felt makers make sense of their practice through their material interaction. Accordingly, material interaction can produce different practices and continuously transform the creative field while being transformed themselves. Therefore, we believe that this study can provide an understanding of the micro-actions and their macro level impacts. In this way, it can present new insights, including an understanding of the fluidity of practices and our strong dialogue with materials.

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About the Authors

Bilge Merve Aktaş is a doctoral candidate in design at Aalto University, Finland. She holds a BSc degree in Industrial Product Design from the Istanbul Technical University and a MA degree in Design, Technology and Society programme from Koç University in Istanbul. Her research interests include textile crafts, design processes, practice-led research.

Maarit Mäkelä is an Associate Professor of Practice-led Design Research at the Aalto University School of Arts, Design and Architecture, Finland. Her own creative practice relates to contemporary ceramic art. In her practice-led doctoral studies she produced visual representations of femininity during the research process. She has published widely in international arenas.

Tarja-Kaarina Laamanen is a postdoctoral researcher and coordinator in the Department of Design, Aalto University. She has a background as a maker, design and craft studies teacher, and a researcher. She holds a PhD and MA degree from Helsinki University, Department of Education. Her research interests are related to processes and activities of design and making in the sociocultural framework.

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Empowering artisans through design: a case study on the dynamics of collaborative projects

Estelle BERGER[a]*

[a] Strate School of Design, France
*Corresponding author e-mail: e.berger@strate.design
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Abstract: A growing stream of design research investigates collaborations between artisans and designers, making the case for balanced and systemic approaches. In reality though, such initiatives rarely provoke new understanding or open new perspectives. This research enquiry seeks to address the gap between theory and practice by analysing the dynamics of co-design projects. A guiding framework was built from the literature, composed of three structuring poles: know-how, materials and concepts. Field study was conducted at a French association offering an insertion program to immigrant artisans, which includes a collaborative project with designers. Data was collected through participatory observation and phenomenographic interviews. Results are expressed in form of a typology of projects' dynamics, leading to recommendations. They relate to preparing the co-design approach, following-up and managing projects, and finally empowering artisans to play an active role in their professional path.

Keywords: artisanship; collaborative projects; project dynamics; empowerment

1. Theoretical frame

1.1 Artisanship and design

Sustainable development can be defined as a model that would not sacrifice the possibility of future generations to meet their needs. This concept has become a global objective since the late 20th century (WCED, 1987), with its understanding evolving from a standard to a comprehensive and systematic view, fostering specific and situated pathways. Echoing this global/local tension, balancing tradition and innovation is a topical debate in such context, particularly exemplified by the situation of crafts. Artisanship builds on systematic learning and repeated practices, to integrate embodied knowledge, skills and experience (Polanyi, 1974; Sennett, 2009). Today, the loss of traditional handcrafted techniques around the world (Walker, 2018) goes along with distributed efforts to re-value them.

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Among these initiatives, design interventions may aim at developing market access, skills, products, processes and/or strategies, each with different missions and collaboration modes. A growing stream of design research investigates cross-disciplinary collaborations between artisans and designers (among which Vencatachellum, 2005; Kaine and al., 2010; Walker, 2018).

The literature generally converges in two directions. Firstly, whatever the nature of partnerships, taking into account the mesh of actors, processes, techniques and markets in which handicrafts are embedded is key to ensure the relevance of a design intervention. Secondly, collaborations between designers and artisans should not subordinate the latter to the former but support an empowering purpose. This entails promoting the culture of crafts (heritage, know-hows) while developing artisans' ability to act and develop future projects on their own (imagination, creative skills). Even more holistically, Kaine and al. (2011) propose a conceptual framework meshing design (methodology and project), transmission means (education and concertation) and human development (individuals and communities) in order to reach artisans' empowerment.

Yet, the outcomes of several studies in different regions of the world are at odds with these principles. For instance, Zhang (2016) critiques the dominant role of external designers, calling on Chinese artisans as 'manual worker' to achieve their concepts. Conversely, Bhatt (in Vencatachellum, 2005) points out that collaborating with designers only rarely provokes new understanding or open new perspectives for artisans.

1.2 Tacit knowledge

Though it is considered the highest level of skill acquisition within professional practice, expertise is largely sustained by tacit knowledge, which is particularly tricky to make explicit and articulate (Dreyfus and Dreyfus, 1986; Collins and Evans, 2009). The outcomes of expertise are to be evaluated in context, since the knowledge involved is domain specific. It is also highly personal, developed through physical engagement with the world building up experience (Polanyi, 1974; Crawford, 2015).

The practice of artisanship entails such personal involvement, along with a certain incommunicability of experience. Making and thinking are closely intertwined, creating a form of knowledge and know-how akin to the Greek metis, or practical wisdom (Sennett, 2009; Détienne and Vernant, 1974). For example, in the process of working with silver, a silversmith relies more on sensory feedback than on numeric values to assess whether the sheet of wire is about to break upon bending. Practice may be informed by defined and codified information, which in turn can only be understood through practical experience (Niedderer, 2013). Both types of knowledge are important and complementary in the decision-making process, which inevitably bears a subjective dimension (Lawson and Dorst, 2009; Berger, 2018).

Design as creative practice inevitably builds on experiential knowledge but can also be used as a reflective approach to access and elucidate the tacit recognitions, judgements and skilful

performances (Schön, 1983, pp. 49-50) occurring in practice. In this case, designers act as mediators or translators, deploying interactional rather than direct contributory expertise. This form of contribution appears particularly relevant in collaborations between artisans and designers: the formers physically work with materials, forming them into artefacts; while the latters aim at "articulat[ing…] findings or judgement, and sometimes to translate the expertise of one domain into the language of another" (Collins and Evans, 2009, p. 37; Nimkulrat and al., 2015). In terms of the T-shaped model of skills, designers would personify the horizontal stroke of the T with their "disposition for collaboration across disciplines"; and artisans the vertical stroke of the T with their "depth of skills" (Brown, 2010).

1.3 The dynamics of projects

Ingold (2012) qualifies the practice of making as "correspondence" between a material and human consciousness, imagination, through the means of a tool. Such reciprocal exchange supposes perpetual answer to one another, in an open-ended and dialogical process compared to a conversation. In this line, designing means engaging in a material – tool – human interplay.

It could be objected that this framework focuses on intimate practice, leaving aside designers' projection towards an audience or users. According to Niedderer (2013), the research questions concerning enquiry into design practice fall into four categories concerning: material, process, concept or the use of objects.

Table 1 proposes a synthesis of these two conceptual models and an adaptation, which will be used as a framework to study the structuring levers driving the dynamics of collaborative projects between artisans and designers.

Table 1 Conceptual model

Ingold (2012)	**Proposition**	**Niedderer(2013)**
Material	Materials Properties, abilities, behaviours	Material
Tool	Know-how Mediation, manipulation, strategies	Process
Human	Concepts Imagination, emotions, culture	Human
(-)	(Users) Projection into needs, desires, aspirations	Use

2. Research aim and method

The literature review allowed to identify a gap between theory and practice, impeding the generalization of balanced and fruitful collaborations between designers and artisans. This empirical study aims at contributing to the current stream of research by analysing the dynamics of such projects, with a focus on the tacit dimensions of skills deployed by

designers and artisans. Theory and practice were articulated through abductive reasoning (Thomas, 2010), both serving as complementary elements to frame and conduct research.

Rather than outcomes or actors, this empirical enquiry addressed the process, with a guiding conceptual model adapted from the literature in order to fit the specific context of the field study. This conceptual model would not allow analysing the design process as a whole, nor its context or network. It rather focuses on the explorative and experimental part of projects associating design and artisanship, in order to study the dynamics by which an artefact emerges. As the projection towards potential users was not addressed in the case studied, only the three structuring poles of know-how, materials and concepts were retained for this research.

Fieldwork was conducted at a French association offering a 6-month program to immigrant artisans. This aims at upgrading their skills, fostering their adaptation to the French economic and cultural context and developing their autonomy. Besides administrative support, coaching and professional training, a core component is the co-creation of a yearly collection. Each artisan is paired with a French designer over a period of 3 months, in order to design and prototype one or several objects demonstrating the artisan's expertise, ability to innovate and to collaborate. This process is managed and followed-up by several supporting actors: artistic director, production director, technical referent and social coordinator. Each of them bares a specific role and intervenes at various steps of the pairs' projects, depending on individual situations. Embedded as a designer in the 2018 session, the author was paired with a Togolese jeweller.

Practice as a process took a role in the generation and collection of data, through participatory and self-observation (Schön, 1983). This approach allowed to root the investigation in concrete experience, and to gather insights from the confrontation of perspectives shared in a trusting environment (Archer, 1995). Being introduced as a designer rather than an outside scholar helped overcoming several kinds of distance and fear, some endemic to most research, some particular to this project involving persons in vulnerable situations (Gaver and al., 1999).

Besides, interviews adopting an experiential perspective were conducted among the participants (6 artisan/designer pairs) and supporting actors of the program (3), as they experienced turning points in the project. The methodology followed the principles of phenomenography, focusing on the various ways people perceive, conceptualize and understand their experience, from which arise different overarching conceptions (Marton, 1986).

The three structurally significant poles of material, know-how and concept were used as a framework to cluster and analyse data, following the precepts of grounded theory (Strauss and Corbin, 1990). They were interpreted in order to be expressed in form of a typology of projects' dynamics.

Due to its situation-specific character, this research does not amount to generalizable findings. The framework proposed rather aims at contributing to knowledge on the dynamics

of collaborative projects with its generative potential for future projects. It provides hypotheses for later testing on more numerous and varied cases (Archer, 1995), in a context of reflection in and on action (Schön, 1983) for managers and participants involved in projects articulating design and artisanship.

3. Three levers to analyse projects' dynamics

Participatory observation helped approaching the "momentums" experienced by artisans and designers in the project, which allowed them to move forward. Scarcely conceptually thought, known or verbalized, these key moments were felt as concrete awareness, carrying strong implicit meaning. Each pair experienced and articulated them differently, which set a particular tone to each project phase, and each design outcome. In a psychological perspective, such breakthroughs can be considered as felt-sense (Gendlin, 1961). They are more intricate than logic and can be conceptualized in a variety of ways: theoretical, creative or narrative – hence deeply embedded in the design project. In line with the three-poles framework, such achievements of experiencing were of three different types:

- Mastering a technique reinforced artisans' self-confidence and know-how (not only technical skills but also creative, communicational, strategic…)
- Discovering surprising reactions of materials allowed for novel experiments able to raise new ideas and/or protocols
- Sharing a story or a confidence allowed for meaningful concepts to emerge

The following sections successively analyse these dimensions and their influence on the dynamics unfolding throughout collaborations.

3.1 Know-how driven approach

Since "the first vocabulary we share is technical" [designer 1], most conversations between designers and artisans started by identifying and reviewing the processes, techniques and tools mastered by each. To this end, artisans started by showing samples and pictures of finished products. But the barrier of language and certain shyness impeded discussion. Although he had years of experience as a ceramist and teacher in China, [artisan 6] was reluctant to show his sketchbooks. His partner designer had to build trust before he could share his designs inspired by Chinese cosmogony and imaginaries. This example shows that know-how cannot be reduced to a level of expertise but bears strong affective involvement. Some artisans needed support to become aware and self-confident enough to step in and make propositions. The supporting actors of the association helped overcoming the bridles often met by immigrant artisans: "socio-linguistic barriers, isolation, unrecognized qualifications or experience, ignorance of local market" [association founder]. As for designers, most of them preferred using drawings, mock-ups or even gestures to engage conversation.

> "First I thought our issues were due to misunderstandings between French and Arabic

> languages, but the help of a translator made me realize we just had different conceptions and expectations for the project." [designer 1]

> "The communication issues we might have had are not exclusive to the language barrier, I already experienced almost the same with French artisans… At least here, when we didn't understand each other, we could laugh about it!" [designer 6]

Such discrepancy is not limited to verbal communication; it also reveals different ways of understanding and experiencing the project process. In later phases, some tensions developed in most pairs. For instance, the merits of prototyping were not quite clear for artisans, who rather relied on experiential knowledge to anticipate the sequence of actions needed to obtain expected results in an intuitive manner. They hence felt no need to systematize work or justify choices. On the contrary, designers' test and learn approach was based on early materialization of ideas, in an iterative manner involving constant feedback loops. An off-the-record dialog gives a humorous look at this gap between artisans' pragmatism and designers' search for meaning:

> " - "Why is it asymmetrical?

> - You see, I was running out of rattan here

> - Be careful, they will ask you why. Always why this, why that… they all are mahboul here!" [artisan 3 + artisan 1]

Although the designers did not consider themselves as project managers calling on artisans for technical execution, occasional misunderstandings made some feel as such. The program includes two one-week workshops, conducted within weeks of each other. In the meantime, designers leave and artisans prototype on their own, supervised by the association's technical mentors and art director. Some of them felt a shift in their role, towards mere "agents under pressure and control" [artisan 4].

For designers also, articulating workshops and remote follow-up was a challenge. Their status as volunteers did not allow them to work full-time on the project. Each of them unevenly engaged in its management, and the lack of shared progress report did not allow for alignment. Capitalizing on know-how while exploring outside of comfort zones is a delicate balance that each pair had to discover for itself – regarding which artisans had not been prepared.

> "It's not for us but for their own benefit that we push them forward to innovate. Yet I'm not sure every artisan feels committed to such objective. Some might give up in the face of fatigue and difficulties. How to accompany them through this, I still can't figure out." [designer 4]

The expected quality of finished products was another shared concern. Whereas some designers valued variation as signs of their handcrafted nature, others aimed at perfection. "Looking at the finalized carpet, I am unsatisfied with the gradient effect which doesn't follow the pattern I designed" [designer 5]. Technical mentors provided support to increase artisans' mastery and make the most of available tools, but it remains highly complex to assess to what extent the final result depends on the loom or the weaver. The limitations

may be due to insufficient or inadequate equipment, uncontrolled conditions, combining with artisans' lack of practice in this specific workshop.

The participants experienced the prototyping phase in contrasting ways. Whereas the artisans feeling technically at ease became sources of proposals, pushing the project further, those who faced difficulties almost came to disengagement. For instance [artisan 4] reported feeling "insecured, tired and discouraged", contrarily to her designer partner, used to working in an environment of uncertainty and ambiguity. The psychological difference between mastering or enduring the design process was underestimated by designers, which raised doubts regarding the potential impact of such projects on the artisans' pathways. Moreover, some designs had to be simplified or crafted by designers themselves in order to achieve a satisfying outcome, which added to the paradox:

> "If we are able to make the products ourselves, it is probably a sign that we failed empowering the artisans. I was supposed to reinforce [artisan 4]'s expertise, but I placed her in difficulty. Had I known her better before, I would have followed a different approach to the project." [designer 4]

3.2 Material driven approach

Some pairs started by adopting a material-driven approach, in order to explore the range of possibilities offered by materials. They approached experimentation as "alchemists" (Ingold, 2013, p.220) interested in seeing what happens when materials are manipulated. Such exploration did not aim at testing hypotheses (as in the Natural Sciences) or measuring characteristics and performance (as in a techno-centred approach), rather at serendipitous discovery. This approach was mainly fostered by designers, possibly due to their profile of skills. As non-specialists, they would be used to exploring from unexpected reactions of materials (connective competencies, interactional expertise), while artisans would preferably rely on proven techniques to reduce hazard (depth of skills, contributory expertise). All pairs had to develop a shared strategy to bridge the gap between different approaches to experimentation.

One of them succeeded in building clear initial intentions: "outside from a logic of results" [designer 3], they explored the palette of fabric weaving techniques, in order to widen it. They strived to delay the moment to transform free experiments into specified products. The designer's ability to demonstrate a serene attitude combined to the artisan's ability to adapt were key in navigating uncertainty, and reassuring the organizing team on their progress.

Apart from this example, the material-driven approach proved deceitful for the other pairs adopting it as a starting point. The technical limitations of the workshop probably impeded experimentation for some part. For instance, [artisan 6 + designer 6] had to wait for weeks before receiving a kiln. [artisan 4 + designer 4] had to face another challenge. The jeweller was used to cast gold into cuttlefish bones, but this ancient technique couldn't be set up in the workshop. She had to work with brass and copper wire and sheets, materials she was unfamiliar with. This was not felt as exciting but endangering, deeply questioning her

expertise. As she strongly identified with her technical mastery, stepping out of her comfort zone made her unsecure.

The pairs concerned with such mental block or inconclusive technical results had to change their approach, for instance by adopting a more conceptual one:

> "Design accompaniment was almost a coaching mission, to spot potentially transferable skills and encourage her overcoming frustration and demotivation. Our relationship also built on sharing personal stories, which brought some levity and provided inspiration for the project." [designer 4].

Another pair had to abandon a lamp project for a more feasible option. This was a source of frustration for [artisan 6], who was in demand for challenge. But he maintained an autonomous and open-minded attitude until the end of the project.

> "Above all, I was curious about the design process. Now that I learnt, I want to apply this approach in my future projects as a ceramist." [artisan 6]

3.3 Concept driven approach

In this configuration, a conceptual idea drives the project. For instance, [artisan 4 + designer 4] revisited a traditional Togolese pattern in their jewellery design: "oval shapes of nails symbolize the jealousy of a woman when one gets too close to her husband" [artisan 4]. The designer brought the image from documentary research, in order to root the design project into something that would make sense and value the artisan's culture. Although this does not directly echo her experience, [artisan 4] easily appropriated the metaphor. In another case, the concept directly stemmed from the artisan's analogical thinking:

> "When [designer 3] brought me a moodboard with fungus pictures, I immediately saw how much they looked like silk ruffles. I shared my vision and right away we started experimenting with fabric." [artisan 3]

On the contrary, some pairs did not meet on the ground of poetic ideation.

> "I asked [artisan 1] in many ways about his dream projects, in vain. As we couldn't come up with ideas that we both liked, we moved towards technical experiments with rattan." [designer 1]

This verbatim raises the issue of subjective choice, which is inevitable since no design project is solely ruled by an analytic or rational approach. Judgement is subtle and based to a large extent on intuition, experience, tacit knowledge – and sometimes also on ego! Even though none of the designers were in a selfish approach, the visibility and value added by their intervention was still a matter of concern.

> "My role was minimal: I just suggested allying two materials through existing marquetry techniques. No big deal, which could be a little disappointing… But what matters is that the product 'works' and the artisan made the process his own." [designer 2]

Incidentally, as designers worked as volunteers, most of them did not consider important

to claim ownership on the products created in the program. More than on the result, they took pride in "the experience shared; the relationships built with artisans, other designers and supporting team; the impact on the artisans' professional attitude and practice" [all designers]. On the artisans' side, partnership with designers was hardly evaluated in itself but as part of the whole program, following the same human criteria:

> "The design project, the teaching, the encounters, the visits… opened my eyes and allowed me to let out a creative part that was hidden in me." [artisan 3]

Demonstrating a true designerly way of thinking and communicating (Archer, 1979), this artisan was hired in a luxury workshop soon after the end of the program. A couple months later, the other artisans of the 2018 session were mainly working as subcontractors. The empowering effect is hence mixed, as only few of them have been reinforced in a project management expertise. Though, all of them recognize the transformative effect of this experience. It firstly strengthened their ability to "communicate and put ideas forward" [artisan 2]. Secondly, working alongside designers also revealed to some artisans the pleasure of ideation phases. "I feel stronger now. I dare to be creative because I believe I can have worthy ideas" [artisan 4].

Table 2 The dynamics of projects

Project	**Dominant dynamics**	**Assessment**
1 Wicker-work	[M-] > [K] Material experiments gave way to a know-how driven approach. Little concept due to distant relationship between designer and artisan	Difficult alignment in the project
2 Wood-work	[K + C] Mostly know-how driven until a concept based on material combination emerged. Artisan strongly implied as an expert (know-how + material)	Process and outcome considered satisfying
3 Sewing	[K + M + C] Balance between free material experiments, know-how, and concept based on analogical thinking. Artisan strongly implied in the design approach	Empowering project for the artisan
4 Jewellery	[M- x K-] > [C] Material experiments impeded by artisan's difficulty to master technical processes gave way to a concept-driven approach. Little reinforcement of artisan's know-how but empowering impact	Outcome does not fully reflect artisan's expertise
5 Tapestry	[C] / [K] Concept-driven approach sustained by know-how but little dialog between these dimensions. Distant relationship between designer as project manager, artisan as technical expert	Little alignment, outcome does not fully satisfy designer

6 Ceramics	[M- x K-] > [C] Mostly material-driven until a concept based on material combination emerged. Artisan strongly implied in the design approach, but modest promotion of his technical skills	Outcome does not fully reflect artisan's expertise

4. Discussion and future directions

When evaluating their experience, all designers highlighted human encounter as paramount. Regardless of the outcome, the most satisfied participants were those who created a personal connection with their partner – who also happened to be those following a concept-driven approach. Although, creating conditions to nurture the relationship between artisans and designers was not a major concern for the executive team, who focused on professional profiles. Yet, personality traits are also in play. Using an explicit matching tool would certainly help raise participants' awareness, clarify their expectations and engage them both as professionals and individuals. Yet, as the relationships evolved throughout the project under the influence of internal and external factors, initial pairing is not sufficient to ensure smooth collaboration. Besides, the scope of this research enquiry did not cover actors' trajectories, solely the dynamics of their projects. A complementary approach, for instance under the lens of actor-network theory, would provide an additional perspective.

As per our know-how, materials and concepts framework, the analysis showed that there is no ideal configuration per se. All projects combined different approaches and dynamics, unfolding with obstacles encountered and stages passed through. Yet, certain correlations and patterns emerged, which allow formulating a few directions for the future of the program. Following sections propose recommendations at project scale as well as in a broader view, so as to foster balanced and fruitful collaborations, in purpose to empower artisans during and after the program.

4.1 Preparing the collaborative approach

Artisans start the project with very little knowledge of the design approach. Conversely, designers have few information about their life paths and know-how. The preparatory phase needs to be reinforced and better structured. Until now, the initial assessment of artisans' expertise relies on self-declaration. A more objective process would certainly reduce gaps between perception and reality. First of all, artisans should be given time to practice freely in the workshop, in order to get familiar with materials and tools that might be slightly different from the ones they used to master. When evaluated, the feeling of being judged is particularly embarrassing for immigrant artisans with rough life paths. Preparation to the co-design project should hence focus on positive accompaniment, to capitalize on past experience and prepare them for the upcoming one. From a management point of view, being aware of the cultural backgrounds and life paths of artisans would allow designers to adopt a more strategic view and play a maieutic role.

From a methodological point of view, this would involve better awareness of the design

process and the designerly way of thinking (Cross, 2011), in particular its abductive and iterative dimensions. Revealing and discussing the elements of tacit knowledge which occur in practice could also be helpful for participants to better articulate their contributory and interactional expertise (Schön, 1983; Collins and Evans, 2009). This last recommendation involves designers as much as artisans, since both rely on experiential knowledge. It would also allow them to better know their partner better before starting to work together, and hence to smoothen communication.

4.2 Projects' dynamics and management

Considering that, for practical reasons, the workshop cannot offer high-end equipment for all crafts, technical constraints and limitations would need to be stated from the beginning. In the current state, the experimentation phase appears blurry to most participants, be they designers or artisans. Framing the expectations to some extend would maybe reduce "writer's block" anxiety for some, as well as fixation on early ideas for others.

The study showed a correlation between the success of a material-based approach and the artisans' self-perception of their know-how. Only those feeling confident of their expertise are able to take pleasure in experimentation. Ultimately, they take an active role in the design process, articulating ideation, testing and storytelling in an iterative manner. In cases studied, this is conditioned by the initial degree of autonomy and secureness felt by artisans. One recommendation is hence to advise against a material-based approach for those with low self-confidence.

As for the concept pole of our framework, it appears to act as "glue", bringing partners together – particularly after having experienced the failure of another approach. This is in line with the general demand for more occasions to connect, before and outside the scope of the co-design project. This could be achieved for instance through visiting exhibitions together, cooking typical dishes of artisans' native regions, playing design serious games, sharing an inspirational sketchbook and/or a project road book… All initiatives contributing to build a common repertoire, which would probably offer inspiration for the project.

Besides, keeping a project road book would also allow to better elicit the path followed by each pair, their iterations and decision criteria. Indeed, mutual understanding between stakeholders regarding project management is currently poor. Artisans do not have a comprehensive knowledge of the design process. Designers are often wary of interventions from the supporting team, which they perceive as interference. Ultimately, the balance between technical, cost, market and aesthetics criteria remains largely tacit. A framework inspired by the Double Diamond (British Design Council, 2005) or the d.school Design Thinking model (Hasso Plattner Institute and Stanford University from IDEO's work, 2001) could serve as a basis for project follow-up, completed with an assessment grid to support decision-making at each stage.

Table 3 Synthesis of the approaches

Pole	Impact on the dynamics of projects	Obstacles
Know-how	Employed to comfort artisans in their expertise and make the most of it. Conditioned by a high degree of autonomy.	Low self-confidence. Iterative exploration is challenging for those with little awareness of the design process.
Materials	Serendipitous approach to experimentation fostered by designers. Conditioned by artisans' confidence in their skills.	Not sufficient to drive projects (maybe due to technical limitations faced in the workshop).
Concepts	Stories and ideas shared create a personal connection, acting as "glue" for partners.	Mismatching personalities and character traits (mediation needed).

4.3 Empowering artisans

The co-design project is only a part of the program deployed by La Fabrique Nomade, aiming at immigrant artisans' professional integration in France. Its accomplishment lies in a training period. Yet, two artisans from the 2018 session could not find a host company. This calls into question the actual empowering effect of the collaboration with designers, supposed to highlight artisans' expertise and stimulate them to take an active role in their professional path. All participants acknowledge that the co-designed collection artefacts are more of a pretext to learn communicating and working together than an end in itself. In this line, the main challenge is to use and develop connective competences, in order to bridge the gap between different ways of thinking and doing. Ultimately, a key success factor of the program is the expansion of artisans' transversal capabilities and interactional expertise. Developing transversal capabilities in artisans through partnership with designers is hence a key success factor for the program (Brown, 2010; Collins and Evans, 2009; Nimkulrat and al., 2015).

This falls into the scope of design management, addressing the whole network of actions and relationships in which artisans are embedded, with potential impacts beyond the mere project. According to Kaine and al.'s conceptual framework (2011), design may represent an empowering agent impacting the artisans' development as individuals as well as a community, their concertation practices and educational pathways. In its current state, the collaborative project fails to encompass these concerns. As a step towards deploying a more global approach, the association has been developing since 2019 an online network aimed at connecting all the artisans, designers and technical mentors who participated in the program. This initiative may help moving in such direction, provided actors are given the human, strategic and operational means to appropriate it.

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About the Author:

Estelle Berger pursues research on the reflective practice of design, aiming at developing a toolbox for reflection in/on action. In particular, she leads Exalt Design Lab, a French joint laboratory dedicated to the value of design and experience for organizations.

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Materialising weaving: embedding a narrative of construction time within experimental woven textiles

Jessica Lynne PRIEMUS[a]*

[a] Curtin University, Australia
*Corresponding author e-mail: jessica.priemus@curtin.edu.au
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Abstract: This paper responds to the theme of processes, and poses the question: what methods and tools of design could be utilised in order to connect the user to textile making processes, in particular, the time involved in hand weaving? I share insights that I have gained from my own creative practice and postgraduate research, and draw on diverse literature including the work of Bauhaus designer and weaver Anni Albers. I reflect on how by attempting to aesthetically capture my own processes in cloth, the weaving act is revealed as a sometimes-flawed marker of time. The potential outcome of this research is the development of a framework for textile designers and weavers that privileges cloth as a conduit for temporal connections between maker and user. I posit that amplifying traces of time through the design of textiles may connect the eventual user/wearer to the 'pulse' of (a) weaving.

Keywords: weaving; making; textiles; time

1. Introduction

In the past three decades, global shifts in cloth and garment production have resulted in the typical person in Australia having low levels of exposure to textile weaving processes. To counteract the implications of a disconnect between consumption and production, the fashion and textile industry has made movements towards greater transparency and traceability using a variety of technologies and media. The intention of my research is not to disregard the role of this additional media, but to explore the potential for the textile itself to serve as the site for further user engagement. Responding to the conference theme of processes, this paper considers a possible synergy between maker and user, and asks: what new methods and tools of design could be utilised in order to aesthetically express a weaver's time through cloth? I explore this by applying a practice-led research methodology, utilising a weaving log to track my actions, and employing Bauhaus weaver, artist and author

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Anni Albers' hierarchical 'three elements of weaving'; texture (weave), yarn and colour (1965).

Through practice-led experimental weavings, I propose a turn to the textile as the site for user engagement with the temporal aspects of weaving, and practice-led research as the vehicle to achieve this. This is akin to Nithikul Nimkulrat's practice-led research in textiles, where she writes of how research can "not only transform ways of designing or making artifacts, but also theoretically inform practice so that the practice can develop the practitioner's aesthetic intelligence, the results of which are craft objects that can be understood more easily by viewers" (2012, p.1). The potential outcome of this research is the development toward a processual aesthetic and a framework for textile designers and weavers that privileges cloth as a conduit for connections between maker and user.

Textiles already show faint traces of their making, though they may be very small or invisible to the naked eye. Additionally, woven cloth has been used throughout history to tell stories, sometimes of making, usually through symbolic and pictorial means, employing a variety of weaving and embellishment techniques. However, as we grow distant from traditions and rituals we lose ways of understanding and transferring craft knowledge, particularly in regard to time. In the global north this is compounded by our inability to operate at different speeds, a tendency towards permanent acceleration and a failure to 'teach time' (Thackara, 2013). There is also a growing inability to pass down cultural stories, that could be embedded and interpreted semiotically, arguably due to "the destruction of [traditional/ cultural] ornament within the Modernist movement" (Fuller, 1988, p.117). In response to this, I examine what an aesthetic rhetoric, or narrative of construction time, might look like, with attempts to measure time, express time (and to eventually even 'teach time') through a weaving.

Reflecting on various lengths of woven cloth that I have designed and/or made, this paper examines weaving as material creation. In her essay 'Work with Material', Anni Albers suggests that if we "want to get from materials the sense of directness, the adventure of being close to the stuff the world is made of, we have to go back to the material itself, to its original state, and from there on partake in its stages of change" (1938b, p.1). Here, I explore how making processes – or 'stages of change' – might be intentionally etched in woven cloth. The experiments explored in this paper were predominantly created by myself in Australia, my place of residence, and Bangladesh, a country known for its high level of garment and textile production for export. As I highlight the tactile intricacies of weaving through practice, I reflect on its inherent complications too: to navigating the unavoidable synthesis of personal life and research. By recording the materialisation of processes in cloth, the weaving act is revealed as a sometimes flawed explicit and implicit marker of time, and the person behind it.

2. Methods and Methodology

Though the experiments here take multiple shapes, forms and origins, the goal was to

eventually produce a series of small woven 'samplers'. Approximately 12cm x 12cm, these samplers were designed to be used in my postgraduate research interviews in order to determine particular aesthetic markers that may allude to construction processes. The inspiration for the sampler1 was from Sheila Hicks' mini weavings2. As mentioned previously, I have also employed Anni Albers' hierarchical '3 elements of weaving': texture (weave), yarn and colour (1965). Albers' hierarchy worked on the philosophy that the weaver should prioritise texture – or structure3 – and then yarn, with colour only as a third consideration. This was in order to express the more spatial and temporal aspects of a textile. In this project I utilise this hierarchy in order to provoke greater haptic experiences to the potential user, rather than relying purely on optical cues.

The woven samplers and lengths of cloth discussed in this paper were created as I was learning to weave in early 2015 in preparation for this portion of my project4. I believe that despite lacking the tacit textile knowledge of a master weaver, my initial minimal skill provided an opportunity for my research. In Anni Albers' essay 'Weaving at the Bauhaus', she considers the new textiles students of the Bauhaus to be fortunate to not have prior training in the craft, as "it is no easy task to throw useless conventions overboard" (1938a, p.1). Much like these students, I had to start at the beginning, "focussing upon the inherent qualities of the material to be used" (ibid.) and disregarding traditional handling techniques. My weaving samplers, while similarly 'amateurish', strive to continue a line of thought from the Bauhaus, where introducing a new craft to an untrained person leads to "an unprejudiced attitude toward materials and their inherent capacities" (ibid.).

My postgraduate research is about expressing traces of making processes through cloth, with my personal goal to allow people connect with everyday textiles – the primary source of this being garments. So though somewhat experimental, the idea of usefulness was still at the forefront of my work. While my work here was occasionally impractical5, I did employ a kind of 'disciplining'6 to ensure that all textile samplers and lengths of cloth were seen as something that could potentially be adapted to be worn.

In this paper, I take influence from practice-led research that has taken shape during the last three decades in the field of design research. My motivation for using a practice-led research methodology is to produce and express new knowledge and theory originating from my

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1 The name 'sampler' is taken from the traditional term for a small textile practice piece (Humphrey, 1997), though usually showcasing embellishment.

2 As featured in her retrospective text Weaving as Metaphor (Danto et al, 2018).

3 This hierarchy represented a position shared by the majority of weavers that I worked with in both Bangladesh and Australia.

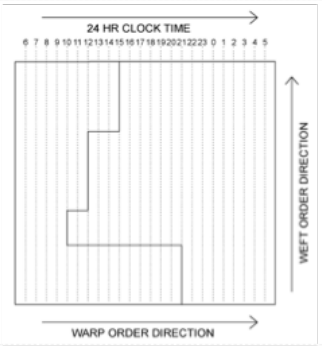
4 I learnt to weave through attending a variety of workshops, talks and meetings facilitated by The Spinners, Dyers and Weavers Guild of WA, The Hills Weavers Group, and the WA Fibre and Textile Association.

5 Some dyes used were not colourfast, and the structural qualities of some samplers may not stand up to regular washing.

6 Anni Albers describes the shift from free play cloth to utility/purposeful textiles at the Bauhaus as a kind of 'disciplining' (Albers in Danilowitz (ed) 2000, 4).

design practice (Pedgley, 2007). As Owain Pedgley states of practice-led research, it is "highly personal, being centered on the creative practices of the self" (2007, p.464). To capture my own personal time, I utilised recording techniques such as my weaving log (Figure 1), to record the quantitative and qualitative aspects of weaving that I had recently encountered.

COMPOSITION:

	WARP	WEFT	COMBINED TOTAL
WEAVE	1/1 PLAIN WEAVE	CLASPED WEFT	
ORIGIN	MADE AT RESEARCHER'S HOME IN PERTH, WA. COMBINATION OF WA(?) WOOL AND CHINESE COTTON.		
TOOLS	ASHFORD RIGID HEDDLE SAMPLING LOOM. SINGLE HEDDLE. 2 SHUTTLES USED AT ONCE.		
LENGTH (m)	12	12.8	24.8
ORDER	WARP LEFT TO RIGHT	WEFT BOTTOM TO TOP. LOCATION OF 'CLASP' CORRESPONDED WITH 24HR TIME MARKED ON HEDDLE	
SKILL	26-Sep	30-Sep	
MATERIAL	BENDIGO COTTON 'PARCHMENT' 8 PLY (CHINA)	WOOL TBC - GO TO SUBI WOOL SHOP AND BILBY BENDIGO COTTON 'PARCHMENT' 8 PLY (CHINA)	
TIME (MINS)	78 8	61	69
MATERIAL $			

PROCESS PATTERN:

DATE	START	STOP	DURATION IN MINS	ACTION	ACTIVITY DURING	STOP REASON	REFLECTIONS
26/09/16	13.20	13.45	25	STRETCHING WARP		TOOK BABY FOR A RIDE	THIS WARP ACCOMMODATED 11 WEAVINGS THEREFORE TOTAL LENGTH OF WARPING TIME - TO BE DIVIDED BY 11??
	13.50	14.09	19	WINDING ON		BABY CRYING. COFFEE BREAK	
	15.48	16.22	34	THREADING HEDDLES, TIEING TO FRONT BEAM, FIRST WEFT THREADS TO EVEN WARP	REPLYING TO SEVERAL TEXT MESSAGES THROUGHOUT	FINISHED WARP	
30/09/16	20.38	20.42	4	WINDING BOBBIN		FINISHED WINDING	WARP WAS ALREADY DONE FROM PREVIOUS WEAVINGS
	21.31	21.44	13	WEAVING		BABY	21 MARK ON HEDDLE
1/10/16	9.37	9.44	7	WEAVING		BABY	10 MARK ON HEDDLE
	12.07	12.13	6	WEAVING		PAUSE	12 MARK ON HEDDLE
	12.24	12.30	6	WEAVING		BABY WOKE UP	12 MARK ON HEDDLE
	15.21	15.30	9	WEAVING	TV IN BACKGROUND	FEED BABY SNACK	15 MARK ON HEDDLE
	15.37	15.41	4	WEAVING	TV IN BACKGROUND	FINISHED WEAVING	15 MARK ON HEDDLE
14/10/16	14.35	14.47	12	CUT OFF LOOM AND TIEING		FINISHED	TIEING COMPLETED ALTOGETHER WHEN ALL 11 WEAVINGS ON THIS WARP WERE DONE

Figure 1 An example of my 'weaving log', tracking the creation of textile sampler 2Y17

I remain mindful that by trying to express temporality I risk reducing it to the measurable, possibly designing cloth that becomes – as interior theorist Suzie Attiwill might describe– "about time" rather than "an experience of time" (2005, p.6). However, I look toward time as organised and understood through my weaving practice, and how it materialises. I then attempt to amplify these processual traces in order to narrate a textile's construction through the cloth itself. Every weaving sampler produced in this paper acts as "a piece of evidence from the event [of weaving] itself, a material witness" (Solnit, 2003, p.17) – or the temporal journey of a thread.

As previously mentioned, the act of weaving is commonly defined as forming fabric by interlacing horizontal and vertical threads. The creation of a woven fabric requires much more than just the act of 'weaving' fibres together. Constructing a textile involves multiple people, multiple tools and multiple processes. These multiple processes could be included in experiments, such as yarn preparation; spinning, dyeing, winding skeins or balls, or even the picking of cotton and the shearing of livestock. However, due to my own limitations I restricted the total weaving time recorded to include the warping (or preparation) of the loom and ending with the cutting and tying off of ends after completing the weaving.

In her text 'Hands-on Intellect: Integrating Craft Practice into Design Research', Nimkulrat discusses how "craft as a way of thinking through material can be incorporated into practice-led design research" (2012, p.1). She states that "through handling materials in practice, a form of tacit knowledge arises, providing a particular way of understanding the practice that is grounded in the hands-on practice itself" (2012, p.3). Reflecting on Nimkulrat's work in textiles and practice-led research, this project demonstrates how weaving can drive a practice-led research process, and how research can potentially enhance woven cloth.

3. Rhythm

The event of weaving involves repetitive cyclical motions – spinning, winding, warping the board, 'throwing' a weft left to right, right to left, looping back and forth of what is essentially a very long line, directed as a snaking thread, reflecting back the "rhythm that [weaving] imposes on the body" (Frampton, 1988, p.61). I initially explored the idea of rhythm in cloth when working with Mst. Shuily Khatun, a hand weaver at Thanapara Swallows Development Society (TSDS) in Rajshahi, Bangladesh. TSDS is a collective of weavers I had previously worked with for my former fashion and textile practice. Time Fabric (Figure 2 and 3) was a length of cloth woven on a hand-loom, with each stripe representing a visible change that marked the stopping and starting of Shuily's weaving.

Figure 2,3 Creating the Time Fabric on the loom, rhythms of working amplified through the fabric

During my time at TSDS, I observed that it takes a considerable amount of strength and endurance to operate a large fly-shuttle handloom. As a weaver begins, they have more energy and pull both the fly shuttle cord with one hand and beat the weft hard and consistently with the other. However, as the weaver works they gradually become more tired, and the beater is pulled less vigorously. As a consequence, the weave may progressively get less dense and looser, until the weaver needs a break. When they return from their break they have somewhat regained their energy and will go back to weaving at full speed. This narrative becomes embedded in the cloth. The change in weave closeness is visible. I refer to it here as the 'rhythm stripe'.

In Time Fabric, the rhythm of the weaver is visually amplified. Whenever she decided to pause or take a break she was asked to switch bobbin colours. Through the varied widths and quantity of stripes a pattern of work became visible; reflective of both "an experience and actualisation of time" (Attiwill 2005, p.7). The outcome is completely dependent on the maker and the situation – designed to map a weaver's rhythm of making. This temporal and bodily narrative becomes embedded in the cloth. Like Sue Rowley, I similarly ponder whether it is overly romantic to suggest that the "temporalities of craft are somehow bound up with those of the human body" (2012, p.234), even though the shared perception of craft through literature (as well as my own experiments) align with this notion. According to Octavio Paz, craft encourages the sharing of physical life by transforming an everyday item, such as a textile, into a "sign of participation" (1987, p.60).

Throughout the following creative experiments, the rhythms of my own life and body were analysed alongside the rhythms of weaving. In order to explore this further, a weaving log was designed to track not only the material concerns of the samplers, but also my own rhythms. Time Fabric only examined the rhythm of weaving the weft. The Rhythm Scarf (Figure 4 and 5) incorporates both the warping and weft weaving as a more encompassing examination of a weaver's work. A warping board was used to prepare this particular loom8, and the stopping and starting of the warping was recorded by changing the colour of the yarn. The Rhythm Scarf was the preliminary example of recording warping time through the amplification of rhythm.

Figure 4, 5 Using a warping board to prepare the Rhythm Scarf warp, before it is transferred to the loom. A gradient emerged by changing yarn colour every time that I stopped.

For the Rhythm Scarf, I recorded the duration of each period of weaving by writing down the times that I started, and the times that I stopped. Like the Time Fabric, the pattern of working was actualised through the textile as I changed the colour of weft yarn every time that I paused. The resulting data (Figure 6) – both recorded in writing and recorded through cloth – was used to calculate the speed at which I was working. Initially I wanted to use speed as a measure of skilfulness in these experiments. However, as I was performing the calculations I realised that my speed was not akin to skill, but rather, general productivity, affected by multiple rhythms and events occurring throughout the weaving process. I finished the final five rows while watching a movie late at night, and kept taking extended breaks and working slowly, occasionally looking up to glance at the screen. It occurred to me that these experiences of weaving were not being recorded. I adapted the future weaving log with a section to remark what I was doing simultaneously, highlighting any possible distractions. However, I am still unsure of how such fleeting moments might be wholly embedded – and interpreted – in cloth.

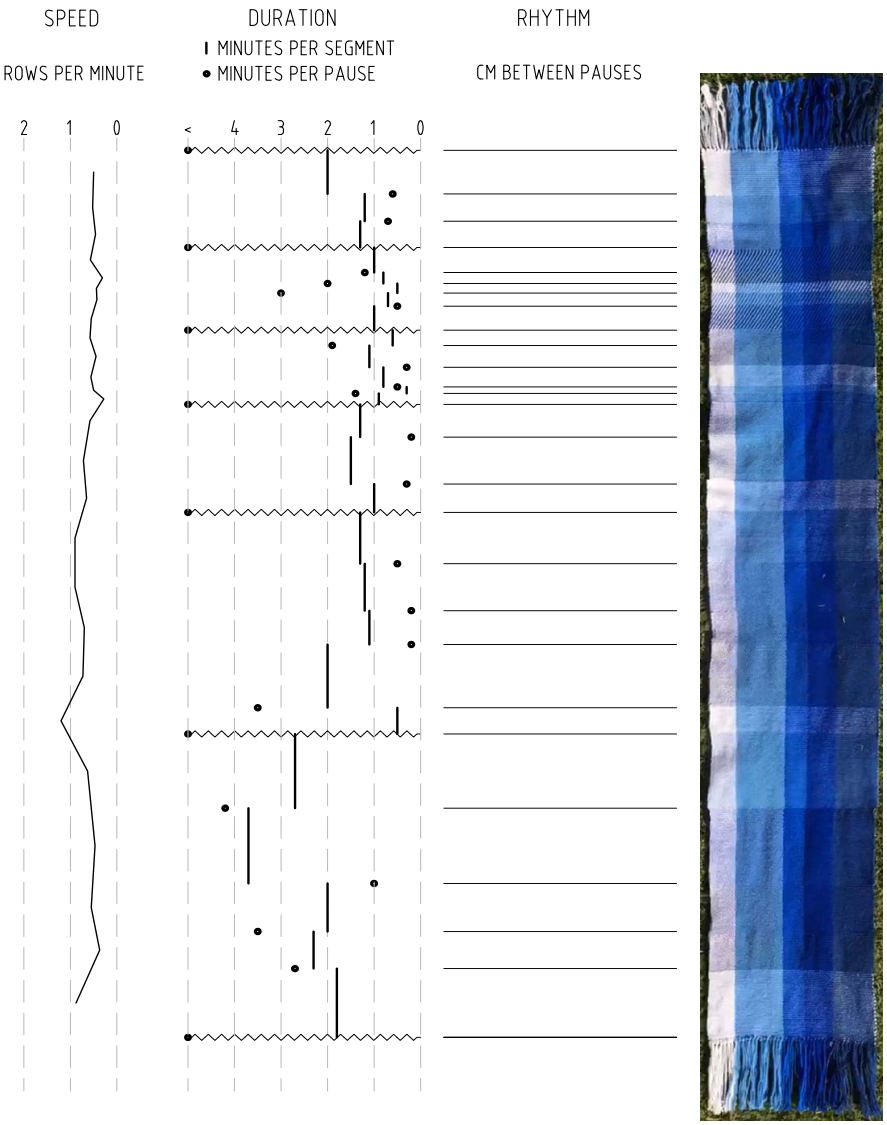


Figure 6 Rhythm Scarf data

User feedback on the Rhythm Scarf indicated that it may be a little complicated for a user to decipher, and thus difficult to interpret9. The decision was made to experiment a simpler version, and as such, the following two samplers focussed purely on the weft rhythms only. Both were plain weave samplers produced through the same brief – that I was to change yarn whenever I stopped working. Textile sampler 1Y1 (Figure 7) was produced using a contrasting yarn of a similar colour, and 1C1 (Figure 8) was made with a contrasting colour and yarn10. Though using the same weaving brief (only the colours varied), the stripes produced were different sizes due to the event of weaving being unpredictable and dependent on the moment in time.

(L-R) Figure 7 Textile sampler 1Y1, Figure 8 Textile sampler 1C1, Figure 9 Textile sampler 1TCY1

Though I expected the patterning to vary in size, by creating irregular stripes it seems to almost contradict the rhythm of weaving that I had experienced. Being in the workshop at TSDS meant hearing the constant rhythmic clicking of the looms – a rhythmic chaos, or as Paz describes it, "the heartbeat of human time" (1974, p.24). Getting out of sync or losing rhythm on the loom would result in mistakes. However, there was not as much consistency to my own weaving on my small table-top loom11. Manually feeding the shuttle between raised/lowered warp threads was quite different to using a fly shuttle loom (shown in Figure 2) at TSDS. Keeping constant rhythm on a fly shuttle loom is a necessity and guided by the loom, whereas the rhythms of working on a table top loom (shown in Figure 5) were much more dependent on the mood of the weaver and the movements of the hand.

As mentioned, the rhythms of weaving have a repetitive regularity to them, as does the physical grid of the textile itself. Textile sampler 1TCY1 (Figure 9) has a check pattern echoing the structural grid of weaving through the (graphical) intersections of two 'threads'. This particular sampler aimed to incorporate all three of Albers' 'elements of weaving' – weave (through the use of two heddles to create a twill), yarn (by using wool, cotton, and polyester), and colour (utilising a colour scheme/gradient to indicate change and order for both warp and weft). This sample involved a lot of unexpected stopping and starting, and subsequently more stripes (or checks) than projected. Samplers 1Y1 (Figure 7) and 1C1 (Figure 8) had less stop-start moments, purely by accident as there were less distractions at the time. At TSDS the Time Fabric was usually disrupted either by choice (taking a break) or by running out of yarn on the shuttle bobbin. However, many of my interruptions during the weaving of the previous three textile samplers reflected a large impactful event in my life – having a child.

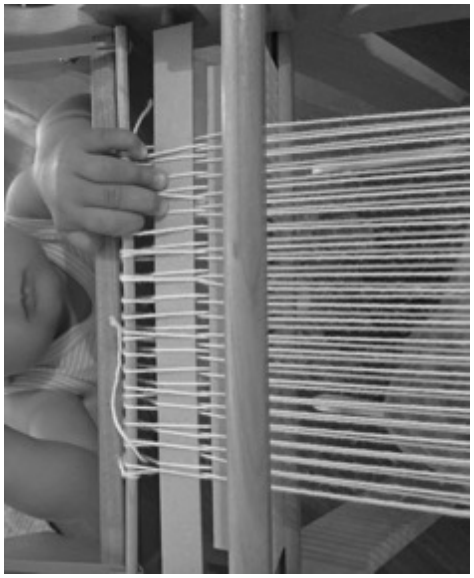


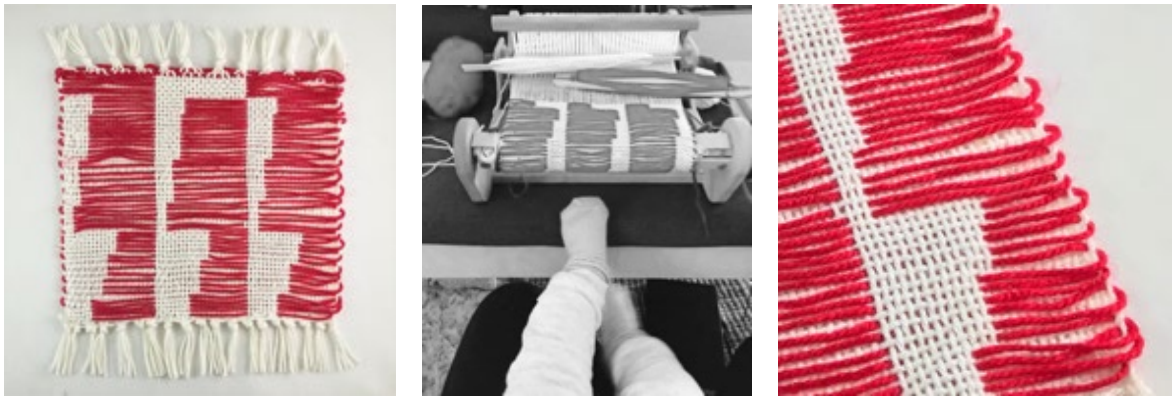
Figure 10 An 'interruption' recorded in both my weaving log and inevitably, the weaving sampler.

Despite cloth being made for our body, the mechanised looms on which our everyday textiles are produced are a technology that, as Solnit states, "regards the very terms of our bodily experience as burdensome" (2003, p.11). In contrast, the speed of my small table loom is comparatively slow, and the effect of parenting on timing is dramatically disruptive. The urge to control time must be released as every day is full of unpredictable events, even though having a baby comes with suggestions of scheduling in itself. At the time I was recording feeding times and sleeping times, as well as weaving times. Though recording my child's movements originally seemed excessive, Pedgley states that "practice-led researchers must subscribe to the goal of making public one's private design discourses"(2007, 464). The Rhythm Scarf was completed before the birth of my child, and the similar sampler 1TCY1 was completed when she was almost one year old. Whilst questioning the unevenness of the weave in Time Fabric and Rhythm Scarf as being unreflective of a weaver's working rhythms, there was an irregularity to my circumstances that synched with the outcome of 1TCY1. In this way, the maker, the body and rhythm were inextricably linked.

Textiles are constantly in flux. Construction, use and disintegration are all temporal processes that the textile undergoes throughout its life: it's becoming (or unbecoming). However, the focus here is not on human use and its impact on cloth and its life/death, but rather an examination and amplification of the duration of the weaving process. According to Pallasmaa, we live in a world inundated with youth, beauty and perfection and therefore we "need experiences that mark and measure the course of time" (2007, para.16) in order to express time's depth, and its availability (2007). I had endeavoured to measure time in a textile, and had some success measuring the patterns of making through my rhythm studies. However, representing the amount of time spent in quantifiable terms proved difficult. In the following experiments I attempted to acknowledge abstract time (or clock time) through cloth as a way to track duration.

4. Duration

For textile sampler 2C2 (Figure 12) I determined how many warp threads to skip at a time based on the 24-hour clock (for example, if it was 10:00am then I would skip ten threads). I was frequently disrupted during the weaving of this textile sampler. I left it set up in my living room for several days, just catching a moment here and there, often with a child on my lap. The resulting pattern captures that rhythm through the shifting size of the red thread float, as well as marking the time of day that I was weaving (the weft).



(L-R) Figure 11, 12 and 13 Textile sampler 2C2, reflecting duration, in various stages of its production

Using Albers' hierarchy, I also explored ideas solely through weave techniques. Textile sampler 2T1 (Figure 13) was made using a loop pile technique, similar to that used for making carpets. In this case, different diameters of timber dowel rod were cut, and the weft looped around. The diameter of dowel rod used corresponded to the time on the clock while weaving.

(L-R) Figure 14 Textile sampler 2T1, the length of pile corresponds to the time of day woven, Figure 15 Textile sampler 2C1, Figure 16 Textile sampler 2Y1.

To make a more 'disciplined' or garment-like textile12, I designed samplers 2C1 (Figure 15, contrasting blue cotton weft) and 2Y1 (Figure 16, same colour, contrasting wool yarn weft), using a clasped weft technique to mark duration. This was done using a similar technique to the previous experiments where clock time was marked on the heddle. However (like most

of my weavings attempting to embed clock time), when the sampler is turned over then the coding is reversed, and the 'message' becomes undecipherable. While there is such a thing as a textile having a right side up, especially in pictorial fabrics, woven cloth is generally experienced in a multitude of ways. We feel cloth from the inside and see it from the outside. We may stand upright in clothing, but we also sprawl across upholstered furniture and lie horizontally wrapped in bedlinen. The common experience of cloth at multiple axes (Krauss, 1997) and from multiple sides is one that I would have to consider in future research.

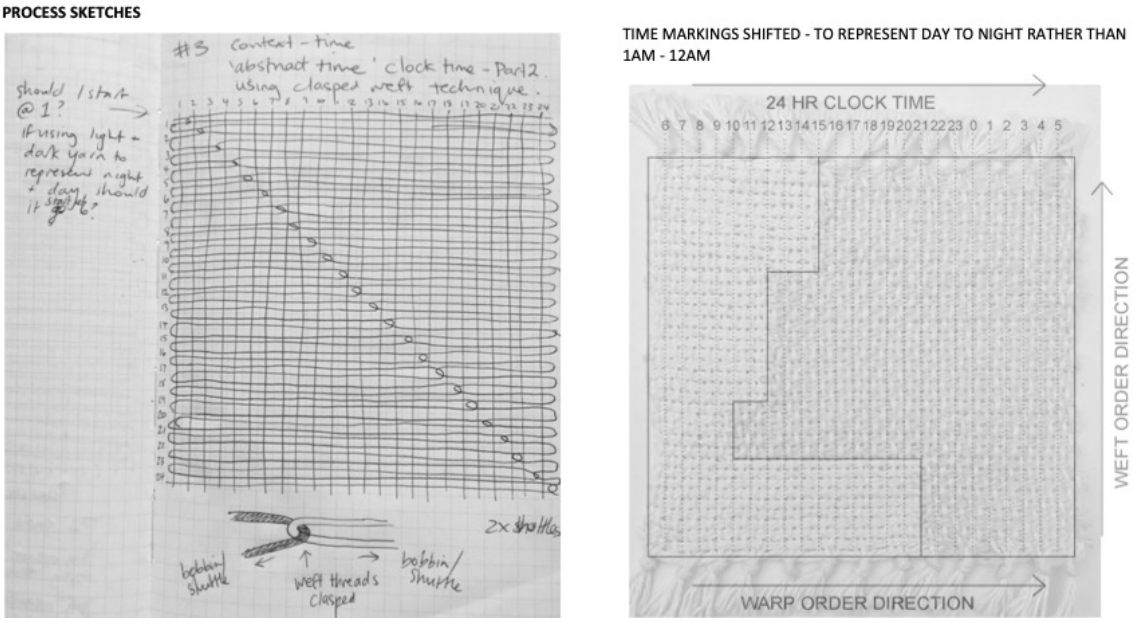


Figure 17 Duration sketch - to determine how to record clock time within cloth using a clasped weft technique and by assigning a time to each warp thread, Figure 18 Textile sampler 2Y1 diagrammed, with 24-hour clock time shown.

Additionally, the actual amount of time (duration) spent weaving was not quantified through the textile itself, only the accompanying process pattern data recordings. The resulting textile sampler may therefore be a better representation of rhythm, aesthetically logging patterns of making throughout the day. There is also the issue that duration is experienced differently, particularly experiences of time making textiles, wearing textiles, or simply sitting and touching textiles. Solnit describes how Einstein, in his attempts to explain relativity to the public, "repeatedly seized upon the image of a train running across the landscape, a train whose passengers were experiencing time differently to those who were on the ground" (2003, p.13). This can also be likened to one of Mihaly Csikszentmihalyi's eight characteristics of being in a flow state: the transformation of time – time as experienced differently when engrossed in weaving and appearing to speed up or slow down depending on engagements and/or enjoyment (1990). One hour of weaving with concentration, bodily actions and movement, would be experienced differently to one hour of somebody sitting and holding a cloth that had already been woven. The subjectivity and relativity of time are the things that I must consider when trying to express something such as duration.

5. Conclusion

Making my own cloth, and handling cloth made at human speed, allowed me a chance to see myself in a textile; to participate in a wholeness (Solnit, 2003) that has been taken away from many of us due to technological and global changes. There are multiple aspects of time and memory that I successfully recorded on my weaving log but proved difficult to capture in cloth – such as background noise, distractions and life-related reasons for pausing. Though I did not record my own mood for this project, it is worth nothing that there are ways in which to capture and record emotional aspects of making textiles. Using similar recordings, Nimkulrat writes of how research can theoretically inform practice in order to develop a designer's aesthetic intelligence in order to design objects that can be interpreted more easily (2012). As the future intention for this work is to distribute the samplers and ask a series of questions in order to gauge how they might express temporality to others, by exploring and employing more of Nimkulrat's methodology in my future work I might work towards a clearer implicit and explicit expression of time through cloth. The cloth samplers continued to represent a rhythmic pattern of working without any explicit stories visibly attached. Tacit findings may be detected through the interviews with participants in my future research.

The outcome of this research was the movement toward the development of a processual aesthetic, supported by a framework for textile designers and weavers that privileges cloth as a conduit for temporal connections between maker and user. However, most textile experiments and samplers featured here were physically incapable of expressing (explicit) quantitative aspects of time. They cannot be read and interpreted without some kind of accompanying chart, and even if a decoding chart was provided, it could only show the abstract time or 'clock time' at the moment of making. As Rowley suggests, there are multiple temporalities to textiles that are already present (1999), without having to reduce it to the measurable or calculable; to space (Grosz, 1999). Some of the textile temporalities that I intend to explore further in my weaving involve mutability, or changefulness - including movement, order, and subsequent wayfinding.

Another consideration of the temporal qualities of woven cloth lead to the question: when does a textile begin, or end? In light of this query, the textiles in this paper might be considered more as projects, or processes. Throughout my research I have struggled to identify a beginning or end point to weaving, with the woven textile being constantly in a state of becoming. As a changescape, textiles "tend not to finish" (Gibson, 2005, p.17). It remains open as to whether the woven textiles in question were ever 'finished' or whether they are still unfinished – remaining infinitely in-process.

Working with what is basically an ancient technology, using plant and animal yarns, and restricted to an unregimented and slow – yet chaotic – rhythm due to being a new mother, weaving these samplers often reminded me of larger forces at play, as well as my own impermanence (Macklin, 2007). On making and corporeality Paz states that "handiwork teaches us to die and hence teaches us to live" (1974, p.24). The weaving log recorded

the unpredictability of the things around me – a mixed tempo, often distracted and bodily affected pattern of weaving. The samplers attempt to display what Attiwill might describe as a "performative quality … event-objects where objects are part of events and not discrete, self-contained objects" (2005, p.6). The work eventuating from these experiments will eventually be examined beyond this paper for not only its temporality but also its mutability, a creative outcome "where material and process becomes content" (p.6). Based on my weaving experiments I posit that amplifying traces of time through the design of textiles may connect the eventual user/wearer – or in this case, the interview participant - to the 'pulse' of (a) weaving.

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About the Authors:

Jessica Priemus is a PhD candidate, interdisciplinary designer and lecturer in interior architecture, design, fashion and textiles. Her research explores how materials and objects may be designed to amplify traces of the making process.

The Tangible Embedded Networked Technologies SIG

Overview of papers in the Tangible, Embedded, Networked Technologies SIG highlights

Editorial 2373
Sarah KETTLEY

188. **A Tarot of Things: a supernatural approach to designing for IoT** 2377
Haider Ali AKMAL, Paul COULTON

139. **Designing for the Internet of Things: a critical interrogation of IoT processes and principles** 2392
Boyeun LEE, Rachel COOPER, David HANDS, Paul COULTON

195. **Open-Source Philosophy in Fashion Design: Contesting Authorship Conventions and Professionalism** 2410
Natalia SÄRMÄKARI, Annamari VÄNSKÄ

377. **A Curated Chronology: Traits of Electro-Energy from Research-through-Design Practices** 2427
Karthikeya Satish ACHARYA, Matteo CAMPINOTI, Mirko PRESSER

237. **Signs of the Time: Making AI Legible** 2442
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331. **Data Science for Service Design: An exploration of methods** 2460
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Editorial: Design for Tangible, Embedded and Networked Technologies

Sarah KETTLEY*
Convener of the DRS Special Interest Group for Design for Tangible, Embedded and Networked Technologies - TentSIG

[a] ECA, University of Edinburgh, The Edinburgh Futures Institute, UK
* Sarah.Kettley@ed.ac.uk
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The third DRS conference tentSIG section builds on at least two of themes explored in 2018, and in many ways extends the theme of this year's conference, *Synergy*, beyond any simple conceptualisations of collaborative or co-created design research. In particular the papers this year demonstrate further the continuing 'geometric expansion' of the design space, first discussed by Lee, Cooper and Hands in 2018, through worked examples of diverse aspects of the design experience, impacted in quite profound ways by a shift away from the human-centred, and towards a 'flat' ontology through distributed notions of users, processes, authorship, value creation, business models, and of course, products and services. Simultaneously, these papers do a sterling job of flying the flag for design research, and particularly for Research-through-Design (RtD), demonstrating and articulating its value to responsible research and innovation where it is needed most, in ensuring agency, negotiability and legibility in complex product-service and 'intelligent' systems. Between them, these researchers are mapping a new relational landscape of design, akin to Ingold's world without objects.

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Of all the authors, Akmal and Coulton (paper 188) are the most explicit in presenting this landscape, in their discussion of an Object-Oriented Ontology (OOO) as a framework for thinking Internets-of-Things. It is key to this section in its attempt to bridge design and the 'flatness' of the OOO. Where the other papers more or less implicitly unpack the emergence of flat ontologies in practice, of distributed, open-source imaginaries of technology and design, Akmal and Coulton introduce us to the philosophy itself. Through Bogost's *carpentry* (tools for 'doing philosophy'), a set of Tarot cards is developed to act as a provocation to designers, asking them to envisage how objects might be acting on each other in unexpected ways, and to see Internets of Things from the perspectives of a wider

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range of possible (non-cognisant) actors. Like Kunneman and Alves da Motta-Filho in their paper on data science, they touch on a move away from "the generalisation of user bases in design" as a result of object-oriented ontology, while introducing questions over the potential for "ever accumulating loops" of information based on data extraction. They point to "collectives of users" – not quite practices, which are more explicitly brought into play by Acharya, Campinoti and Presser's *Curated Chronology*. Instead the *Tarot of Things* makes a methodological contribution through the discussion of a playful methods for breaking apart HCD and HCI – a kind of breach experiment for otherwise user-oriented design practitioners, which aims to open our eyes to the possibilities and challenges of the OOO.

Set loose in this landscape, our first point of call is the process of New Product Development (NPD), and the impact of the IoT on these practices, developed for 20th century manufacturing paradigms. Lee, Cooper, Hands and Coulton (paper 139) continue the work of their 2018 tentSIG paper, exploring further the non-hierarchical ecologies of distributed innovation, endlessly scalable, but with increasing levels of risk due to increased interdependencies and interconnectedness – a constellation, rather than a routemap. In their discussion of the commonalities and differences between success in traditional and IoT business activities, the first item shifts the imaginary of 'the user' as a phenomenon to be understood and designed for, towards an entangled and active stakeholder role which is "mutually rewarding". Values in this new field of NPD are built through a constellation of relationships, rather than built into autonomous, market leading products, and data becomes jointly curated. Lee et al finish with a question highly pertinent to the DRS community: if innovation is distributed, what is the role of designers … generating values for IoT products and services within value constellations?

Särmäkari and Vänskä (paper 195) answer this question in part, by examining open-source approaches in the fashion industry, and the decentralisation of authorship that this entails. Even where practices could not be claimed to have been entirely autonomous previously ('traditionally'), their reconfiguration draws attention to distributed ecologies of creativity and production in new ways. They show how protectionism and secrecy, conventionally the guardians of value, are challenged by new constellations of design activity; the identity of the designer as heroic individual is no longer possible, or relevant as "unprecedented operational processes" are developed. They bring forth the question of the active versus the passive consumer, who must now become politically, materially and conceptually invested in these open-source models of production and consumption; their agency, having been somewhat designed out of the competitive, agile design process, is now necessary for the success of the whole new egalitarian network of design. They become "authorized", given authorial status and capabilities – not fashionable, but "fashion-able". The authors go on to show how the ontological shift cannot stop there, but must necessarily underpin the redesign of the design process as a service; the case studies they use illustrate the difficulty of then extending this to the redesign of the industrial business model itself, seeking ways to become or remain viable in a wider field.

Acharya, Campinoti and Presser, in 'A Curated Chronology' (paper 377), address the

subject of material itself, namely energy as material, and the ways in which it too is subject to an object-oriented ontological turn. They explore how design engages with technologies, transforming them into things available for negotiation and value creation, as 'design subjects'. Through their methodological contribution, which will help doctoral design candidates look for the traits of projects beyond their visual representations, and complement the standard literature review, they illustrate the opening of technology to become more undecided, through "designing through material and form" rather than "predicting use". Functionality and use are nudged away from "individual action" towards practices and the creation of publics, without losing the embodied, phenomenological dimensions of experience, which remain preserved in a "socio-relational' framework.

Another paper that demonstrates the benefits of a well-articulated Research-through-Design approach is that of Lindley, Akmal, Pilling and Coulton (paper 237). In using Design Fiction as World Building, these authors seek a way to approach AI responsibly, and summarise Piercian semiotics into the bargain. The design of a range of icons to make legible the presence and dimensions of AI systems highlights the potential for human agency given relevant information, or at least, points to its potentially tightly controlled parameters by various commercial and political interests. The speculative nature of this design research also goes effortlessly beyond the human, through the introduction of AI as an actor imagined as one of a constellation of contributors in the authoring of a creative work; what happens to (human) heroic authorial identity then?

Kunneman and Alves da Motta-Filho (paper 331) map out how data science plays a role in service design development, systems which contain "social, material, and relational elements". Like Lee at al, they see a need to extend previously discrete models of design to include preparation and maintenance phases, although this version stops short of moving from an essentially linear progression with internal feedback loops, to an ecological constellation of connected interests and practices. What this work does, is provide us with another aspect in the design landscape that is becoming 'flattened', that is, the concept of user testing. In the context here of data-mining, the experimental setting is suddenly exposed as entirely inadequate to the iterative development of an IoT; instead, in-the-wild approaches such as that discussed by Lee at al are necessary. At the same time, a shift from user segmentation by characteristics (and in the case of health, diagnosed conditions), can be seen both here and in Lee et al. The user is becoming a schmoozer, no longer so easily confined and codified; however, data depends on pattern recognition and lends itself to predictive algorithms, and users now share behavioural rather than demographic characteristics. Perhaps the socio-cultural frameworks mentioned elsewhere will start to challenge even this turn - Akmal and Coulton mention a psychodynamic approach, but others, such as person-centred theory, may also fit well with the non-directive design of "generic but customisable systems" as in the SPHERE project discussed by Lee et al – there is plenty of further work to be done in this direction.

As a whole, this group of papers allows us to spot the edges of our imaginaries when it comes to decentralising the world of design: what would it be like to remove the single

person from the visualisation of an IoT constellation in Akmal and Coulton's paper, or to replace it with bats, cats and trees, in an extension of the discussion on consciousness? What would it be like if the data collected and shared in Kunneman and Alves da Motta-Filho's account of data science came not only from 'users', but from machines, developers and organisations, and was accessible and legible to more than one kind of stakeholder? What if the business models struggling in Särmäkari and Vänskä's account were to apply Lindley et al's icon for intrinsic labor to the fashion sector, so that reward might be negotiated more openly and flow in more than one direction - have we in fact been guilty of imagining involvement in a creative network to be reward enough in itself?

About the Author:

Sarah Kettley is a Professor and the Chair of Material and Design Innovation at the University of Edinburgh, The Edinburgh Futures Institute, UK.

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A Tarot of Things: a supernatural approach to designing for IoT

Haider Ali AKMAL[a]*, Paul COULTON[a]

[a] Lancaster University, United Kingdom
*Corresponding author e-mail: h.a.akmal@lancaster.ac.uk
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Abstract: This paper looks at an alternative approach to design research for IoT, through a practical engagement with philosophy; based on the concept of Carpentry, introduced by design philosopher Ian Bogost. It presents this exploration through the design of a bespoke digital Tarot deck, rooted in Object-Oriented Ontology. This branch of philosophical inquiry withdraws from conventional perceptions of objects and people. Viewing them as equally important 'things', operating with a range of independent and interdependent perspectives; which have been described as "constellations". Through our philosophical carpentry we present a Tarot of Things, which acts as boundary object, for understanding how taking constellation perspectives of networked IoT devices can produce new design approaches.

Keywords: object oriented ontology; human centred design; internet of things; carpentry

1. Introduction

In the 90's British sci-fi comedy sitcom *Red Dwarf* (Rob Grant and Doug Naylor), a toaster with a highly advanced AI and speech capabilities appears as a recurring character. In the fictional universe, its purpose is to act as a kitchen companion providing light breakfast banter along with toast. The device also is highly intelligent, causing it a great deal of angst over its predicament of being *just* a toaster. For the purposes of a comedy series set in a sci-fi future, this presents comical scenarios with characters entering philosophical debates with the appliance. In real life though such situations seem less plausible. In todays connected world, the closest approximation to *Talkie Toaster* from *Red Dwarf* is an Internet of Things (IoT) enabled *smart toaster*[1]. Of course, the latter doesn't speak and enter philosophical discussions—but unlike an 'ordinary' toaster, this one aims to produce an *improved toasting experience*.

Generally, when one considers the design of an object, such as a toaster, the approach is to

1 See: https://www.engadget.com/2017/01/04/griffin-connects-your-toast-to-your-phone/

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see it from the perspective of its user; in this case humans. Human-Centred Design (HCD), is the prevalent format for designing object's, services, and business models in technological settings. With one of its core axioms being, to drive an object's design towards simplicity such that it becomes 'invisible' in use (Norman, 1999). Where this might prove beneficial, such as with the design of a toaster where it's unnecessary for the user to understand the electrical workings of heating coils inside. It can become problematic when approaching to design much more complex artefacts, such as a smart toaster.

The reason for this, is because smart devices create hidden networks between the user, itself, and other *smart* devices—such as the user's phone. The act of toasting bread in this manner is thus approached from different angles. For example, one may create options to save different settings for different kinds of bread, or, trigger the toaster from their phone and other linked devices. This interaction creates an ecosystem where these smart devices, users, stakeholders, and the services they provide all reside. It doesn't stop there, as the ecosystem could involve other external devices outside of the same design sphere; such as Smart Assistants (Alexa, Google…), or interaction services like IFTTT (If This Then That) that were not initially part of the designed ecosystem.

Thus, treating the interaction of such devices as 'simple' is difficult, and often results in obfuscating its complex workings in the aim of designing *for* humans (Coulton & Lindley, 2019). This is not to say that HCD's simplification mantra doesn't have its merits. All users are different, and one may argue both for and against the generalisation of user bases in design (Hashizume & Kurosu, 2013; Stickdorn & Schneider, 2011). However, the lack of legibility may lead to problematic aspects for some users; the most common, with respect to IoT, being related to security and privacy on how the data is handled (and accessed) within such systems.

The argument we present, is for an alternative view of simplification for the design of IoT. In that regard, this paper approaches IoT's complexity from a philosophical perspective, suggesting the adoption of a world view for IoT devices using Object-Oriented Ontology (OOO). The toaster if perceived in this manner, presents new avenues for designers to approach from; new spaces of inquiry within the design process of IoT. To facilitate this, we introduce the *Tarot of Things*. A philosophically charged artefact around IoT with the intention of *doing* philosophy, to provoke a potential for designers to *see* IoT from the perspective of its inhabitants—its objects. We will introduce both the philosophy behind its creation, and the methodology of using philosophy in this 'practical' manner. Following on from this with insights from user testing of the artefact, and a discussion into the findings. First though, we must discuss our rationale for introducing philosophy more directly into the design process.

1.1 HCD and IoT an ill-fated combination?

Despite its perceived benefits, HCD and its typical characterization within Human-Computer Interaction (HCI), have increasingly raised concerns among scholars (Lindley & Coulton,

2017; Steen, 2011; Stewart & Williams, 2005). Traditionally, the adoption of HCD within HCI presents consumers of technology as "passive recipients" of the value embedded within said technologies (Sørensen, 1994). This is seen as a straightforward mechanism for delivering an experience to the user, that is enriching and designed to be rewarding (Stewart & Williams, 2005). The intention is that by embedding value within a device, HCD moves towards creating the sense of a rewarding experience focusing on the *human user's* needs.

Unfortunately, this is not always the result. Stewart & Williams (2005) argue that there is a "design fallacy" within HCD for computer systems, with designers assuming, that in order to meet user needs the localized knowledge of users must always take precedence. This creates an ever-accumulating loop of knowledge extraction. They assert this approach as "unrealistic" and a hinderance towards "opportunities of intervention", resulting in targeting unique groups of users with the intent of extracted knowledge being applicable to a wider group—conversely aiding in oversimplification. The argument is against seeing design as an inductive process of accumulating data about "current user requirements", rather, acknowledging the "complexity and diversity" of users with differing perspectives and requirements.

IoT, in this regard, may be described as an "ill-defined construct", because it involves the interconnection of different devices where each device can be observed from a unique tangentially differing perspective (Lindley & Coulton, 2017). The stakeholders involved around any given IoT device range from the device's users to the service providers in overarching companies, such as ISP's, data providers, and data collectors etc. In such situations the design of an object, intended to be used in or around IoT, would effectively have a collective of users with unique needs as opposed to an individual user with a singular need. As previously discussed, this *fallacy* may also be attributed to HCD's mantra of simplification, which Coulton & Lindley (2019) view as, creating contradictions for users when used around "hyper-connected and data-mediated assemblages"; such as IoT. Contradictions often arise in the form of depriving users their privileges and affordances from devices or services that they encounter. They give the example of door locks, one being a conventional lock with key, the other an IoT enabled lock. Where the formers usage is clear and simple, the latter involves sending data between the door and any parties vested in its interest. One gives full autonomy to the user, while the other "obfuscates" the role played by data, thereby removing the user of some of their agency. When seen from their own vantage points, the traditional lock and the digital lock intend for the same interaction, yet, the latter creates what Coulton & Lindley call "independent but inter-dependent" perspectives and relationships (Ibid).

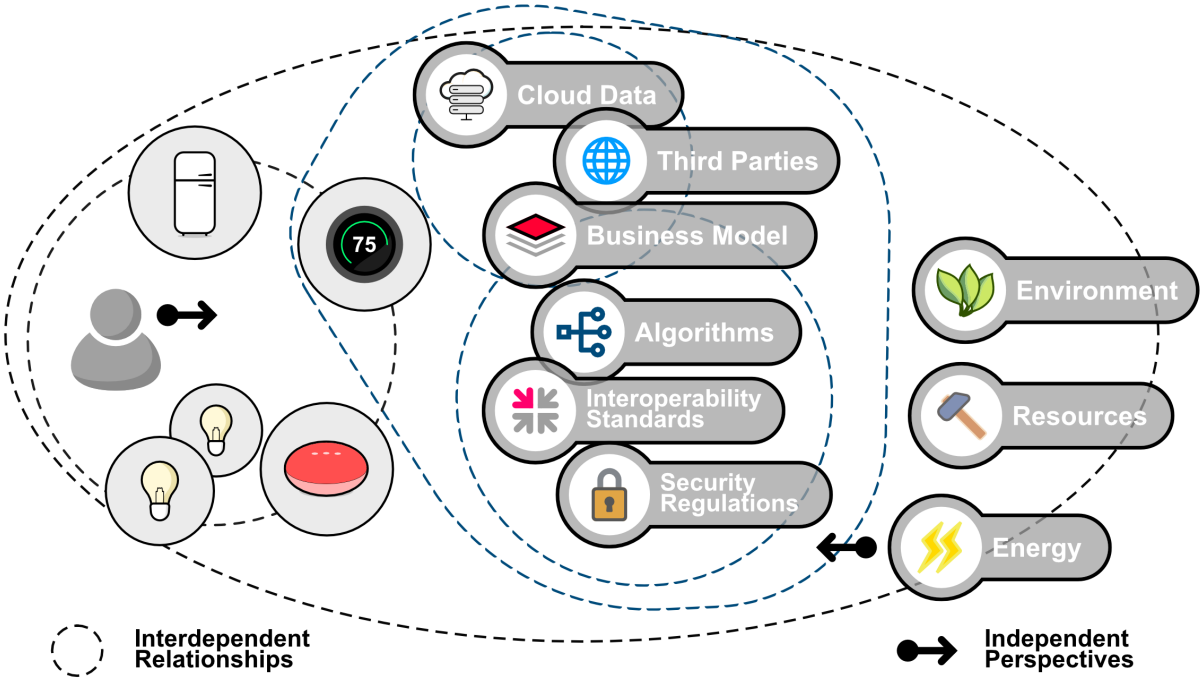

Figure 1 *Depiction of how a constellation for IoT could be imagined (Coulton & Lindley 2019)*

As a solution, they propose seeing IoT through the metaphor of "constellations" (Figure 1). Each device, service, stakeholder, etc. become elements within various constellations, with the intent of allowing designers to better visualize IoT. This approach takes the focus away from the human user, and instead, presents foci on the myriad *things* that entangle themselves within a networked IoT system. It attempts to use OOO as a medium for exploring the design of IoT objects as non-human entities; independent of their human users.

The artefact described in this paper, intends to act as a boundary object utilizing philosophy to further the discussion of *constellations* with IoT. It does this through the forecasting of a *Tarot* of the many things that may constitute such constellations. In the next section we go into the philosophical roots behind the artefact in more detail, along with an explanation of what we mean by, *doing* philosophy.

2. Thinking and Doing

In *The Quadruple Object*, Graham Harman (2011) describes objects as unit entities with the ability to both display and conceal their traits; in a manner he calls "overmining" and "undermining" respectively. By viewing objects in this manner, his aim is to enhance them to the levels of other non-objects around them. Morton (2011) describes this view as an attempt at reimagining realism in the wake of anti-realists. Generally, when we consider the perception of physical objects around us, they are perceived indirectly, i.e. they exist as real entities but independent of the act of perceiving them (Maund, 2003). The realist would say, this perceiving of physical things is only possible indirectly, for what is direct to the perceiver

is the act of perceiving the physical object through their senses; ergo, an apple exists because it can be seen, tasted, smelt, or touched. These qualities are what would create the apple for the observer. Conversely phenomenologists would say, the senses are aware of the apple—therefore, allowing us to experience it—yet, the apple's existence is not predicated by the presence of, or interaction with, the senses.

To further this debate Quinten Meillassoux introduced *correlationism,* in his ground-breaking work *After Finitude* (Meillassoux, 2010). It described a viewpoint, whereby, things may only exist in relation to humans. For the correlationist, subjectivity and objectivity are intertwined. Their understanding cannot be undertaken without one influencing the other. Zahavi (2016) explains it as a view where "thought cannot get outside itself", with the intention of revealing to us its intricacies. Our imagining of an apple cannot exist before our having experienced the apple, as it is, in relation to ourselves. Therefore, the apple cannot be thought of in isolation.

OOO refutes such correlationism, in an attempt at rethinking realism (Morton, 2011). Through the view of OOO, humans and non-humans are seen on equal footing, ergo, having no precedence over the other and equated as *objects* (Harman, 2018). This is in lieu with Levi Bryant's notion of a "democracy of objects" (Bryant, 2011):

> "Objects need not be natural, simple, or indestructible. Instead, objects will be defined only by their autonomous reality. They must be autonomous in two separate directions: emerging as something over and above their pieces, while also partly withholding themselves from relations with other entities." (Harman, 2018, p. 19)

In OOO's light, *objects* need not conform to any prejudiced view of what an 'object' is, or what might traditionally be thought of as objects; i.e. cupboards, teapots, the ocean, a symposium, and Alaska are also considered objects. Much like Latour's (1994) proposition for a "parliament of things", this view raises objects to the standard of Latour's "quasi-objects". This constructed view of *object-oriented-ness* by Harman, uses these ideologies and taps in Heidegger's infamous tool-analysis as a foundation (Bogost, 2012; Harman, 2011), to explain how objects don't need to relate through any human-use but rather any form of use—including any *format* of inter-relational use.

Seen in this light, the *Talkie Toaster* from *Red Dwarf* becomes on par with other characters in the series; an actor like all other actors in its play of existence. For IoT objects, this means they may be imagined existing upon a plane equivalent to that of their users; and to that of the services they provide; the companies they benefit; the spaces they occupy, and so on. With this in mind, from this point forward in this paper all things that form IoT will be referred to as ***objects***; rather than devices, services, users, etc.

2.1 Anthropocentrism for IoT

At first glance, objects may be seen as "phenomenon present in consciousness" (Harman, 2011). Yet, they exist in our vicinity, occupying physical spaces around us. Where this discussion of OOO leads to is, an imagining of the vicarious lives of equally animate and

inanimate objects in our existence. Though such an imagining of the world, from a non-human perspective, presents its own difficulties (Harman, 2018; Lindley et al., 2019). The premise provides a starting point to discuss a potential alternate view for designing in IoT; a view of the object as opposed to the user. In *The Uncommon Life of Common Objects*, Akiko Busch narrates the unseen backgrounds of common objects around us, explaining how their design was influenced by the mundanity of everyday life. Her poetic approach towards household objects, such as strollers and potato peelers, evoke their mystique. The suggestion is, that the objects around us have lived lives of their own, signifying more than what one may assume through their instrumental value.

This giving of life to an inanimate object may be seen as an anthropocentric approach of viewing life through the eyes of such objects. OOO though, suggests going beyond anthropocentricism in the pursuit of understanding objects. Lindley et al. (2019) discuss the potential for using a "post-anthropocentric" view as a way to view IoT networks as seen by IoT devices. They do this by suggesting the presence of metaphorical "ghosts in the machine", in hopes of having an alternative view of interactions. *Talkie Toaster* is shown to present the world from its own perspective, creating new perceptions of interacting with a toaster for comic relief. Those same interactions, if presented within the confines of a design problem, could offer an opportunity for intervention in the process of design for IoT objects; such as smart toasters, forks, bathtubs, apparel, etc.

2.2 Doing Philosophy

The *constellations* metaphor presents a novel opportunity to see IoT interactions as "flat ontologies" (Coulton & Lindley, 2019); a concept introduced by Harman (2018). Flat in OOO's regard should not be mistaken for a metaphorical flatness, rather, it is acknowledging a perspective of viewing objects in relation to each other as being flat; i.e. as seen from 'above' or 'below'. In the words of Wiscombe, "In the [flat ontology] model, everything exists side by side, like a collection of treasures laid out on a table" (Wiscombe, 2014). Coulton and Lindley's approximation of constellations as flat ontologies, attempts to lay out IoT objects before designers for scrutiny. The deep contentions around flat ontologies aside (Brassier, 2015), scholars have touted certain benefits of viewing the world in this perspective (Bogost, 2012; Simon, 2018; Lindley et al. 2018).

Bogost (2012) predicated his methodology of *"carpentry"* on the flat ontology concept. Bogostian carpentry entails, the making of artefacts that explain the workings of the worlds they occupy (Ibid); which he equates to as "philosophical lab equipment". He argues for the benefits of using this approach, as a keen way for practitioners to enhance their "natural talents". By using the act of philosophical carpentry in one's own practice, one may effectively create different *formats* of philosophers; philosopher-programmers, philosopher-chefs, philosopher-designers, etc. In relation to the counter argument in the previous discussion, around anthropocentrism and the potential difficulties of seeing things through alternate perspectives, arguments exist for the use of *"carpentry"* as a way to work around the human-to-non-human hurdle (Bogost, 2012; Coulton & Lindley, 2019; Lindley et al.,

2019).

Carpentry, introduced by Bogost (2012) in *Alien Phenomenology*, provides a method for creating objects that *do* philosophy. In this case, it would be philosophically experiencing the world view of an IoT object. Bogost describes carpentry as an extension of the term more associated with woodcraft, accompanied by, a phrasing from Graham Harman and Alphonso Lingis' explanation of how things influence one another and the world around them as a "carpentry of things". He explains the relation of carpentry with HCI as such:

> "Just as the painting infects our material understanding of the photograph, so the influence of photography and cinema on television can cloud our understanding of how computers construct visual images…Human-Computer Interaction (HCI) concerns itself with human-computer relations, not computer-computer relations—or house-computer relations, for that matter. Despite its technical tenor, computing is just as correlationist a field as everything else, obsessed with human goals and experiences." (Bogost, 2012, pp.101-107)

Bogostian carpentry takes liberties with the world around us, creating assemblages of interactions that help explain how they (in turn) make the worlds around them. Quoting Latour, "If you are mixed up with trees, how do you know they are not using you to achieve their dark designs?" (Bogost, 2012) He suggests the viewing of objects through a lens of *"ontography"*; or the description of their natures. Very much entering the space of metaphysics, he compares Latour's *Litanies* to Stephen Shore's photograph series titled *Uncommon Places*. Where the former creates lists of quasi-objects creating unique ontologies through their assemblage, the latter, in his view, explodes these objects into *ontographs* or descriptions of their realities creating "tiny, but contiguous universes". As an artefact of carpentry, he presents the *Latour Litanizer*[2] that fetches random pages from Wikipedia to create assemblages in the form of lists of things—or *tiny ontologies*.

The idea of flat (or tiny) ontologies, becomes the basis for our approach to carpentry. Utilizing Coulton and Lindley's constellation metaphor for IoT, we carpenter an artefact that allows us to communicate with the *stars* in our *IoT constellation*. These are the core constructs for our approach through philosophy. Going into further details would be exiting the scope of this paper, and risk convoluting the argument. That said, for those interested, our detailed exploration of philosophy and IoT is published elsewhere (Lindley et al., 2020). The following section explains the artefact in detail, its workings, and is followed by an inquiry through feedback and discussion from user testing.

3. Scanning the *Stars*

The precursor to this *Tarot of Things* was the *Internet of Things Board Game* (Akmal & Coulton, 2019), which used another approach to describe the idea of constellations to users through a procedural rhetoric emerging from gameplay. Whilst this approach had merit, due to the nature of game design, the artefact created was left not fully able to engage players with its underlying philosophy. Thus, the drive to create a *Tarot of Things* was to approach

2 See: http://bogost.com/writing/blog/latour_litanizer/

the philosophy of constellations head on. The reasoning for the use of Tarot comes from its widespread cultural influence as a practice that invokes a *spirituality*. As we are coming from an anthropocentric view of IoT objects, this artefact attempts to raise the bar for agency within said objects by introducing an air of the *supernatural* akin to Lindley et al. "ghosts in the machine" (Lindley et al., 2019).

The supernatural view of IoT is our way of expressing an alternative perspective of the devices interacting in networked assemblages. This approach does not suggest any human-like agency in non-human objects, rather, it is intended as a provocation of HCD presenting a dialogue different to that of more general approaches towards the design of these objects. That said, as we are about to discuss these objects with agency, it would help in clarifying our approach of Tarot. Its use here is similar to Semetsky's (2006) endorsement of Tarot within psychoanalysis, as capable of enabling an awareness of "unconscious material into consciousness". Here the *unconscious-consciousness* is hinting towards the inanimate IoT object, but, is meant to act as a bridge for practitioners. We intend the users of this appropriation of Tarot, to see through and dive within their own unconscious materials for insight, through what Semetsky calls "projective hypothesis". The *divinator* of a Tarot session is no different to a psychoanalyst in this regard; keying the possibility for a philosopher-designer-psychologist through the view of carpentry.

3.1 A Tarot of Things

The deck consists of a custom Tarot deck with unique illustrations and card names, appropriated for IoT (see Figure 2). The deck is not a physical deck, but rather a computer program created in a variant of Python and thus is entirely digital[3]. This is a deliberate design choice to *relate* more to IoT objects which, though have physical bodies in some cases, primarily operate within digital systems.

3 The program and a compilation of the different bespoke cards used to define the Tarot system is available online, and can be experienced here: https://www.fictionware.org/tarot-of-things/

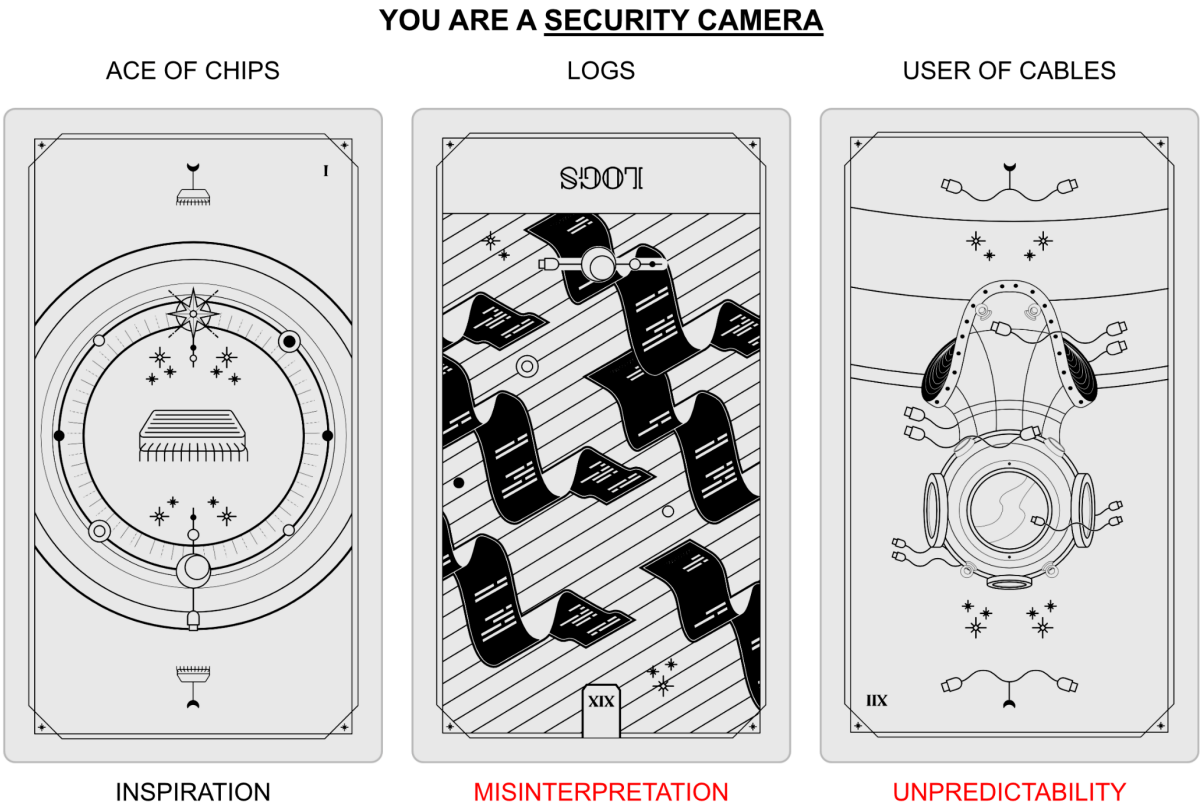

Figure 2 *Adaptation of Tarot of Things presenting a configuration of digital Tarot cards*

Tarot is a tool under the guise of a card game. It takes 2 to 'play', whereby, the divinator reveals the meaning of chosen cards for the subject in the manner of telling a story. The standard Tarot deck consists of 78 cards out of which 22 form the *Major Arcana* cards, followed by 4 suits of 14 cards each within suits of *Cups*, *Pentacles*, *Wands*, and *Swords*. As the theme for Tarot is taken from folklore and mythical fantasy, the imagery associated with tarot is of a similar nature. This is most visibly seen in the names and imagery of the major arcana cards: *High Priestess*, *Magician*, *Hanged Man*, etc.

For our purposes, the suits and the major arcana cards were altered to relate better to IoT (Akmal & Coulton, 2020). As such the suits became *Sensors*, *Chips*, *Cables*, and *Clouds*. The major arcana were given equivalent card names according to their most common descriptions. For example, *The Fool* became *The User* as it normally relates to the person having their fortune read. As in our case we do not differentiate between users and devices, the object itself becomes the user in this card.

To begin the process of Tarot, the one being foretold their future shuffles the cards and presents them on the table. In this case, the shuffling is done digitally on command and the table is on screen. After which, cards are drawn and placed in various configurations according to the depth of foretelling that is required in sequence. For our program, we opted for the simplest configuration of 3 cards in a single line.

Each card acts as a visual aid in the experience of foretelling, followed by the divinator's

description of events. This description can be reduced to a series of keywords that each card represents; which may differ according to the orientation of the card. For instance, the *Magician* card suggests *structure*, *ambition*, *authority*, and *rationality* when upright. Alternatively, it may suggest *chaos*, *anger*, *domination*, and *tyranny* inverted.

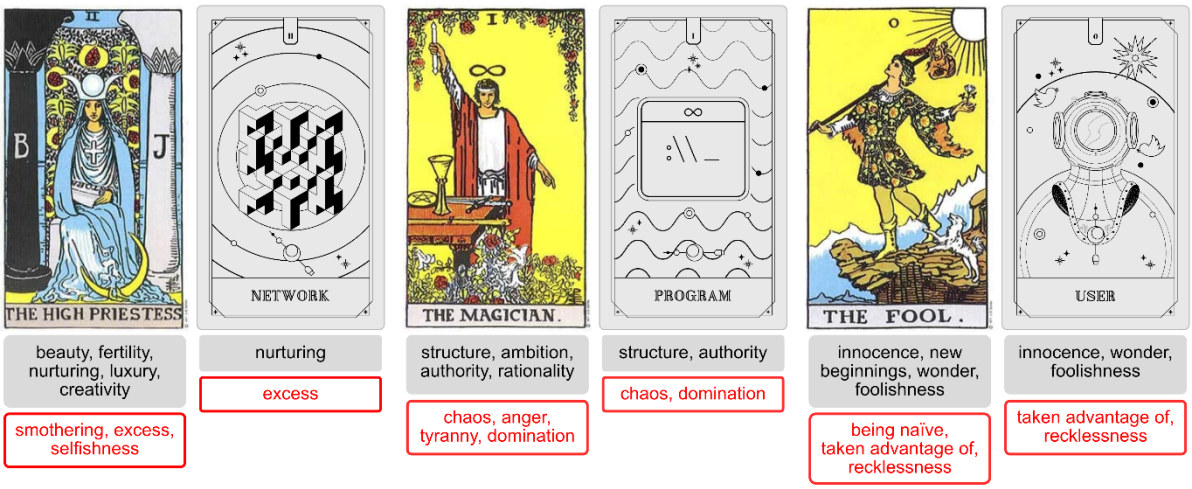

Figure 3 *IoT Tarot cards compared to traditional Rider-Waite Tarot cards with their keywords and curated keywords upright and inverted*

As with the titles and imagery, the keywords had to be curated for our purposes to relate more to IoT objects. That said, there was still enough variance left in them to allow ambiguity of meaning (see Figure 3). So, the *Magician* in our deck becomes *Program*; utilizing *structure*, *authority* (upright) and *chaos*, *domination* (inverted) from the original definitions. This does not necessarily mean there is no way of understanding a tyrannical or ambitious IoT object, but rather, we purposefully reduced the keywords to allow for an easier assessment of the Tarot.

3.2 Forecasting IoT Futures

This keyword reduction on our placed Tarot cards, in effect, creates a tiny ontology of its own that is intended to relate to the IoT object. Currently the program presents a random object to be foretold its Tarot. But as it is programmed, and exists in a digital space, it can be linked to any IoT object to retrieve a forecast of whatever action the object attempts to undergo. For instance, if synced to a bulb that can be switched on with a smart phone, the program can present a series of keywords to define the interaction with the bulb; such as a reading for being switched on, switched off, sending data, receiving data, creating a log, etc. Subsequently, the ontography of the keywords presents a platform for practitioners to raise questions; that otherwise would seem implausible.

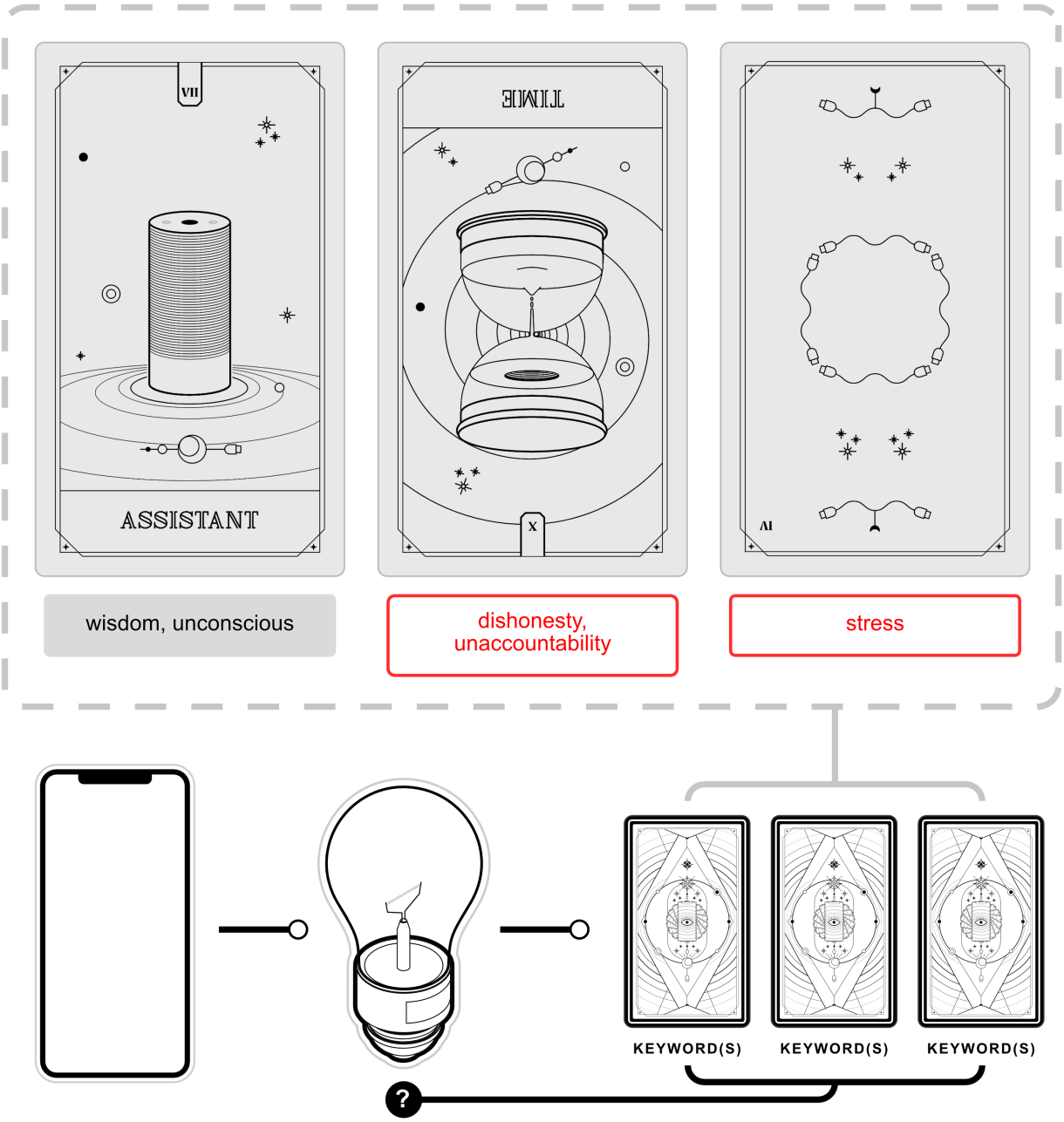

Figure 4 A smart bulb being forecasted its Tarot through the program

Consider an example of a lightbulb remotely switched on by a smart phone (Figure 4). The Tarot program is present on a separate device connected over the cloud. On switching on the bulb, it pings the server triggering the generation of a forecast saved to a log. The configuration of cards is random, the same as with traditional Tarot. In our case, let's assume the cards along with their keywords logged are:

- **Assistant (upright):** Wisdom, Unconscious
- **Time (inverted):** Dishonesty, Unaccountability
- **Four of Cables (inverted):** Stress

When presented with these keywords, in relation to an IoT enabled bulb, it raises questions such as: What is wisdom for a bulb? How can a bulb be unconscious? Can a bulb be dishonest or unaccountable? What about stress, what stresses a bulb?

Where some of these questions might seem more straightforward to answer—for example dishonesty: does it send its operating data to a third party without informing the owner? — others present unique challenges. Of course, all of this is subject to the understanding of the designer. How much they can create an interpretation that connects the object and keyword. But it does provide a useful starting point for the discussions, which otherwise would likely not be considered under pretences of HCD. Some of these questions might very well lead to novel design solutions.

4. Feedback and Discussion

Though Tarot can hardly be seen as a scientific starting point for the discussion around design of IoT, we nevertheless, attempted to see how much of an effect this approach could have in inducing alternate viewpoints. The program was evaluated through semi-structured interviews with participants where they were asked a series of questions around their knowledge of IoT and their experience of the cards. Participants were given random IoT objects and asked to roleplay as them when questioned. The questions were around their impression of the cards, and whether the keywords related to them as IoT objects. Each participant underwent a series of card/keyword/object configurations, to see how much of the concept could be passed across.

The immediate issue faced by participants was the lack of a starting point for role playing. Questions like, *"How can I think like a backpack?"*, were common. But after the initial few hurdles of configurations and aligning their thoughts to those of non-human objects, they all began embodying the objects more freely. That said, their embodiment was heavily influenced by their own *humanness*; as in, the objects no longer took on the guise of bulbs and forks but instead became *bulb-person*, and *fork-person*. This was partly due to the keywords, which though were heavily curated, still had enough variance to invoke odd interactions from the objects. In one instance, a thermometer was presented to a participant along with the keyword *Discipline*. They managed to make a story out of how thermometers would make your mind more rigid according to the reading; ergo, you need to rest because you are sick, '*says the thermometer'*.

Still, a prevailing argument presented by participants was, *"Why does this matter?"*. When asked about how they see the nature of IoT objects as being capable of more than their designed intentions; for instance, how a telephone is only a feature in a smart phone capable of doing a lot more (even though it is recognized as a *phone*). Some participants argued, that though that is the case, they would see the object as being more *useful* than its otherwise non enhanced variant. This aside, what also emerged was how doing the exercise made them aware of how these objects might be doing things they had not envisaged. One participant suggested how the keywords and cards made her wonder if she should be more careful with

her devices. If an object can be identified as *Manipulative* in the program, then what else could it be?

5. Conclusion

This paper presented an artefact that attempted to do philosophy through Bogostian carpentry in a manner of provoking questions around the design of IoT objects. The argument we present is a reaction to the excessive use of HCD and HCI in the design process for IoT. Building upon the works of Coulton & Lindley (2019), we suggest a plurality of alternative design approaches to foster heightened understandings of IoT actants. We take inspiration from OOO and Ian Bogost's carpentry, to create a bespoke deck of digital Tarot intended for the divination of IoT objects.

The compulsion of design to be *for humans*, coming from the oft quoted Bauhaus phrase *"form follows function"*, keeps the foci of design forever revolving around the human user. The convoluted nature of IoT interactions (Lindley & Coulton, 2017), particularly in the wake of post-GDPR events surrounding IoT, have been the centre of debate around design for these systems. With scholars presenting caveats around HCD and the insistence on human-centeredness, the main reason for entering this research was to approach IoT from a non-human perspective; seeing how much of it could make sense.

OOO withdraws from conventional perception of objects, creating a bubble where strange possibilities may be presented as normality. Allowing non-humans to coexist among, and on par, with humans. This study approaches the viewing of IoT through a philosophical lens of OOO. Eloquently expressed by Morton (2011), human beings are merely "one way of being in a mesh of strange strangeness"; our objects among them.

The reduction of OOO brings with it a few caveats for design. Firstly, the heavy curation of keywords makes one wonder how unbiased have we been towards our IoT objects, and, whether we unknowingly still asserted meaning and value upon them through selective ontography? Secondly, the divide between non-human and human is still one that is difficult to overcome without further philosophical inquiry. We are not philosophers writing this paper, but, have attempted to make sense of these philosophical debates around ontology. Perhaps in hindsight, we should have brought in actors more capable of taking on the role of an inanimate object, or, philosophers more capable of presenting arguments for non-humans. But even then, this reasoning is flawed. How exactly can one remove the human from the *human-object*, to become a *non-human object*?

As stated before, this work is intended as a provocation of current orthodoxies in the application of HCD. The program, cards, the assessment of keywords, all of it are not intended to be for any single user. Rather, to act as a modality of viewing IoT design practice. It could have been enough to simply have a set of keywords randomly assigned to an IoT object. But the setting of Tarot, adds a secondary layer of interpretation; a *medium* for self-assessment.

In the end, whether we design with human users in mind or non-human, the end-product is still (at least for now) operated by human users. Which could suggest the reasoning of participants on whether this exercise matters. None the less, this approach did open the minds of our participants. That might be enough to encourage greater development of a post-HCD view of IoT design; and maybe design in general. Shifting its focus from solely considering the needs of the human to more adequately consider the non-human i.e. the climate, environment, flora, and fauna etc.

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About the Authors:

Haider Ali Akmal is a PhD Design candidate and practicing visual artist at Lancaster University. His research focuses on the intricacies of human experience around digital and physical interactions using Speculative Design, Philosophy, and Ludic Design as exploratory mediums.

Paul Coulton is the Chair of Speculative and Game Design in the open and exploratory design-led research studio Imagination Lancaster. He uses a research through design approach to creative fictional representations of future worlds in which emerging technologies have become mundane.

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Designing for the Internet of Things: a critical interrogation of IoT processes and principles

Boyeun LEE[a]*, Rachel COOPER[a], David HANDS[a], Paul COULTON[a]

[a] Lancaster University, United Kingdom
*Corresponding author e-mail: b.lee12@lancaster.ac.uk
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Abstract: With the emergence of Internet of Things (IoT) as a new source of 'big data', businesses face new opportunities as well as emergent challenges. However, although academics and practitioners often critically debate the IoT, little attention has been focused on the design and development of IoT. Re-framing of NPD for IoT is compulsory as the integration of software in physical products is radically challenging the innovation processes and practices. Thus, the aim of this paper is to contribute to a comprehensive understanding of IoT New Produce Development (NPD). Based on a featured case study, a new approach towards IoT design and development process and their relevance against the characteristics of existing NPD processes are reviewed and critically debated. This paper summarizes how NPD processes and value creation could be improved and proposes guidelines with the conceptual framework for IoT NPD processes.

Keywords: digital innovation; internet of things; design process; development risk management

1. Introduction

Gartner (2014) forecasted noteworthy growth in the number of connected devices and areas of application. Cisco (Evans, 2011) estimated that by 2020, 50 billion devices around the world will be connected to the Internet. IoT is "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols"(Vermesan et al., 2011). Amalgamating sensors, radiofrequency identification (RFID) tags, and cloud computing with non-digital products and services possibly gives products and services new properties (Yoo, Lyytinen, Boland, & Berente, 2010) and create vital opportunities for new innovation (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014; Radziwon, Bilberg, Bogers, & Madsen, 2014; Xu, 2012; Yoo, 2013). In this regard, it is estimated that the total global impact of IoT technologies could generate anywhere from $ 2.7 trillion to $ 14.4 trillion in value by 2025 (Cisco, 2013; McKinsey, 2013).

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With the emergence of Internet of Things as a new source of 'big data', businesses face new opportunities as well as new challenges (Porter & Heppelmann, 2014). The IoT remains a fertile field for commercial enterprises and so that one in every six businesses is planning to roll out an IoT-based product (Burkitt, 2014). These pervasive adoptions of digital technologies are radically changing the nature of products and services that affect not only how organisations develop new products and services (Yoo, Boland, Lyytinen, & Majchrzak, 2012) but also how they create meaningful value (Hui, 2014). It also opens new opportunities in terms of how organisations increase turnover. Consequently, the 'Internet of Things' (IoT) is becoming a popular theme of exploration amongst academics and industry practitioners, i.e. a new technological orientated paradigm regarded as a vision of connectivity, for anything, at anytime and anywhere, with an impact on everyday life more dramatic than the Internet had in the past twenty years (ITU, 2005).

However, although academics and practitioners often critically debate these emergent opportunities and challenges to the adoption of the IoT, little attention has been focused on the new product development (NPD) process of IoT; arguably one of the most critical marketing planning and implementation process activities undertaken within the organisation (Lee, Cooper, & Hands, 2018). Recent researchers claim how the unique properties of digital technology enable new kinds of innovation processes that are evidently distinctive from the innovation processes in 20th century (Henfridsson, Mathiassen, & Svahn, 2014; Yoo et al., 2012). However, there is a paucity of established academic theories and industry practices to support and re-think traditional processes of product design and development activities to meet current needs and potential commercial opportunities in the era of IoT and digital economy. Scholars from marketing and design argue that it is time to reframe traditional processes of product design and development to satisfy current needs and potential commercial opportunities in the era of IoT (Ng & Wakenshaw, 2017; Speed & Maxwell, 2015).

1.1 Research Aims

This paper offers initial results of current doctoral research, based on a comprehensive literature review, exploratory interviews, and case study in order to identify and debate how contemporary design and development process can be revised to embrace new market opportunities. It concludes by offering key insights and observations as to how design and development process for IoT products and services are reframed, which could then enable academics and industry practitioners to further understand the process of designing IoT products and services. The following research questions will be both offered and critically debated:

1. How the existing NPD processes could be related to their counterpart in the digital economy?
2. How IoT products and services are actually developed and what risks are inherent over the development process?
3. How design and development process for IoT could be reframed?

4. In order to answer these primary questions, this paper commences with a common understanding of; traditional product development and innovation, digital innovation, design process for IoT, and fundamentals of IoT business success. The term IoT business used within this study is referred to the business, running B2B or B2C business based on sensor embedded smart products, while having a payment system which is oriented toward services rather than physical goods. The primary questions will be explored through case study research of the SPHERE (Sensor Platform for Health in a Residential Environment) project which is to design healthcare technology for the home environment for five years, from 2013 to 2018. A new approach toward IoT products and services development is presented based on findings arising from the SPHERE project.

1.2 Methodology

The research study currently involves three qualitative research methods, including an extensive examination of current literatures, exploratory interviews and a comprehensive case study. As part of the literature review, books, articles and academic texts which are broadly selected through searching through electronic databases such as Springer Journals Archive, Wiley Online Library Journals, ProQuest Business Premium Collection, and Google Scholar. Search terms used, included 1) “NPD”, “NSD”, “design and development process”, and “Innovation process”, 2) “IoT”, “Digital innovation”, “Digital artefact” and, “Digital economies”. These are then supported by a manual investigation of abstracts and articles published in select journals- Proceedings of CHI, Journal of Product Innovation Management, Journal of Information Technology, and European Journal of Innovation Management. Each text was critically examined for their relevance to the primary question(s) of the main research study.

The case study design is selected as a method, which is particularly appropriate for an exploration of why and how the phenomenon (Yin, 2009) of IoT systems are developed in the context of the case for the study. Case study research is identified as an ‘empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009).’ The SPHERE project was selected as a primary case study prior to subsequent multiple case-study activities. In line with an exploratory approach, the SPHERE project was selected for the following reasons: 1) easiness of recruitment of potential participants; and 2) its aim which is to develop IoT products and services in the residential environment is aligned to the central area of focus for the research study.

The case study was conducted through a series of semi-structured interviews and engagement tools lasting up to two hours in July 2018. The recruitment criteria for participants for the case study featured experts who have knowledge and practical experience over 10 years; who understand the whole system of IoT products and services development; and who hold the authority to drive the project and make strategic decisions. The interviews were recorded, transcribed, coded and analysed for themes that were then

clustered into defined categories and then compared across interviews, and the literature review. The internal validity in the case studies was enhanced by member checks. The case was reviewed by the original informant asking them to confirm whether there is any incorrect information or missing point.

2. Design and development processes in the manufacturing economy

2.1 New Product Development (NPD) process

As pace of technological change and contemporary competitive pressure increases, companies face the challenges of creating breakthroughs, increasing efficiency, and pre-empting competitors (Meyer & Utterback, 1995; Kessler & Bierly, 2002). In this context, the continuous development of new products is commonly regarded as a requirement for corporations' growth and long-term prosperity. As a consequence, the subject of New Product Development (NPD) has received extensive attention from product development professionals and researchers over the decade (Durisin, Calabretta, & Parmeggiani, 2010; Marcelo, 2013). Its contribution to the growth of the organisations, its role as a key factor in business planning, and its influence on profit performance have been proved (Booz, Allen, and, 1982; Crawford, 1987; Urban & Hauser, 1993; Cooper, 2001; Urlich & Eppinger, 2011). For example, a number of leading high-tech companies have identified that more than 50% of their current sales come from new products (Balbontin, Yazdani, Cooper, & Souder, 2000).

The term has been defined by a large number of academics, such as the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale (Krishnan & Ulrich, 2001). Bruce and Cooper (2000) identify that NPD is to capture a range of different types of innovative activities leading to the production of a new service or product from radical innovations to simple modification and adaptations to existing products. Moreover, there is no single design and development model, which is agreed to provide a satisfactory description of the design process despite numerous research efforts conducted (Bahrami & Dagli, 1993).

Over the past fifty years, NPD processes have progressed from 'tried and tested' ways of problem solving and are constantly refined by the practitioners applying them to 'real' client projects (Best, 2006). As a result, a number of factors have widened the designer's horizon and working methods in design process (Jacobs & Cooper, 2018). By reviewing design and development process including highly cited NPD process models, such as 'over the wall' process (Trott, 2012), a 'stage gate' system (Cooper, 1990), a 'rugby' approach, a 'double diamond design process mode' (Design council, 2007), and a 'service design' process (Johnson et al, 2000), this paper will review the trajectory of progress of design and development process.

2.2 Traditional NPD processes

Within manufacturing economies, NPD processes are close to conventional sequential approaches such as 'over the wall process' or 'departmental-stage models' which represent the early form of new product development model (Trott, 2012). This is particularly accepted by large manufacturers in which the insular departmental view of the process hinders developing products (Jacobs & Cooper, 2018); different functions are responsible for completing each phase so that projects are transferred from one functional area to another during the development cycle, thus increasing time and cost of product development.

In correspondence with the growing literature on the significance of, considering the project as a whole, and integration between functions such as marketing, R&D and manufacturing (Crawford, 1980; Gupta, Raj, & Wilemon, 1986; Hauser & Clausing, 1988; Souder, 1988; (Clark, 1989; Gomory, 1989; and Narver & Slater, 1990), different approaches have emerged which are deemed as 'simultaneous approach' or 'rugby approach' such as parallel processing models (Takeuchi & Nonaka, 1986). This way of approach not only increases the speed of the development process but also enables it to be accompanied by new philosophies of design, such as market-led design, implementing flexible manufacturing in order to respond to the flow of new information on customer demand and preferences, allowing products to be more tailored, adaptable and desirable to the customers (B. Evans, 1985).

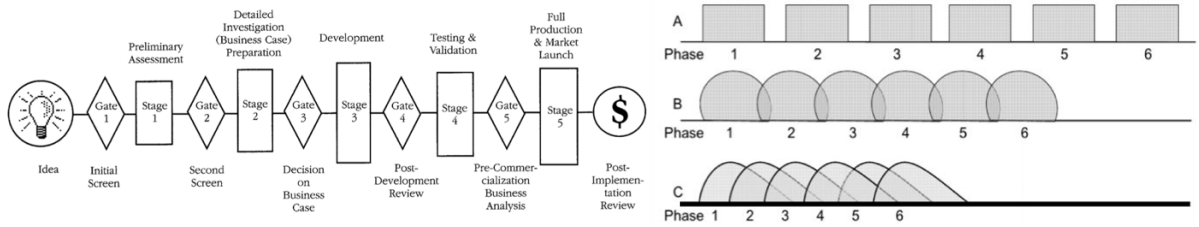

Figure 1a A Stage-Gate System, Figure 1b. Sequential (A) vs. Overlapping (B&C) Phases of development

Double diamond design process model (Design council, 2007) and Chesbrough's (2004) open innovation model are not presented as a model of NPD process per se; however, they have many commonalities with generic NPD processes. Although double diamond design process does not illustrate the full scale of the NPD process, it matters significantly among organisations since they require their designers to get involved in creating value from initial idea to final recycling (Design council, 2007). The open innovation approach emphasises the significance of having open mind for ideas and suggestions driven from outside a firm in relation to design and development activities (Chesbrough, 2004).

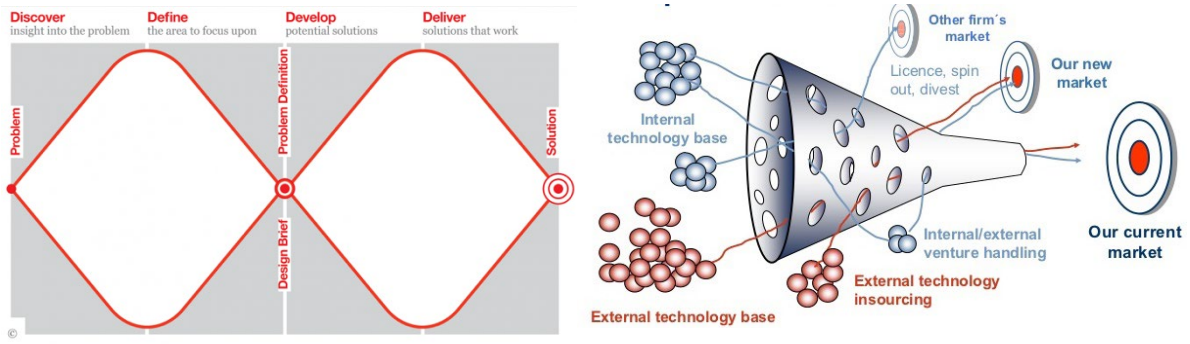

Figure 2a Double Diamond Design Process Model, Figure 2b Chesbrough's Open Innovation Model

As manufacturing economies in the late 20th centuries started to be replaced by service and digital economies, diverse approaches towards NPD are considered eminent method to create value for customers in industries, such as service design process (Johnson, Menor, Roth, & Chase, 2000) or agile development method (Beck et al., 2001). One of the representative service model is developed by Johnson, Menor, Chase, and Roth (2000) and the rationale is the changeover in focus, from product-orientation to understanding why customers buy a particular service (i.e., a focus on value creation) (Andreassen et al., 2016).

In addition, as flexible product development is becoming a critical aspect, agile development method, which is for software development based on iterative and incremental process consists of a number of short cycles, known as 'sprints', begins to attract interest from designers and developers of physical products (Cooper, 2014; Ovesen & Sommer, 2015) who experienced the challenges and limitations of existing NPD processes. Although it is argued that these 'short cycles' improve communication and coordination activities, speed to market, and faster responses to changing customer requirements (Begel & Nagappan, 2007), a series of challenges for manufacturers adopting agile practices have been identified, i.e. a lack of scalability and a lack of management (Cooper, 2017).

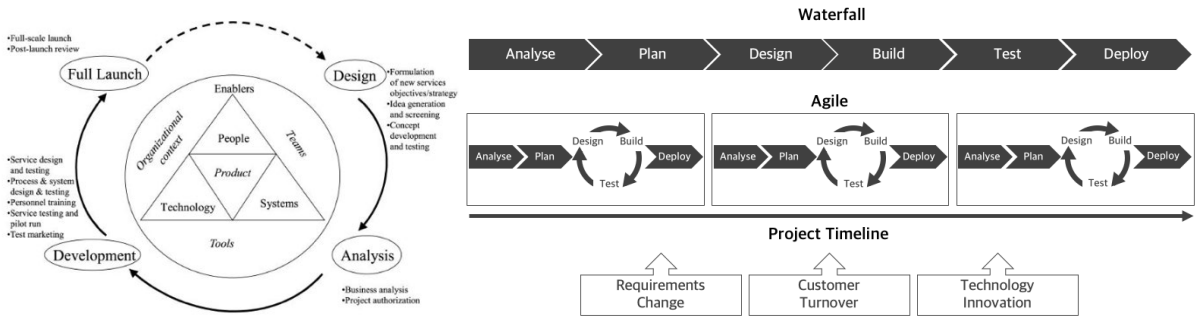

Figure 3a New Service Development Process, Figure 3b. Agile Software Development adapted from Mistral

To summarise, existing NPD models are continuously evolving and supported by emergent trends of increasing particular significance in product development, such as a) the models illustrate linear processes involving sequential phases; b) the NPD process

runs simultaneously; c) recent approaches are more likely to work with customers, and competitors; d) in certain industry fields, such as electronics, the sprint approach becomes more suitable within NPD processes. However, existing models are regarded as obsolete in order to create value for the IoT products and services. This is because they do not reflect the characteristics of digital technologies (Yoo et al., 2012), the dimensions of data (McAfee & Brynjolfsson, 2012), and the dimensions of digital innovation (Yoo et al., 2012) which influence value creation and design and development activities for IoT. Therefore, the attention of this discussion focuses on more details of NPD process for IoT products and services and how they differentiate from existing design processes through the case study.

3. Design and development processes for IoT in digital economy

3.1 New process for IoT products and services development by SPHERE

Healthcare services in the UK need to be prepared for the transformation from clinical setting into the home (Burrows, Gooberman-Hill, & Coyle, 2015). SPHERE (Sensor Platform for Health in a Residential Environment) aims to contribute to this issue not only by developing a sensor platform for monitoring inhabitants' physical and mental wellbeing but also by measuring the value of the system and value and cost of acquiring pieces of data. The system does not target specific age groups or health conditions, but rather it intends to develop a generic but customisable system to support clinical diagnoses and self-management of wellbeing (Burrows et al., 2015).

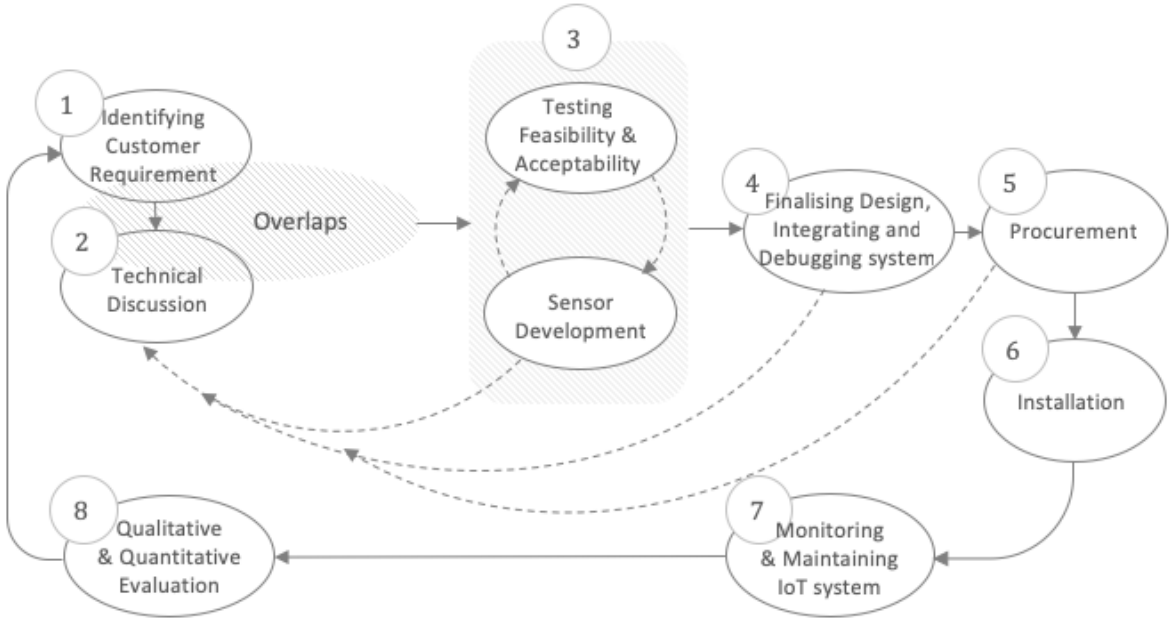

Figure 4 NPD process for SPHERE IoT products and services

In the SPHERE project, the new process for IoT products and services development (Figure. 4) is identified and illustrated by a researcher at Bristol University. The process involving eight

stages seems to be similar to a generic design and development process (discover, define and develop) however, due to the issues and characteristics of digital artefacts development, how IoT products and services are developed and what should be considered is distinctly different in a variety of subtle ways.

1. Identifying customers latent requirements

The IoT product and service development process begins with identifying customers latent requirements. In the SPHERE project, it was challenging to identify customers' requirements, as both of clinical researchers and customers were unfamiliar with IoT systems and did not know the opportunities and benefits it could give them. The risk at this stage is that customers generally are not trained to articulate and define their needs that is generally found in traditional NPD process. Requirements identified by customers could be badly defined, contradictory, or impossible to solve. Thus, the SPHERE team ran a series of workshops and meetings, making proper commitment to identify customers' requirements in greater detail (see Figure 5 below). More significantly, beyond understanding what the future customer wants, this first stage is vital in terms of building a strong relationship with customers to prepare scaling up or commercializing IoT system.

Figure 5 SPHERE Clinical-Brainstorming.

2. Technical discussion

This phase revolves around customers' requirement to explore adequate technology for the system. As it is argued that technical risks may be encountered in the majority of NPD process phases (Škec, Štorga, & Marjanović, 2013), with regard to data and complex IoT system, there are numerous technical risks require strategic discussions such as: what kind of system to develop; whether to use labelled data; and what level of smartness and intelligence the system would have. Having the customers' needs identified accurately, the way to deliver value could be various so that strategic discussion is inevitable in order to identify the system to develop. In addition, in relation to the smartness of IoT products, the appropriate set of capabilities should be strategically considered (Porter & Heppelmann, 2014) (Figure 6).

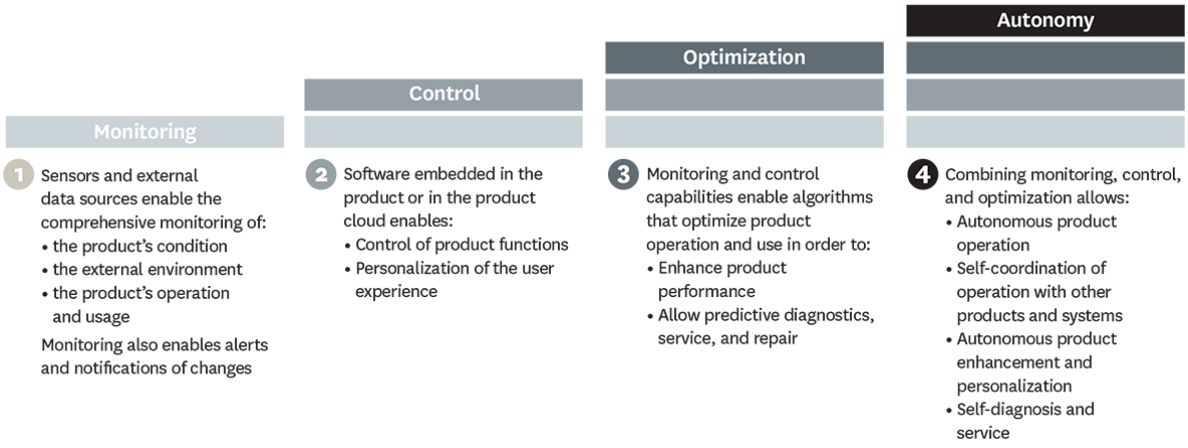

Figure 6 Capabilities of smart, connected products

Each capability (monitoring, control, optimisation and autonomy) is valuable and depending on the level of smartness of the product, different risks would follow. The issue of labelled data would elaborate this issue further in detail. If a company decides to have IoT system work autonomously and to use labelled data, they can save financial resources to deploy elsewhere; however, they might be challenged to differentiate their business to that of the competitors. Alternatively, having decided to build annotated data sets and testing the algorithm in-house costs more in terms of time and money; but they have opportunity to develop a novel service. Another significant risk at this phase is that not knowing the performance of the system until the system is actually developed and deployed. Thus, the sensor development and IoT system prototype stage must follow with agility in order to comprehend if the right decisions have been made.

3. Testing Feasibility and Acceptability, and Sensor Development

After the Technical discussion phase, the IoT system was installed into the Sphere House (see Figure 7 below) which is a physical space for the purpose of prototyping the system. Feasibility and acceptability were tested through a combination of traditional ethnographic methods and participatory techniques. 15 to 20 households spent two weeks each living in the Sphere House and how they used and perceived the system was monitored during this time. The participants ranged a different group of people aged between 19 to 77, from having no formal qualifications to having a higher education degree (Burrows, Gooberman-Hill, & Coyle, 2016). At this point, the sensors had not been completely developed so that the Bristol University team used commercial sensors rather than their own. In this case, the feasibility and acceptability testing, and sensor development ran parallel to one another. The major risks identified at this stage was that the small sample size which result in: a) not enough data to make decisions and a consensus; and b) random data in acceptability depending on users' competence in digital technology. Evaluating IoT products and services thoroughly was almost impossible without completing the product and service ecosystems.

Figure 7a A woman with SPHERE wearable technology on her arm, Figure 7b. The SPHERE House in Bristol.

4. Finalising the design and, integrating and debugging the system

After testing feasibility and acceptability, and sensor development, a company is able to finalise their design, integrate, and debug the system. Developing physical and digital product challenges the designer with a continual pressure of never being able to finish design and integrate system. In NPD projects, keeping the design fluid is regarded as a primary risk, increasing the time and/or cost required for project completion (Gil & Tether, 2011). However, in the context of IoT development, this risk is more vulnerable due to the pace of innovation and programmability, one of the material properties of digitalised artefacts (Yoo et al., 2010).

For example, the old chip may no longer be available in the marketplace, or new vulnerability issues may make you have to change the processor or software. Another issue in integrating IoT system is that it is notoriously complex to build strategic alliances with device manufacturers, software developers, or service providers. To create value through IoT products and services, it is important for a company to have the whole value constellation. Having bigger value constellation means there are likely to be more opportunities in value creation. However, with more partners getting involved, there is likely to be significant risks in data leakage and managing distributed diverse stakeholders.

5. Procurement

During the procurement phase of the IoT system development, it was identified that special attention should be paid to issues around quality control. For example, issues in being unable to procure hardware components that can lead to new suppliers found, the design being changed or the whole system having to be started again. In an unconnected world, a single device may have a minor problem, but for the IoT system as a whole, the chain reactions of other connected devices can become catastrophic (I. Lee & Lee, 2015). Prior to moving to

the installation stage, there would normally be a recruitment, marketing and retail phase. However, it has been omitted within this discussion, as the process is based on the SPHERE project, which did not aim to commercialise the IoT products and services.

6.Installation

In SPHERE project, the team did not have many issues regarding installation as their system was not being commercialised. However, in the installation phase, SMEs and start-ups should consider who installs the IoT devices. If qualified technicians are used, this will raise costs, result in a company's business model, and as such, this could prove to be a risk to its overall success (See Figure 8).

Figure 8 Pilot home installation

7. Monitoring and maintaining the IoT system.

During monitoring and maintaining the IoT system, the user data and diagnostic data is collected on the products and services in order to evaluate and improve the IoT offering(s). If a company build their own annotated data sets, they can start to test their AI algorithm within the IoT system.

8. Re-designing products and services based upon qualitative and quantitative evaluation

This is the final phase that involves quantitative and qualitative evaluation of the system and users, and the value proposition of IoT offerings would be defined and redefined. As IoT is multi-disciplinary area, the data collected is generally outside of technology domain, such as air quality, health, or energy consumption. Consequently, it is more than likely that external experts' opinions will need to be obtained in order to generate insights from the data and again building strong relationships with experts is significant in this regard. The properties of digital technologies make solutions for a wide variety of needs possible (Yoo, 2013; Yoo et al., 2010); hence, through this phase it is essential to continue identifying the way of transforming needs to value. In this way, the IoT development process continues to re-designing IoT products and services in an iterative way.

4. Discussion

The NPD process found in SPHERE project seems to be similar to a generic process as a) it is likely to work with various customers; b) the stages run simultaneously; and c) the stages within IoT NPD process are not much different to its counterpart within traditional NPD processes. However, the approach towards NPD for IoT system is not linear but a continuous and never-ending process. The cycle of discover, define and develop phases are supported by an enormous amount of real-time information. It is succinctly explained through a model developed by Jacobs and Cooper (2018) (See Figure 9). This new approach is due to digital components in IoT which are able to modify subsidiary functionality or introduce entirely new functionality over the product lifecycle (Benkler, 2006; Svahn & Henfridsson, 2012; Yoo et al., 2010; Zittrain, 2006). With these distinct characteristics, the scope, feature and value proposition of IoT products and services can continuously evolve even after being launched and whilst being used.

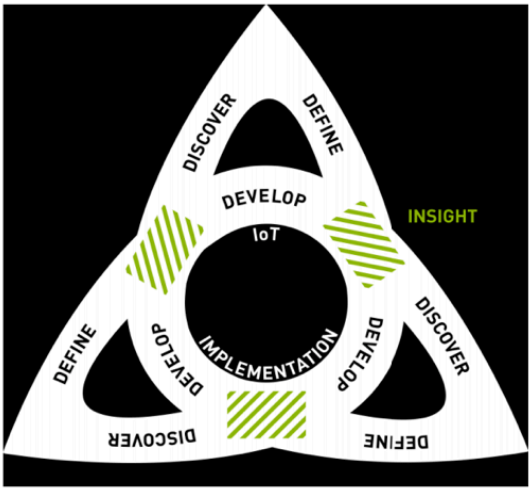

Figure 9 A new process for designing IoT products and services.

As the primary aim of the SPHERE system development was not to commercialise it, the discussion of the SPHERE process is limited. However, a couple of commonalities and differences in the fundamentals of business success between IoT business and traditional business are identified as below (See Table 1). The fundamentals of business success from traditional economy still applies to IoT businesses, however different factors are required for IoT business success. In the phase of Discovery, it is vital to make customers understand what benefits they would derive from the IoT system. This is because awareness of IoT remains low, with less than 1 in 4 people fully understanding the term (Bayern, 2019). Moreover, during this phase, to establish a firm relationship with stakeholders and future customers is identified as one of the key success factors in order to commercialise the system in the future.

Table 1 Commonalities and differences of the fundamentals of IoT business success to its counterpart of traditional business activities.

	Commonalities	**Differences**
Discover	Understand customers' requirements	Make customers to understand what they would benefit from the IoT system
		Establish a mutually rewarding and strong relationship with experts and future customers
Define	Accurately identify customers' requirements	Strategically consider the level of smartness of the system for the right solution
	Fuse users' needs into the right solution within the right business purpose	
Develop	Quickly start to build products	Carefully expand the value constellation
	Be agile	Access to many users to test and refine algorithms
Deliver	Manage customer relationship and supply chain	Critically question how to curate data
		Continuously strive to add meaningful value by speaking to various stakeholders within different domain knowledge
		Transform business orientation from product to service

At the Define and develop phase, it is identified that the development risks in IoT are more difficult to manage compared to its counterpart in traditional product development due to the distributed innovation activities of IoT, the complexity of building smart products and the diverse ways of creating value. The level of smartness and the access to many users should be strategically considered for testing and refining the algorithms. Moreover, there are many dependencies on the development context and circumstances especially when the system relies on AI or complex ecosystems; and IoT systems are developed with diverse players within a value constellation which means the risks do not fall under the one company but falls out of the company.

Data is not only changing the design process but also the role of the designer(s) within this process. They no longer have to anticipate and develop generic products at the early stage of design process, with limited access to the data on customer needs. Designers, within this context, should continuously and critically question how to curate data to add meaningful value to IoT systems by speaking to various stakeholders within different knowledge domains even while delivering products and services. Value in the IoT era is created through data within the value constellation. Consequently, IoT firms need to have a robust approach toward IoT design process that are more strategically able to contribute to the value of products and services. Therefore, the attention of this discussion now focuses upon a new approach towards design and development for IoT.

4. Conclusions

As IoT innovation advances and permeates our daily lives, it will disrupt entire industries and have a profound impact on business. Despite a number of companies considering incorporating IoT components to their products and service portfolio (Gerpott & May, 2016), there is still a paucity of academic studies on the development process of IoT products and services. Through examination of established literatures, a series of exploratory interviews and a primary case study, this paper provides attention to the core research questions at large: 1) What are the characteristics of design and development processes in the traditional economy and how they could be related to its counterpart in the digital economy? 2) How IoT products and services are actually developed and what risks are inherent over the development process? 3) How could the design and development process for IoT could be reframed?

In this paper, the characteristics of existing NPD processes and the factors affecting value creation for IoT were critically reviewed. Then through exploratory interviews and the case study, how IoT products and services are developed and value is created, and distinctive risks and issues in IoT development are identified. Finally, it suggests a new approach towards design and development process for IoT. Although this research study has explored issues related design and development process for IoT, there are limitations which is that it solely relies on a limited literature review and a single case study. Thus, it leads to having the research outcomes difficult to generalise to a wider set of context and applications.

Notwithstanding these limitations, however, the authors argue that our research also has some important contributions. For academics, this research project contributes to augmenting the body of literature regarding design and development process for IoT and can serve as starting point of future in-depth research on IoT NPD processes. For practitioners, this research helps industry to understand how value should be created through NPD process. When a company decides to apply IoT technology into a specific proposition, this study serves as a tool to guide as to how IoT products and services could be developed.

Related to the limitations of this study, practical questions are identified for further research: How IoT organisations manage risk(s) in terms of scaling up their value constellation during the NPD process for IoT? What is the role of designers in respect of generating values for IoT products and services within value constellation? Further research will enable organisations to have a deeper understanding of the economic value through IoT and enlighten design academia's expanded role of developing designers for emergent digital economies.

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About the Authors:

Boyeun Lee is a PETRAS PhD candidate as well as a PDRA in Imagination Lancaster. The core of her research is design strategies for emerging technologies in public and private sectors.

Rachel Cooper adds is Distinguished Professor of Design Management and Policy at Lancaster University. Her research interests cover: design thinking; design management; design policy; and across all sectors of industry, a specific interest in design for wellbeing and socially responsible design.

David Hands is Director of Postgraduate Studies at Lancaster Institute of Contemporary Arts, Lancaster University. David has also written and published extensively on design management and design as a strategic resource for both profit and non-profit organisations alike.

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Open-Source Philosophy in Fashion Design: Contesting Authorship Conventions and Professionalism

Natalia SÄRMÄKARI[a]*, Annamari VÄNSKÄ[a]

[a] Aalto University, Finland
*Corresponding author e-mail: natalia.sarmakari@aalto.fi
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Abstract: This paper investigates open-source fashion approach as a design philosophy and a phenomenon that demonstrates an alternative to the concept of authorship of fashion designers. We argue that the concept contests traditional professionalism in fashion design in today's digitalized, data-driven culture. Investigating open-source philosophy in fashion design as a dimension of professional fashion designers' authorship, the paper presents three case studies with different ways of applying open-source principles to existing fashion design practices. The article builds on multiple-case-study research conducted during 2018–2019. The case studies were analyzed from the perspective of authorship and professionalism. We ask whether, how, why and to what end fashion designers contest the authorial and professional conventions of fashion design. Secondly, we analyze the role of technology in such questioning.

Keywords: open-source philosophy; fashion designer; authorship; professionalism

1. Introduction

Digital technology, the Internet and social media have shaken up professional fields ranging from media and music to politics. Likewise, fashion design professionals and the fashion industry are facing several changes. A small number of academics and designers have suggested applying an open-source philosophy to fashion, as a way of updating the profession of fashion design, tackling sustainability issues and, in many cases, utilising new technologies. Open-source fashion aims to challenge the traditional "closed" and designer-centred fashion design professionalism. It is a design philosophy and a set of practices that expose design processes and invite non-professional "prosumers" (Toffler, 1970) to actively participate in the creative space of design and production, as well as in operational innovation (van Strien & de Pont, 2016). This paper focuses on *open-source fashion* cases that are initiated by *fashion design professionals* in *existing real-life settings*. We ask, what

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are the implications of the open-source approach in fashion design? Does it mean designers give up their professional authority? Or is it just a redefinition of the concepts of "author" and "professional"?

Open-source fashion is related to the field of "open design", which is considered the most user-driven co-design activity, and is manifested in the hacker and DIY maker culture (Marttila & Botero, 2013, pp.105–106; van Abel, Evers & Klaassen, 2011; Hyysalo, Jenssen & Oudshoorn, 2016; Niessen, 2010; Bakırlıoğlu & Kohtala, 2019; Kohtala, 2016). While open-source fashion shares the same philosophical roots as open design, this paper does not discuss amateurism or user-centredness in fashion design. Rather, we understand "openness" in a broader way, as consisting of elements drawn from the open-source philosophy (Vainio & Vadén, 2012). Unlike open design, which is characterized (at least partly) by anti-capitalism (Bakırlıoğlu & Kohtala, 2019), open-source fashion is also identifiable in the (mass-)customization and transparency practices of companies that operate *within* the capitalist system. Cutting-edge research on open-source fashion has focused on questions of sustainability and social design (von Busch, 2008; Niessen, 2010; Fletcher, 2008; Fuad-Luke, Hirscher & Moebus, 2015; McQuillan, 2018; Niinimäki & Hassi, 2011; Seppälä, 2017), as well as customizable on-demand production (e.g. Peterson, 2016; Pine, 1993). More often than not, designers and companies that apply an open-source philosophy (whether they specifically name it as such or not), tend to either involve users in the creative design processes or produce garments on demand, with the explicit aim of enhancing transparency and/or sharing their designs for others to use or modify.

On a philosophical level, open-source fashion aims at a decentralized and open structure and defies the hierarchical and secretive conventions of fashion design. In his field theory, Bourdieu (1993a, 1993b) talks about dominant groups with a required habitus as a trajectory of their social position, and of the "newcomers" who search for revolutionary strategies to enter or take over the field. Could questioning authorship and professionalism be one such strategy? The goal of this paper is first to contextualize open-source fashion and then to explore how the two-way communication tendencies of our digital network society (Castells 2010), together with the "social turn" (Bishop, 2006), are manifested in the work of fashion designers who intentionally challenge the traditional authorship of fashion design culture. We will first discuss the concept and then present and analyse empirical research data from three case studies.

2. Defining open-source fashion design

"Openness" is a buzzword in a digitalized society where all information wants to be "free" rather than "enslaved" by copyrights (Pomerantz & Peek, 2016; de Mul, 2011, p.37). The open-source philosophy has its roots in the mid-twentieth century's scientific, technological, political and social environment, as well as in the open-source software movement (e.g. Illich 1971; Toffler 1970; Leadbeater, 2009; Vainio & Vadén, 2012), whose proponents believed in software sharing as the path to personal liberation, flat hierarchies and unleashed collective

creativity (Leadbeater, 2009: p.39). “Openness” is understood as a means of collaboratively solving contemporary problems, enabled by “commons-based peer production” (Thackara 2011, p.44; Benckler 2006).

In contrast, the traditional field of fashion design is a designer-driven activity with roots in industrialization and in the Romantic notion of the author as a solitary, autonomous genius with inexplicably acquired skills and vivid intuitive knowledge (Bennett, 2005; Burke, 2008; Barthes, 1968; Foucault, 1969). This creative subject is *authorized* (Nagy, 1996: p.92; Bennett, 2005: p.34), performing a certain author function (Foucault, 1969) in a given socio-cultural context. The importance of authorship is directly linked to the exclusive jurisdiction system (see Abbott, 1988, pp.59–86) and the professional hierarchy of fashion designers (Doeringer & Crean, 2006). The whole modern fashion system is arguably built on the idea of legitimizing the designer as an author (Kawamura, 2018; Särmäkari, 2020). The institutionalized *authority* of high-end designers and the *autonomy* of independent designers are central aspects of professionalization processes (see Beckman, 1990). The traditional fashion system has its roots in nineteenth-century France, but it is still in force today (Bourdieu 1993a, 1993b; Lipovetsky, 1994; Kawamura, 2018: pp.67–69).

Open-source fashion can be an attempt to shake up the status quo of the fashion system (e.g. von Busch, 2008; van Strien & du Pont, 2016). The external and internal disturbance (Abbott, 1988: pp.91-98) of the professional system and the dismantling of the authorial role have often involved new technologies. In 2005, Bollier and Racine’s paper *Ready to Share: Creativity in Fashion & Digital Culture* proposed a new “grand narrative” of creativity, in which the open, participatory culture of the Internet and digital media redefined both creativity and authorship. In fact, the writers suggest that fashion’s environment has always been open, ever-evolving, dynamic and social – similar to the online world – and that even the work of haute couturiers builds upon preceding cultural elements and designers. In other words, open-source fashion only exposes the myth of the fashion designer’s “genius”.

3. Framing the field of open-source fashion

There are different levels of open-source fashion, ranging from transparency to DIY (Mustonen, 2013), and from meta-design to design activism (Fletcher, 2008, pp.185–194). According to Otto von Busch (2008, p.109) the fashion myth can be decoded and the “cathedral-like” top-down hierarchy can be turned into a “bazaar”: a flat, networked organization (Raymond, 1999). *Shareable* (15 Dec 2015) suggested that the “open-source revolution” will solve the social and ecological problems of the fashion industry through the production of quality clothes by people relying on technological innovations, open online exchanges of ideas, and open-source design and manufacturing. The possibilities for adopting open-source fashion principles in the fashion industry are, however, limited. The following types of (overlapping) open-source fashion forces are identified in literature and by existing proponents: (1) academic advocates; (2) practitioners; (3) commercial agents; (4) amateurs; and (5) activists.

The "academic advocates" of open-source fashion see fashion as a dynamic, flexible, synergetic activity and an open system that is difficult to force into a mechanical, closed and hierarchical paradigm (Bollier & Racine, 2005; von Busch, 2008; Openwear, 2010; Fletcher, 2008; Nixon & Blackley, 2015; Mustonen, 2013). Fashion design is in dialogue with other designers and brands, previous collections, influencers and celebrities, the history of fashion and culture, visual and popular cultures, and the street. Authorship of a work is hard to define, due to the interplay between new and familiar, the collective team effort and the mix of originality and imitation (Kawamura, 2018; Raebild, 2015; Eckert & Stacey, 2001; Vangkilde, 2017; Racine & Collier, 2005, pp.14, 29). For example, *Openwear* is an e-book (Niessen, 2010) providing an overview of the open-source fashion approach, a web community and a platform (now inactive) for knowledge, tools, discussion, collaboration and customization of free collections under an open-source licence.

"Practitioners" hope to change the fashion system to reduce its negative social and environmental impacts. For example, Martijn van Strien and Vera de Pont have written an *Open-Source Fashion Manifesto* (2016) in which they state that open-source fashion is the change that the system needs to save the value of fashion as culture, by starting a "technologically fuelled revolution". The designers believe that the revolution starts with transparency, multidisciplinary community and co-design, as well as with DIY personalization, increasing people's emotional attachment to garments. By using globally available digital designs and locally available Fablabs or Makerspaces, anyone can be a maker and innovator. With modular clothing, garments can be assembled and reassembled by the users themselves. In such an environment, the designer becomes a purveyor of open digital blueprints and a "facilitator" (van Strien and du Pont, 2016, p. 16). These ideas are evident in the design philosophies of *Atacac, Minuju* and *Self-Assembly*, the case studies for this paper.

The "commercial agents" of open-source fashion typically limit themselves to mass customization and overall transparency. Mass-customization can offer cost-effective goods that fulfil individual wishes by being customized within the context of a given product line (Pine 1993; Nayak et al., 2015; Satam et al. 2011; Lee et al., 2002). The most notable mass-customization example, Nike ID, demonstrates the essential roles played by digital technology, modular design and flexible manufacturing (e.g. Pine, 1993; Aichner & Colletti, 2013; Wang & Liu, 2017; Nayak, 2015; Lee et al. 2002, p.139; Peterson, 2016). *Unmade* is one of the technological enablers of mass-customization, providing both customization platforms and rapid knitting. *Print All Over Me*, in turn, allows consumers to create custom-produced jersey garments on the condition that they permit anyone to purchase their designs.

"Amateurs" are individuals making or customizing clothes. Burdastyle, for example, promotes open-source sewing and connects users for sharing thoughts and advice on design and sewing. It was established by the German globally distributed fashion magazine *Burda*. The initiative aims at open, free, sustainable and participatory fashion practices based on creativity and individual needs. Under the Creative Commons licence, the platform offers a "sew-pedia" of freely downloadable and printable patterns, as well as a community that exchanges tutorials, templates and tips.

The final group, the "activists", combine design or hacking with activism (Fuad-Luke, 2009; Hirscher, 2013; von Busch, 2008). The "hacktivism" mindset is that contributing to a larger system helps to tune the system in the desired direction. Envisioned by Otto von Busch (2008, p.29), "fashion hacktivism" is an alternative fashion practice, where the prestigious auteur is replaced by a cooperation between users, designers and producers, and where inspiration, instructions and tools are provided for becoming "fashion-able". Von Busch's research, book and website (http://selfpassage.info/) offer a range of frameworks for designers to implement when they want to act as intervention agents and turn their practice towards social inclusion, knowledge diffusion, craftsmanship and affection (von Busch, 2008, p.27). Another example is the *Hacking Couture* project, with associated workshops, run by the open-source fashion pioneer Giana Gonzalez. *Hacking Couture* documents the design code of established brands to derive new fashion ideas and serve as a platform for self-expression (Scaturro & Granata, 2006). The project was inspired by open-source software development, and Gonzalez has created an open-source library of famous designers' most repetitive design elements ("codes"), which users can reinterpret and modify.

4. Case studies: Atacac, Minuju and Self-Assembly

The aim of this multiple-case study was to determine the nature of a contemporary phenomenon through existing cases (Yin, 2018, p.13), while fathoming the complexity of each case (Stake, 1995, pp. xi, 39). A case study protocol was drawn up to define the focal points, interview themes and methods of inquiry. Three cases were studied in depth: *Atacac, Minuju* and *Self-Assembly*. They were chosen on the basis of their application of the following open-source elements: open-for-modification sharing of free "blueprints" or "code"; customization services and shared creative agency; DIY and assembly practices; on-demand production; and transparency.

Semi-structured interviews and observation were the primary data collection methods, supplemented by multiple secondary sources. With the participants' consent, the interviews were sound-recorded and transcribed. During the observation, field notes and photographs were taken. The study on *Atacac* took place in their studio in Gothenburg (Sweden) over three eight-hour days of observation and seven interviews (lasting 20–90 minutes). In the case of *Minuju*, the designer was interviewed for 90 minutes at their home studio in Vantaa (Finland). The founder-designer of *Self-Assembly* was interviewed (1 hour 43 minutes + online), with an additional three 6–8-hour days of observation and further non-recorded interviews at their studio in Helsinki (Finland). The research data from all three cases was analyzed using the thematic analysis method (Braun & Clarke, 2006).

4.1 Atacac

Atacac is a small fashion company whose aim is to develop an alternative model and an upside-down process for designing, presenting, selling and producing garments. They create and sell their garments virtually, with minimum sampling or inventory, producing items on-

demand and pricing them according to the flight-ticket logic (pre-order = low price; buying from stock = high price). All of these operations take place locally at their studio and mini-factory, allowing for the required speed and agility in prototyping and production. At the time of our field work (March 2019), Atacac employed its founders (Rickard Lindqvist and Jimmy Herdberg) plus two design interns, one assistant designer, one producer and two mini-factory tailors. Atacac's main income comes from consulting, designing and digitizing designs for other companies, as well as running its mini-factory and renting out studio space.

Atacac was chosen as a case study mainly because of its *Sharewear* online platform, where they share 2D patterns and garments' 3D files for free and encourage downloaders to make and modify their Atacac garments. Atacac does not believe in protectionism, because the internet facilitates access to the "best-of-the-best" knowledge, skills and high-level fashion anyway. They emphasize transparency as their core strategy, referring to the typical elements of open-source fashion: keeping the code open-ended, exposed and distributed, working as a community, and considering their clients as participants. The founders come from software development and academic fashion culture which both promote openness and sharing. However, sharing also brings clients and attention. Lindqvist and other interviewees brought up the case of a customer who downloaded a pattern, updated it, asked Atacac to make the shirt, and sent them the fabric with the pattern. Later, Atacac used the customer's design as the basis for a new release. For Lindqvist, this case inevitably brings up the question of "what will a brand mean for a future generation of Minecraft players […] if anyone can produce or design anything?" As technology advances along with people's digital skills, brands might lose their power over online fashion tribes.

Atacac also sells garments to the virtual world and works with a beta version of Clo3D that personalizes avatars for virtual fittings in motion. Lindqvist, however, does not believe that digital prototyping will replace the physical, underlining that his design practice and academic research (Lindqvist, 2015) have always built upon his background as a pattern maker.

> "I think that's one of the reasons why I so easily and happily adopted this [Clo3D] – because this is the way I have always worked […] for the industry in general. I think this would be very good for products because it would require a closer collaboration between pattern cutters and designers." (Lindqvist, 8 March 2019)

Clo3D is software intended for professional designers and pattern makers, but its user-friendly interface and visualization possibilities have also attracted amateurs. The interviewees see the program as a key driver behind the increasing interest in digitized 3D-clothing. Possessing traditional pattern-making skills is helpful when adopting Clo3D, but the software also teaches how to construct a garment.

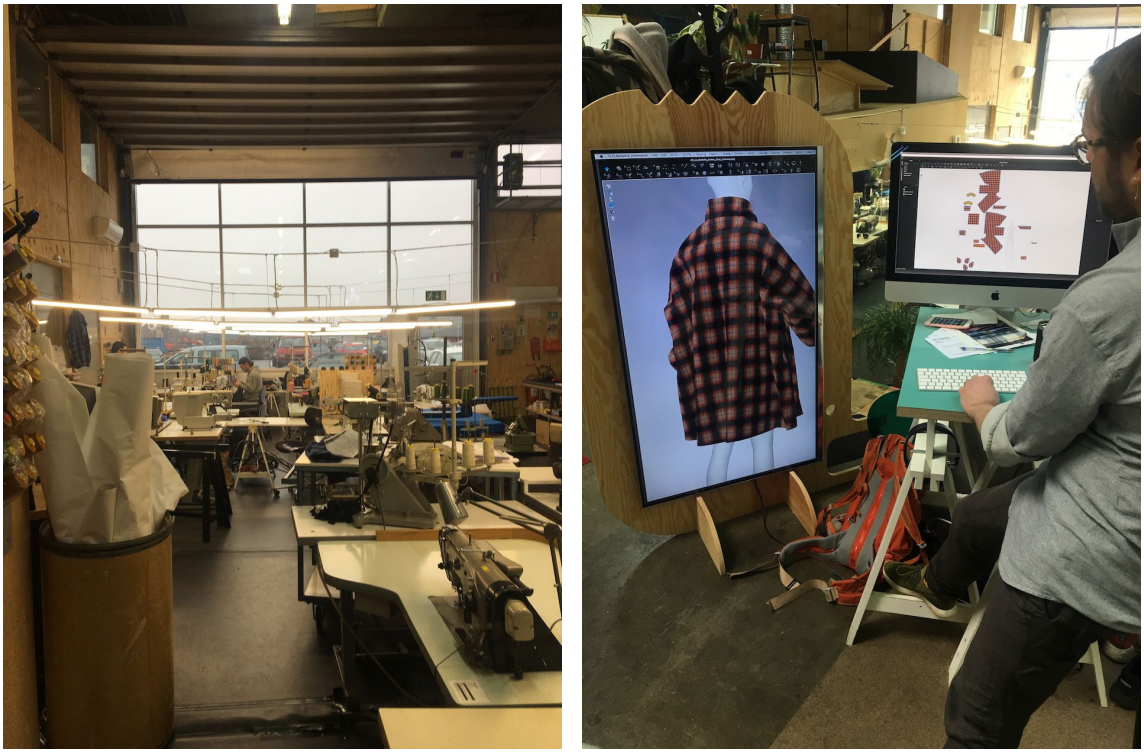

Figure 1 *The Atacac mini factory in Gothenburg (left) and founder-designer Rickard Lindqvist working on Clo3D and a human-sized screen (right). Source: Natalia Särmäkari.*

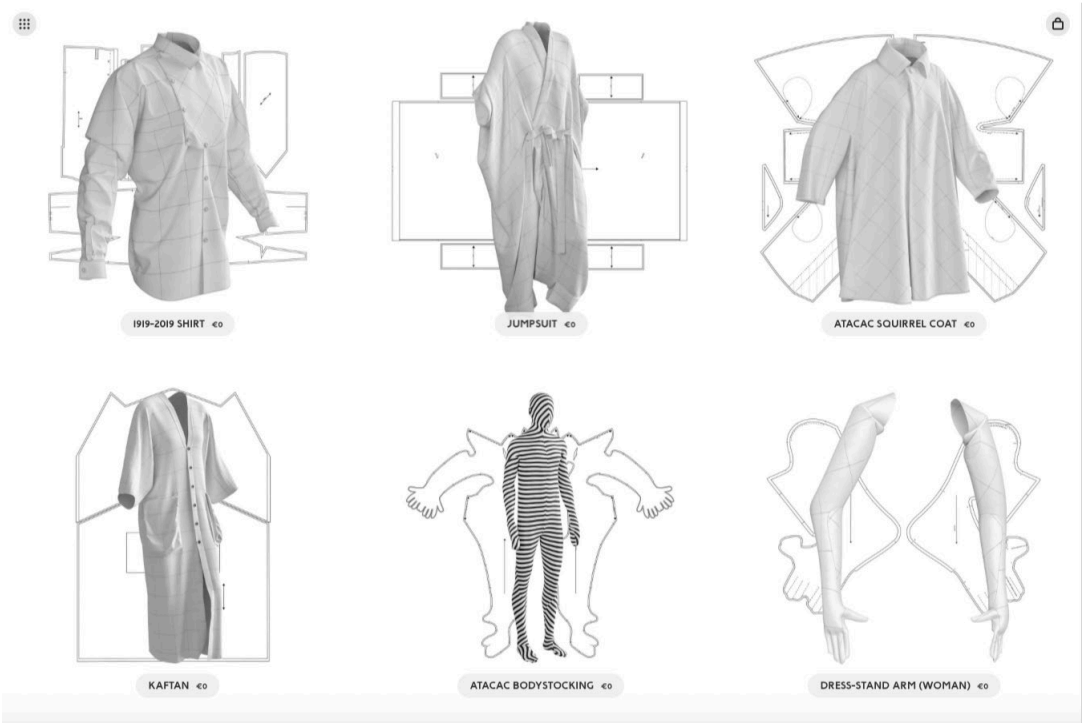

Figure 2 *Screenshot (2 December 2019) from Atacac's Sharewear online store (https://tinyurl.com/rt6lxmd), from where garment and pattern files can be downloaded for free or for a voluntary donation. The files are licensed under the Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) Creative Commons licence.*

4.2 Minuju

Minuju is a children's wear company with a personalized product-service concept that implements modular design through an online browser-based user interface (cf. mass-customization) and relies on on-demand production in their small studio. Minuju wanted to provide an ethical, sustainable and locally manufactured alternative to the traditional children's clothing supply, stemming from the finding that user satisfaction leads to longer product use.

According to the Minuju designer interviewed for this study, Nina Kyber, the name of the company comes from the words "*minun juttuni*", "my thing" in Finnish. Besides developing a pioneering business and service model based on iterative user research, also the materials and modules had to be developed and productized from scratch. The selection was reduced to two qualities, seven colours and five garment types. Reduction was also applied to the fashion element to achieve timelessness. Minuju aimed at simple and multifunctional solutions, such as a triangle piece that can be transformed into ears or spikes. Effort was put into designing the *modularity* in detail and into the garments as interfaces, entailing a service design approach. There was an emphasis on the high quality of garments and the realism of visual representations. No ready-made sample collection or inventory were produced – only a stock of *ready-cut* pieces that were sewn together on order.

> "We didn't want to produce for the sake of producing, but to make something more sustainable. […] It's sick how much unused, unpurchased clothing ends up as waste […]. We didn't want to make anything that is not needed, we only produce on demand. Because of the modularity, the waiting time is not that long; it's not tailored in this sense." (Kyber, 6 May 2019)

Minuju was founded by the economist Elina Ibounig, who developed the service system concept together with Kyber, an experienced clothing designer. Kyber's input focused on visual and technical implementation, garment module development and user research (Kyber, 2017). Both founding members had to learn coding in order to upload the garment module images and maintain the platform. The designer's role thus expanded widely beyond clothing design. Kyber believes that her long experience as a children's clothing designer helped significantly, because she had an idea of what people look for in the sector. Minuju was very popular at events, and yet its sales were low.

> " […] they wanted to make the purchase decision immediately. But when we gave them flyers and said that you can design this at home and order online, the customers disappeared on that journey."

The company is currently on hold for financial reasons, but the founder and designer have not lost faith in the business and are looking for someone to take it over. Kyber believes that a further simplification of options and possible in-store assistance might be the key to success, in addition to a skilled marketing professional.

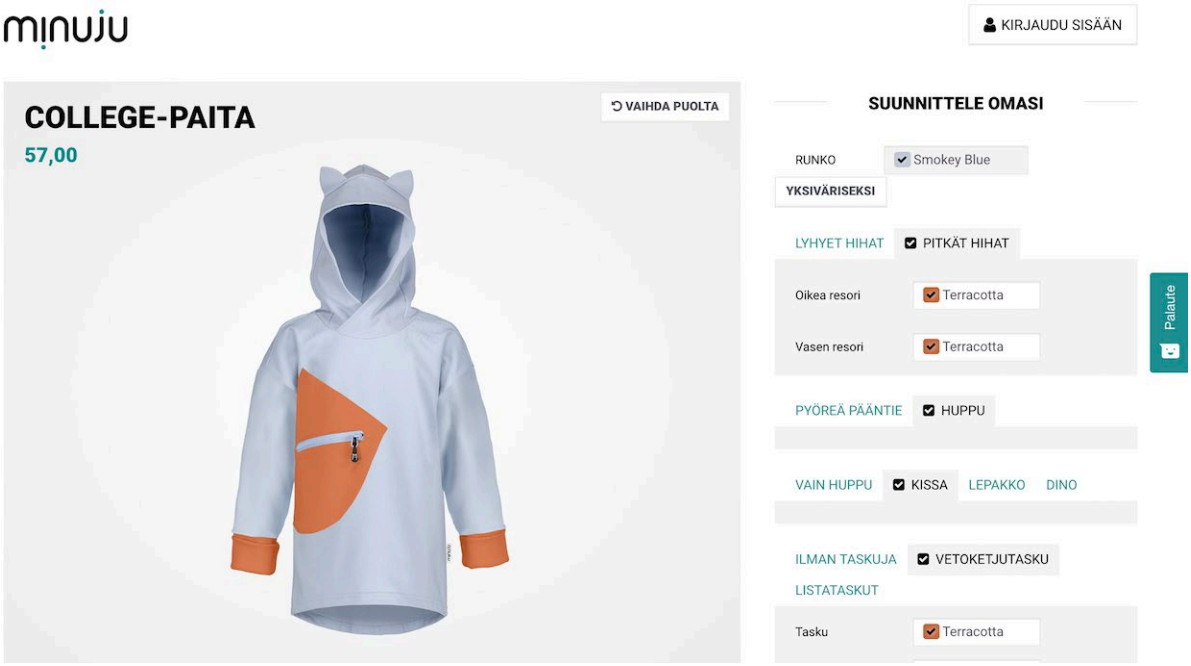

Figure 3 *Screenshot (30 April 2019) from the Minuju web store and product/service user interface (https://minuju.com/products/).*

4.3 Self-Assembly (S-A)

Founded by the Finnish fashion designer and doctoral researcher Matti Liimatainen, Self-Assembly (S-A) is a clothing label that makes "ready-to-assemble garment construction kits" (https://self-assembly.fi/). The production method and design philosophy resemble those of Post-Couture Collective, but coupled with a strong element of automation. The designer wants to combine post-industrial (digital) and pre-industrial (handmade) production by involving users in the assembly phase of garment-making. The products have special seams based on a loop-and-hole system, enabled by algorithms developed by the designer. The garments can be assembled by hand, without tools, machinery or any garment construction skills. An assembly manual is included in the kit. The pieces are laser-cut at Liimatainen's small studio using a self-built open-source laser cutter, and are sold as a component pack. The garments can be reassembled and the pieces mixed into new colour combinations or even garment designs.

> "This idea of construction kits came from the time when I was creating a lot of paper prototypes at the studio because I had paper and a printer […] and the flow would be interrupted if I wanted to have prototypes made by someone else in a sewing studio […] This laser cutter replaces the printer […]." (Liimatainen, 27 June 2018)

Liimatainen is also working on a new project entitled ITSE, which he envisions as the "Lego" and "IKEA" of Finnish fashion thanks to its modular self-assembly nature. The next step is to start a crowdfunding campaign in order to ensure the product-market fit and to establish a direct dialogue with customers.

Liimatainen's academic research focuses on generative design development, applications of graph theory and automation of different phases. He creates algorithms and codes for each piece, shape and garment, using bottom-up programming language. Provocatively questioning the idea of ownership in fashion, Liimatainen's ultimate goal is to create a garment designing and producing machine that requires no human input or economic profit. In order to computerize the rules and tacit knowledge of fashion design, the developer must understand the mechanisms behind design conventions. For Liimatainen, automation augments the human input and eliminates mundane tasks, freeing space for creativity. He hopes that his automated system can serve professionals and non-professionals alike. Thus, Liimatainen's work is in line with open design, which is rooted in providing instruments that allow users to become a "one-man factory, the world player operating from a small back room" (Stikker, 2011, p.17).

Liimatainen believes that his *combination of fashion designer expertise and software development skills* is both the strength and a prerequisite of his work. He is only able to spend 10% of his time on developing S-A, however, as his day job is to lead a team of fifteen designers at a Chinese apparel company, and the income from S-A is not sufficient to live on.

Figure 4 *Small self-assembly studio with self-built open-source laser cutter (left) and an S-A cap showing the special seams. The mailing package has laser-engraved instructions (right). Source: Natalia Särmäkari.*

5. Cross-case analysis

5.1 Elements of open source

The following open-source themes were drawn from literature and identified from the case studies. Themes were used to assist in the comparison between the empirical cases, to answer the question of *whether* and *how* fashion designers' professionalism and authorship are contested.

Table 1 Mapping the elements included in each case study

Case	Trans-parency	Sharing free blueprints	Customi-zation / co-design	On-demand produc-tion	DIY / Self-assem.	In-house production / Rapid prod.	Together-ness
S-A	X			X	X	X	
Minuju	X		X	X		X	X
Atacac	X	X	(X)	X	(X)	X	X
	sharing know-ledge & social resp.	code distribution	authorship shared with non-professio-nals	Custo-mized produc-tion / two-way	user empow./ partici-pation	(digital) fabrication laboratory	horizon-tal team-work, commu-nity

All the cases rely on transparency, but Atacac takes sharing the code one step further, as they also share their patterns for free, enabling DIY production and modification. All three cases are similar in terms of the combination of digital and analogue fashion design and in their production methods, as they primarily produce in-house and on-demand using either traditional equipment (Atacac and Minuju) or digital rapid manufacturing (S-A). While Atacac bases its designs on kinetic pattern theory, S-A and Minuju rely on garment modularity. The user experience in customization and the service aspect are at the core, especially of Minuju's business model but equally of S-A's assembly process. However, gamification and playfulness are regarded as a key to success.

All of the case designers pointed out the importance of *making* clothes in their lives or professional backgrounds, and they all had solid work experience before starting their businesses – either in independent design (Atacac and S-A) or industrial clothing design (Minuju). All three have a strong vision, both aesthetically but also on conceptual service and production model aspects. They emphasize the *appreciation of fashion and dress as culture*, to which they want to contribute by inviting non-professionals to the behind-the-scenes processes. Minuju and Atacac developed *open-ended design* that is customizable before production, and S-A offers an *open-ended garment* that is customizable after production. *Internal and external synergies* build the feeling of social togetherness in the cases of Atacac and Minuju, whereas S-A contrasts with them as well as with the conventional fashion design processes by collaborating only with machines.

Three main themes behind the *how* were identified: (1) dialogue and open-ended products; (2) own fabrication laboratories; and (3) visionary craft-based designer expertise. The third theme points to the importance of the habitus and embodied knowledge (Bourdieu, 1993b) of professional fashion designers, as it enables them to move beyond product design on a meta-level of fashion design (cf. metadesign, Fuad-Luke, 2009, pp.151–152), where user involvement and horizontality become possible.

5.2 Drivers and limitations

Drivers and limitations were further drawn from the empirical data to answer the questions of *why* and *to what end* fashion designers contest the traditional authorship and professionalism conventions.

All the case studies highlight the idea of defying the *traditional* fashion paradigm by developing an *alternative paradigm* of how to make and sell clothing. Their work is based on experimentation and development of unprecedented operational processes. Their new approaches have raised vast interest and media attention. Every case underlines the *importance of transparency* of their operations, *longevity of their products* and overall *sustainability values*. Construction of clothing based on given blueprints and modules augments the user experience dimension of clothing consumption – or "prosumption." An anti-commercial attitude is observable, as the cases operate on the outskirts of the traditional fashion system. The cases accent the importance of clothing construction, the culture of design, and apparel as a service and a means of self-expression. All cases find it crucial to stand behind their work, even at the expense of financial well-being (cf. McRobbie, 1998).

The impetus for the alternative open-source fashion practices comes down to the accessibility, attractiveness and affordances (see Norman, 2013, pp.10–13) of today's digital technology from both the designer and user perspectives. In the case of S-A, the designer's software skills and automation system allow for assembly without any tools or skills. Minuju and Atacac rely on online platforms, where visualization of garments and user-friendly software are crucial to the user experience (Ulrich et al., 2003; Fiore et al., 2004; Wu et al., 2015). Atacac, in particular, accentuates the authenticity of virtual representations provided by Clo3D, which are not only an image but also a container of garment data. The software inspired the creation of the company in the first place.

The main problems across the presented cases are *marginality* and the current lack of actual proof of concept, scalability and solid revenue models. All the cases earn their living from external clients (freelance design and consulting work). They await further (affordable) technological advances and cultural transformations, for example in the self-confidence of non-professionals who, at the moment, do not sufficiently appreciate their own work. Certain problems have also been identified with open-source fashion in general, related to the economically, socially and culturally privileged position of active, networked and tech-savvy users; to the risk of exploitation and negative free-ridership; and to concerns around the degradation of expertise and poor-quality products as an outcome of "post-democratic" mob rule (de Mul, 2011, p.39). Despite its inclusive intentions, open-source fashion might create involvement where none is needed, resulting in user exhaustion, development of ethically questionable products, and a loss of privacy. The sharing and transparency culture can also be criticized for "panopticism" (Vallor, 2016, p.188; Foucault, 1995).

Four main themes behind the *why* and *to what end* were identified: (1) research-based alternatives to traditional fashion system with frustration as a driver; (2) the social turn and

environmental values with professional ethics as a driver; (3) technological UX, its enablers and limitations; and (4) marginality and problems with openness.

6. Conclusions

The aim of this paper was to contribute to the discussion on the transforming dimensions of authorship and professionalism by exploring a set of technologically enabled alternative fashion design practices that involve users in design and production processes. “Open-source fashion” was used to refer to the design philosophy behind such fashion practices.

The empirical evidence collected for this study supports the premises found in literature regarding the *drivers* behind open-source fashion practices. Deriving from a frustration with the traditional ways of designing and making clothing, particularly their environmental and ethical aspects, each case was inspired by new digital opportunities to re-think business models in fashion. Their purpose was not to abandon professionalism or give up authorship, but rather to propose strategies that *elevate* the conceptual and ethical standards of fashion design towards greater *autonomy* from the conventional fashion system, and to *update* the fashion field into the digital age. Facilitated by external disrupters – the technological tools and “grand narrative” of digital culture – the old jurisdictions of fashion design were replaced (Abbott, 1988, pp.91–94). Internal disturbances did not destroy existing jurisdictions, but both strengthened and weakened them, resulting in new stratification systems (ibid., p.96; Bourdieu, 1993a). Far from de-professionalizing, the deauthorization of fashion designers can be seen as an act of *professionalization*, raising the *ethical and technical standards* of the fashion field. By *authorizing* users and promoting open collaboration, in contrast to the industry’s secrecy and protectionism, open-source fashion design explicitly or implicitly represents the social turn in fashion, where underlying processes become more important than a professional aesthetic authority. Thus the industry evolves from “closed” into “open” professionalism through a revolutionizing act by “newcomers” (Bourdieu, 1993b). Distributed, open authorship requires a shift in our cultural perception of the author function and of authorship as an embedded “principle of specificity” (Burke, 2008, p.194). Open-ended design cannot offer a closed object or one-way information flow, nor can it be controlled. The designer designs the design process, as well as the action and interaction spaces.

All the presented designers use their traditionally acquired embodied skills and have established their new, extended design processes upon their professional expertise and tacit knowledge. Current technology already allows non-professionals to gain knowledge, skills and aesthetic fashion sense, but the automation of tools and processes means that not even production needs as rigorous a skillset as before. Furthermore, virtual digital clothing would preclude physical production altogether, which opens new possibilities for professional and amateur designers and active users alike. Such developments provide a fruitful ground for future research on the transforming professionalism of fashion designers and the fashion industry as a whole.

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About the Authors:

Natalia Särmäkari is a Doctoral Candidate at Aalto University, Finland. Särmäkari's professional background is in fashion design and her research interests concern fashion studies and design research, as well as the digitalization and datafication of the field of fashion design.

Annamari Vänskä is Professor of Fashion Research at Aalto University, Finland. Vänskä is the Deputy PI of the consortium "Intimacy in Data-driven Culture", as well as PI of the WP "Intimacy, Creative Work and Design" of the Strategic Research Council at the Academy of Finland (2019–2025).

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A Curated Chronology: Traits of Electro-Energy from Research-through-Design Practices

Karthikeya Satish ACHARYA[a]*, Matteo CAMPINOTI[a], Mirko PRESSER[a]

[a] Aarhus University, Denmark
*Corresponding author e-mail: karthikeya.acharya@gmail.com
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Abstract: Over the past two decades a number of design-led projects undertaken on the topic of energy research have contributed to the research-through-design domain. We present selected studies from design and HCI undertaken as research-through-design on the topic of energy as a curated chronology. Four design practice-based research groups from different global regions engaging with energy related issues are discussed in a chronological presentation. Using descriptive analysis of these projects we interpret four specific traits of design for approaching energy as a design subject. The interpretation is presented through tracings of traits and are analysed in a sequence. Building such a curated chronology of prior projects we generate an approach for designing a relation building consumer reward system for a project on wind-based electricity production. With this we show that such a curated chronological approach can be interpretive and generative, complimenting and strengthening conventional literature reviews when undertaking research-through-design projects.

Keywords: research-through-design; energy studies; curation; design methods

1. Introduction

Since 1960s contemporary art and design practices in the West have raised energy-related issues. These have been towards, political action, activism, community engagement and also for academic interest(Beuys et al., 2004; Coles & Rossi, 2013; Hemauer & Hemauer, 2013; Klimke & Scharloth, 2008). Within design research, the topic of energy, has gathered interest over the past two decades (Backlund et al., 2006; Dunne, 2005; *ECDC*; Pierce & Paulos, 2011). We have seen projects where the politics of electricity and its networks have been theorized by design(Dunne, 2005; Dunne & Raby, 2001, 2013). There have been programs where design practice has occupied a central position as an output of research that address energy issues(Backlund et al., 2006; Pierce & Paulos, 2010; Pierce & Paulos, 2013; Mazé, 2008) and a significant corpus of design studies from HCI has engaged with designing energy feedback for behavior change(Abrahamse et al., 2005; Froehlich et al., 2010; Holmes, 2007;

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Lau & Vande Moere, 2007)and categorized as involving either antecedent strategies (i.e. commitment, goal setting, information, modeling. Our interest is in a design led analysis of particular design practices that have undertaken research on the topic of energy. Before we proceed further, we would like to make a clarification regarding our use of the term 'energy'. While this term can be broadly interpreted, the scale of attention to energy issues by the design and HCI community has tended to tip more towards electronic and electrical related energy than towards other forms and mediums. Thus, when we use 'energy research-through-design practice' we refer to design practice-based research that are concerned with electrical energy use, its feedback, designing for electricity use as a technology and research that looks into the social and cultural implications of electromagnetic contexts as well. With that clarification, we ask how can we interpret the subject or topic of energy by analysing prior design-led projects that have undertaken research on this subject and how could such a process be further generative by design?

2. Tracing the Design Traits of Energy as a Chronology

Our response to such a question can be considered to be designerly as well. In what is to follow we present four sequential aspects as steps for producing a curated chronology which we consider to be our methodical stance with a designerly approach. With this while we present our particular subject matter relating to energy, it should also be seen as a clarification of the underpinning approach of how to arrive at a curated chronology and how this can be generative to further design.

As a first step we begin by identifying design projects based on the specific topic, i.e. in the case of our research we have selected academic design practices whose projects have engaged with the topic of energy. This provisions us to interpretively analyse how the entity of energy has been approached by them within their design-led projects. In terms of project selection we see this approach to be an act closer to curating an exhibition in a gallery or showroom so as to highlight particular characteristics of a design object (Durrant et al., 2017; Koskinen et al., 2012).

Secondly and essentially our approach to curation has a temporal component. This means the selection of design research projects on a particular topic is made by selecting projects in a temporal sequence of their undertaking. In the case of our research we have deliberated our selection of research-through-design projects dealing with the subject of energy in a chronological sequence. Thus, as a methodical consideration it is pertinent to be aware which projects and programs were undertaken in what year or decade, and these are analytically ordered on a time line, hence the use of the term chronology. Terminologically we have also taken inspiration from the book titled '*A chronology of energy and art related development*'(Hemauer & Keller, 2013). As a methodical arrangement such a chronological sequence is also purposeful. We utilize the sequence for both, analysing the energy component and also such that the sequential pattern is generative to further design.

The third step is to use both description and figures from the design-led projects to 'trace the

design trait' from concepts and objects from the selected chronologically ordered projects. By 'design trait' we mean, the primary characteristic of the topic (in our case that of energy) as approached and considered by the design practitioners in those particular projects. Design traits are the characteristics of the central focus or subject of the project. Gaver & Bowers (2012) discussing annotated portfolios mention of the myriad of choices that go into the design of any artefact. These could be functionality, practicality, motivation to socio-political concerns. These aspects can be considered when identifying traits that could be traced in a curated chronology. In this paper we literally draw a red line tracing the design trait of energy across chronologically sequenced projects from different academic design practices. So, the presented figures and the red highlighting on them are analytical in purpose. Thus in this step the treatment of the trait tracing and following it in chronological order is integral to both the analysis and presentation.

The fourth step after tracing is to be generative by using the sequencing of the trait from prior projects. In this paper we show this generative process by arriving at a concept for designing a relation building consumer reward system for a project on wind-based electricity production. With this overall four step procedure we demonstrate that while undertaking research-through-design projects producing such a curated chronological approach can be both interpretive and generative, complementing and strengthening conventional literature reviews.

In what is to follow in the next sections, our curated chronology begins by presenting a descriptive analysis of energy related projects undertaken by selected four design research groups. Through this process we interpretively distil and highlight four traits of energy as an entity from the design-led projects of four research groups. The interpretation of each trait is presented through a tracing of a design object or concept from the project undertaken by each group. These tracings are treated as traits of energy as approached by the design practices. Then the four tracings of traits from the design approaches are placed and analysed in a chronological sequential pattern. Following such a design-based analysis of prior practices, we present the conceptualization of an ongoing project for designing a relation building consumer reward system for a project on wind-based electricity production. We conclude with a discussion of our contribution to the research-through- design approach and the need for diversity in approaches for furthering energy research.

3. Academic Design Practices' concern with Energy Issues

The four design groups whose approaches to energy are considered in the chronology are from four different institutions. The logic of selecting these groups is that they all have three aspects in common. The projects from these groups are well cited within the academic design research community. Secondly all the academic practitioner groups' works lean towards the more humanistic and artistic approaches. Thirdly they all have undertaken design led projects on the topic of electrical and electronic energy. The order of presentation and the analysis of the research groups and their projects that is to follow next

is chronologically sequenced, i.e. from the earliest to the latest.

The first group from London, with humanist and artistic tangents has been popular for looking into electricity and energy issues through critical and design for debate approaches. The second group of design researchers from Stockholm have specifically addressed energy studies through design research programs with reference to critical practice and post-critical practice-based approaches. The third group of researchers in discussion were based in Pittsburg from the HCI community who have addressed energy-related issues through categories of design-oriented perspective in HCI and sustainable HCI. The fourth group again from London, who are known for their work on cultural probes and ludic design, are reviewed for a project undertaken on co-designing with energy communities. These four design research groups, their projects and programs dealing with energy, and their approaches to energy within these projects will be chronologically discussed next.

3.1 English Design I: For Debate (1999-2002)

Anthony Dunne's doctoral dissertation, *Hertzian Tales* (Dunne, 2005), led to the emergence of what today is considered Critical Design. Basing arguments on speculative design artefacts and their ability to mediate aesthetical experience this approach set in 'design for debate' approach(Kerridge et. al. & ., 2009). This work presented an ideology for product design practice that put social, psychological and cultural experiences as its basis, rather than being technological and commercially based. The portrayal of speculation carried out through prototypes, videos and imagery leading to discussions, reflections and debate spawned a new discourse within academic and artistic design practice.

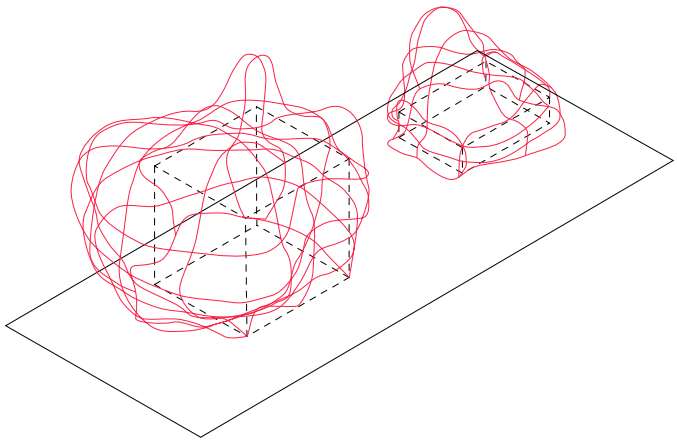

Figure1 *Tracing the Hertzian dreamscape: Radiating electromagnetic waves from a computer and fax machine*

Within the scope of this paper's argument, two initial projects from Dunne and Raby are considered. In *Hertzian Tales: Electronic Products, Aesthetical experience and Critical Design,* Dunne (Dunne, 2005) raises a critique of the aesthetic role of electronic products and indicates the invisible 'electrosphere' that electronic products and artefacts generate around

themselves. He presents the idea that electronic products hold a subversive aesthetical potential because of their dissipating invisible electromagnetic waves. He discusses his experimental process of measuring and drawing electromagnetic fields around electronic objects in order to arrive at an alternative vision of electro-artefacts. He refers to them as 'dreamy objects'. Presenting the design potential in the electromagnetic sphere through designed artefacts, he asks for a more meaningful social benefit than designing merely towards a commercial end. Dunne's thesis on design artefacts is referred in *Hertzian Tales* as 'sublime gadgets'. Through these prototypes, categorized as post-optimal objects, Dunne presented five conceptual design proposals. Each of these design outputs was considered as an interface between the electromagnetic environment of the Hertzian space and people. With these designed objects, Dunne's work raised questions about the technological realm and daily living than offering solutions to conventional problems. This approach from Dunne also got carried over to the next work, titled *Design Noir,* with Fiona Raby (Dunne & Raby, 2001). They again raised attention to the issue of invisible and hidden electromagnetic fields, taking forward the idea that electronic objects 'dream' in electromagnetic radiation. From these early works from a part of the English design academia, we distil 'dreamscapes' of electronic objects, the Hertzian space as the first trait of energy as a design entity.

3.2 The Swedish Shaping: Technology as Material (2005-2010)

The Interactive Institute at Stockholm is the second group whose body of work has approached energy studies through design practice. They mention the formulation of a program/experiment dialectic(Redström, 2011) approach that has provided their process with an alternative and design-led perspective on energy consumption. They also mention of programs that are based on "provisional knowledge regimes" (Binder & Redström, 2006), and position design practice centrally through conceptual designing, making artefacts and staging design interventions. Based on a critique of both modernist thinking and usability, the program has looked at technology beyond functionality and usability and addressed it as 'material', as something to be crafted and formed. Building on a range of critical traditions in design such as post-critical architecture, anti-design and critical design discourse, this program addressed two main interrelated concerns: materiality in design and in use. Three projects have been specifically aimed at energy use and everyday practices: 'Static!', 'Aware' and 'Switch! All have considered an aesthetic and material-based approach to everyday energy interactions, resulting in the presentation of a number of experimental everyday artefacts as examples of staging design interventions on larger urban scales. These artefacts and interventions have attempted to generate reflection and awareness on and through energy use. The design artefacts and interventions through the programs suggest finding and discussing problems rather than providing solutions, whereby design becomes a mode for critical reflection and for shaping a wider discourse.

The Swedish school's program begins by presenting, technology as material(Redström, 2005) and then also energy as material(Backlund et al., 2006). Redström has argued that designing in practice through material and form is different from predicting use, which is how

technology is conventionally understood(Redström, 2005). Redström's concern seems to be centred on the fixation of predefined ways of using and interpreting technology, which he critiques as leading to inflexibility. He is also of the view that electronic technologies have a discrepancy between their inner functional complexity and their surface, which fails to communicate the intended use. To overcome this, he presents technology as design material and asks us to think of technology as form and material rather than technology as prescribing functionality. For Redström, as a basis for design, as temporally forming elements, a material needs some kind of spatial presence through a spatial surface for presenting itself. With this argument, he recommends that computational technologies could also be treated as material that could be worked with in both spatial and temporal forms.

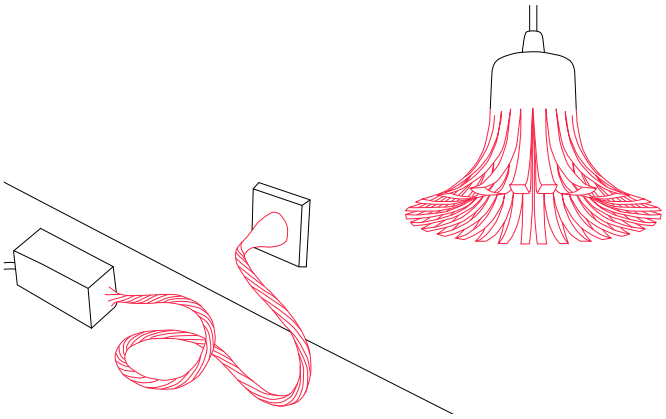

Figure 2 *Tracing energy as material for design: The Power Aware Cord and Flower Lamp*

Backlund and others(Backlund et al., 2006), writing on developing a program for design research and practice, have mentioned the expressive and aesthetic potential of energy as a material in design. They also have mentioned a type of design practice with strategies to invoke engagement for exploring alternative notions of the role, actions and responsibilities of designers. According to them, this results in a 'critique from within' design practice. In the same publication, the authors also present nine prototypes as poetic objects of everyday life and show how energy-related issues could be made more present through form. Eight of the nine prototypes are also interior domestic artefacts. However, these are not furniture pieces like Dunne and Raby's set in *Design Noir*. In *Design Noir,* the furniture pieces could be seen as movable domestic artefacts, able to gain focus on themselves, by being able to move and be taken into any room, by being pieces that centre visual attention within the volume of a room. The domestic artefacts from the Swedish school differ from the furniture pieces from *Design Noir* as they are more peripheral to the structure of the architectural home. These can be considered to be closer and tangibly connected to the wires in the wall of a home. Everyday objects such as curtains, wall heaters, power cords, wall tiles, cord connected lamps, the exceptional odd erratic radio and such domestic objects formed the set of prototypes from this initial energy related project by the Swedish school. In later projects with design interventions into everyday energy ecologies (Mazé, 2008), the program also scaled up, continuing with a material for design centred argument. Thus, to build the

chronology, energy as design material is considered as the second trait of energy, coming from the Swedish school.

3.3 The North American Schools: Sustainable HCI (2009-2014)

The topic of Human-Computer Interaction grew widely through the last two decades of the 20th century. With cognitive sciences, computer science engineering and usability as its foundations, it has been fast in borrowing approaches from other fields and disciplines.

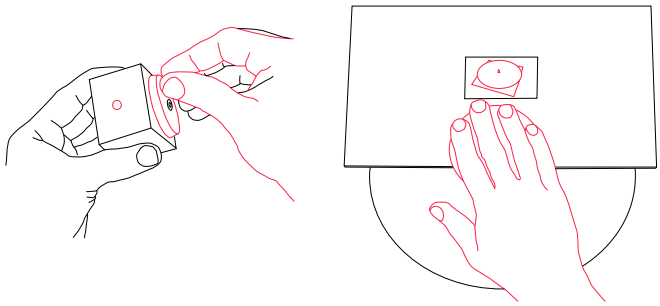

Figure 3 *Tracing of energy through the phenomenological body: Crank LED and Flywheel OLED display*

However, the emergence of sustainability as an issue, through design featuring in its discourse, can be considered to be recent in HCI when compared to the design academia. While approaches such as 'persuasive computing' to address habits and behaviours emerged in the early 2000s, it was in 2007 that Eli Blevis(Blevis, 2007) presented the view that sustainability should be the core semantic for interaction design, positioning it differently from experimental psychological approaches of persuasive computing. Basing his views on the perspective of design values, he defined design in his paper as "an act of choosing among or informing choices of future ways of being". The paper by Blevis set in motion the emergence of 'Sustainable interaction design', or the sustainable HCI approach. It particularly led HCI-based design practitioners to deal with energy use through design. In the same year, Zimmermann and others (Zimmerman et al., 2007) presented a model for research through design as a method for interaction design research. In it, building on various previous models and particularly on Frayling's(Frayling, 1993) model of research through design, they highlighted design practice and making as a method of inquiry. Then, other established researchers in the HCI field such as Paul Dourish also began to contribute, calling for a wider political basis and scaling for sustainable interaction design[15].

Amongst the American researchers the work of James Pierce with Eric Paulos has particularly dealt with issues of energy use through what they call a 'design-orientated' perspective in HCI. Their approach has tackled a range of energy-related issues such as design for awareness, design for feedback and examining energy use as a phenomenon in specific

contexts. They have also approached the issue through wider philosophical perspectives (Pierce & Paulos, 2010; Pierce, 2009; Pierce et al., 2010; Pierce & Paulos, 2011, 2012, 2013). Within this design-orientated perspective, this group's contribution has been particularly useful in reviewing energy use visualizations and feedback design, and in furthering the concept of energy as 'material'. After this the work from this group, too an everyday 'practice turn', moving away from the 'individual action' as a unit of analysis.

When positioning the work of American researchers of energy through design practice within the chronological sequence of practitioner groups for this paper, an article from Pierce and Paulos is of particular interest(Pierce & Paulos, 2013). In their paper 'Electric Materialities and Interactive Technology' they characterize electric technology in terms of three forms of materiality: as electric object, its electric materiality and electric power. In the project, their approach can be considered different from that of the previously discussed Swedish school. For the above triadic categorization, they draw particularly from phenomenology and present a set of bodily powered electric technology artifacts. Their intention with such a presentation they mention, is to amplify the difference between ordinary and bodily powered objects. Then they phenomenologically characterize the bodily powered objects with three themes. Firstly, because bodily powering such electro artifacts can be never without power, second that power of such artifacts can originate within the context of interaction and thirdly such objects invite bodily exertion and involvement. They present two sets of bodily powered prototypes; the first set is of four types of illuminating LED's and another set of two electric visual displays of OLED and e-paper.

Through demonstrations with these prototypes they argue that bodily powered technologies can expand electrifiable space, can engage through bodily involvement and then forge new relationships to electric technologies. Moreover, in their conclusion they mention that electricity cannot stand apart, on its own as an object, distinguishing themselves away from the framework of the Swedish school. From this work by Pierce and Paulos, their position of approaching electricity as energy through the phenomenological body can be interpreted. Such a position of reflecting on energy use as a phenomenon through the individual and experiential body can be traced to their prior works(Pierce & Paulos, 2010; Pierce, 2009; Pierce & Paulos, 2011, 2012). With the above case this subsection has interpreted the third energy trait from design practitioners from the United States.

3.4 English Design II: Ludic making Publics (2012-2015)

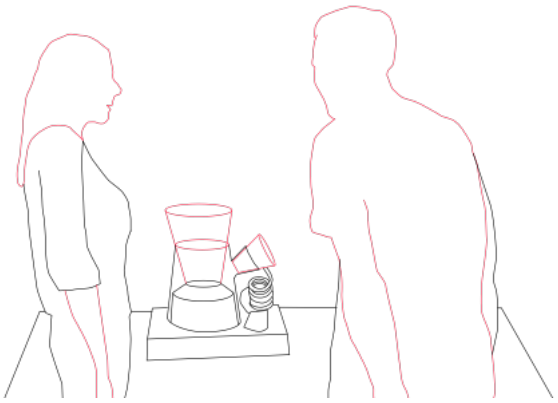

Figure 4 Tracing Energy Babble: Making the publics

More recently another team of English design practitioners has engaged in energy issues utilizing the route of co-designing with communities using fieldwork, workshops and probes(ECDC). They prototyped an automated talk radio service called Energy Babble to communicate about energy reduction with selected communities in South of England. Building on some of their previous approaches of cultural probes(Gaver, 1999), and ludic design(Gaver, 2009) they first engaged with designated communities in their local settings and brought in the participants' imaginative experiences into the design process. After this the team designed and deployed twenty-one prototypes of networked devices called Babbles into the natural settings of communities. The Energy Babble service, through online social networking platforms gathered and communicated energy issues to the designated communities. These were energy and related concerns from people, their devices, from online sources, communities and also programmed bots (Gaver et al., 2015; Kerridge et al., 2013). The group mentions of using technology as a basis for public reflection on energy as a political entity and also as a domestic metric. With such a service as a publicity platform that communicates about energy demand and reduction, this group's approach refers to their design of the Energy Babble for the construction of 'publics'. Referring to DiSalvo(DiSalvo, 2009), Gaver et.al, say that when design brings issues to prominence then it results in the formation of publics.

In this fourth case the trait of energy is interpreted as communicating about energy to form publics. What is further taken into consideration is that the design object uses an input from a variety of sources to communicate about energy issues. This includes humans, non-humans such as devices and appliances and the output generated as a voice through an algorithm does not make a distinction between the sources, if it has been given out from a human or non-human.

4. A Generative Chronology with Energy Traits for Design

From the four design groups discussed, the design trait of energy from the first group can be

considered to be the 'Hertzian dreamscape'. In the second group, the trait is of 'energy as material' for crafting and forming an object for reflection. With the third group, a relationship between the 'phenomenological body' and its experiencing energy was discussed. In the fourth case, energy issues are communicated and spread to 'form publics' by design. As a design-led approach, if these four approaches to energy are to be considered in their chronological sequence, then first comes the conception of the dreamscape, electro-magnetic frequencies emanating from electro-products, after that there is technology and energy get to be material to craft and form everyday appliances and objects. Thirdly a relationship of the electrical artifact and the experiential body is present. With the fourth case, energy related information creates publics. Thus, when considering the design traits of energy by the practitioners from 1999 till 2015, a movement can be interpreted whereenergy as an electro component moves from the dreamy Hertzian space, into an object of design, from there enters into the experiential human body and then moves out with voices of humans and machines, indistinguishable from each other, to form publics. Such a conception is entirely interpretive but based on a framework of analytical chronology sequencing of energy design traits, it becomes useful for generative purposes to further design. So, with such an aim then, what could be imagined next in this sequence after the making of publics? While much could be imagined to further such a sequence, we utilize the ongoing context of energy transition into renewables for conceptualizing an extension of the discussed sequence.

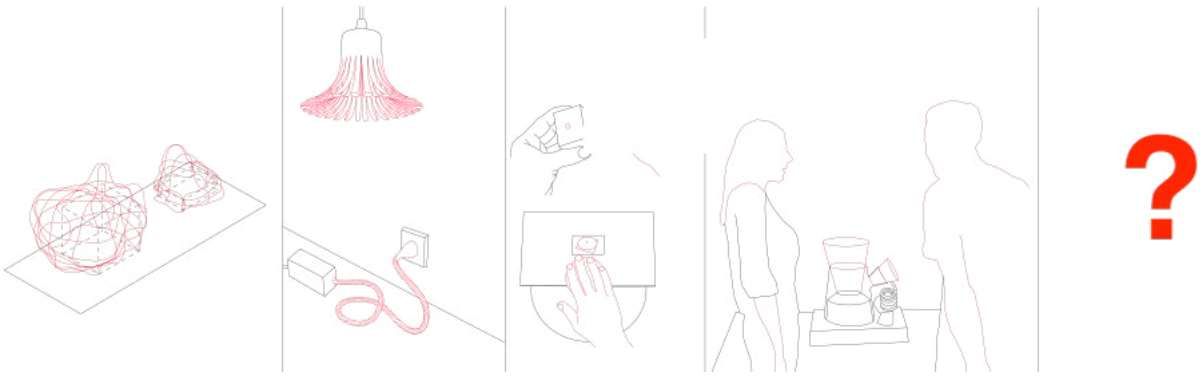

Figure 5 *A Curated Chronology: Traits of Energy from Research-through-Design Practices (1999-2015-)*

4.1 A Generative Design trait for Energy: Transition Shaping New Relationships

With the rise in renewable energy generation, with a sporadic spreading of decentralized power systems, the emergence of the prosumer and net metering where citizens with their own energy infrastructure are able to sell power back to the grid, digitalization of the energy systems, the emergence of more dynamic energy markets and many such ecological and technological changes are shaping a rapidly evolving energy transition globally. In such an evolving context we see a design potential of the information generated publics transitioning to a more dense socio-relational culture. The potential we indicate is that designing for the

energy transition can be made to shape new social relations on one side. Reflexively on the other side using design to shape social relationships between people can be made to foster the society towards a more meaningful and amicable energy transition. By shaping of social relations we mean the implications for the development of social relations between multiple roles and identities, like relations between family members, between neighbours, between communities living in blocks and scaling further to the neighbourhood and city scales. We see a potential for energy systems to matter at a socio-relational level between all these entities with a transition of energy systems. Building on the curated chronology discussed in this article, we have envisioned designing a relation building consumer reward system for a project on wind-based electricity production through a project conception. As design-led energy research our focus is to increase integration of renewable energy sources to balance the energy loads at the neighbourhood scale. For this we are seeking community and citizen led possibilities for collaboratively consuming energy based on the rhythm of wind energy production. Thus, our goal is to bring together neighbourhood communities, energy utilities and the local municipalities together to work towards questioning our future dependencies on fossil fuels and large-scale batteries for energy storage. With this we see a scope for business models with new community centric energy services building new relations.
Our project looks at initiating a longitudinal community engagement, wherein we inform households of time periods when wind-based energy production in a regional-level is more than the total electrical energy consumption within that region. During these periods of wind produced energy production if a minimum of two households or families, were to take care of their daily activities like their dishwashing, laundry, cooking, electric scooter and car charging then they gather points for a special cake and coffee together at a neighbourhood café. Within the project local communities would co-design such a points system that can show ways to manage renewable energy production and consumption in a collaborative way. With such a conception we indicate the potential of the energy transition to shape more collaborative and meaningful energy new services while shaping new relationships between families and households as units of the society. Here the design trait of energy is to not only provide wind-based renewable energy for utility but through its use but to actively shape and mediate new relationships between households at the neighbourhood scale. We see such a service description, built from and generated by interpreting the prior design traits of energy, fit well into the sequence of the chronology we have presented so far.

5. Discussion

In this article we have now presented a curated chronology by selecting projects from design and HCI undertaken as research-through-design on the topic of energy. As a methodical stance we began by clarifying our approach by presenting four steps and aspects for producing such a curated chronology. The four aspects being selection of topical projects, a chronological ordering of these projects in a sequence, tracing design traits with descriptive analysis and after this a generative procedure to further design. Following this, four design practice-based research groups from different global regions engaging with energy related

issues were discussed in a chronological presentation. Using descriptive and visual analytical means from the selected projects we interpreted and traced four specific traits of design for considering energy as a design subject. The interpretation of the design traits was presented through tracings and these are analysed in a patterned chronological sequence. Building such a sequence of a curated chronology of prior projects we arrived at a conception for our project to design a relation building consumer reward system for wind-based electricity production. We see our service description brief fit into the sequence of the chronology we have presented this far.

With such a curated chronology our contribution is methodological for research through design projects. We indicate that such an interpretive and generative approach can be complementary to conventional literature reviews within research-through-design projects. Such an approach could strengthen the design component within design-led projects. Although there are also limitations when undertaking such an approach. Firstly, such an approach cannot replace conventional literature reviews, but should be undertaken to complement and embolden design-led analysis within research-through-design projects. Secondly, as seen within this article, when undertaking such an analysis, there is a need to be selective with projects and approaches, and thus the number of studies that get considered might limit the research to be comprehensive. Thirdly, as concerned with any research the very interpretive nature of analysis could sometimes result in an imprecise understanding of design research work of other practitioners. These risks and limitations could be overcome if such an approach were to be further developed by undertaking it within research-through-design projects that aim to tackle a variety of subjects and topics.

In our case undertaking the development of such an approach from a research-through-design position has been useful for looking at the subject of energy from a design-led analytical perspective. It has also allowed our analysis to be spread over two decades and has helped us interpret and build on prior research-through-design projects on energy. It has also provisioned a generative streak into our approach. With this we hope to contribute to both, to the methodological corpus of research-through-design approach and also provide a diversity in approaching energy studies.

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About the Authors:

Karthikeya Acharya undertakes energy research through design practice. He currently serves as a Design Provocateur at the Interdisciplinary Centre for Digital Business Development in BTECH at Aarhus University, Denmark.

Matteo Campinoti is a software developer working on digitalisation at the Interdisciplinary Centre for Digital Business Development in BTECH at Aarhus University, Denmark.

Mirko Presser is an Associate Professor in Digital Business Development. He is Deputy Centre Director at the Interdisciplinary Centre for Digital Business Development in BTECH at Aarhus University, Denmark.

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Signs of the Time: Making AI Legible

Joseph Galen LINDLEY[a]*, Paul COULTON[a], Haider Ali AKMAL[a], Franziska Louise PILLING[a]

[a] Lancaster University, United Kingdom
*Corresponding author e-mail: j.lindley@lancaster.ac.uk
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Abstract: Artificial Intelligence (AI) is becoming widespread. There are many benefits associated with AI, but it's adoption brings challenges relating to fairness, bias, and transparency. Such issues are particularly hard to address because conventions that highlight when an AI is present, how it works, and the consequences of using are not yet established: AI has a legibility problem. Design-led research can play a key role in exploring this challenge. Applying Research through Design (RtD) this paper explores AI legibility in three ways: (1) explaining why it makes sense to address AI legibility with design; (2) the presentation of prototypical icons designed to enhance AI legibility; (3) experimenting with how the icons may be used in the context of signage relating to potential applications of AI. Via these three lenses the paper argues that design's role in improving AI legibility is critical.

Keywords: artificial intelligence; design fiction

1. Introduction

Humanity's fascination with artificial life is long-lived, appearing in ancient mythology (e.g. Galatea, Talos) and more modern fiction alike (e.g. The Creature in Shelley's Frankenstein, HAL9000 in Arthur C. Clarke's 2001). Arguably, however, it was Alan Turing's seminal research question "Can machines think?" (Turing, 1950) that gave rise to the field and the technologies that we now call AI. In the 70 years since Turing posed the question, AI has experienced cycles of inflated expectation and troughs of disillusionment. While the ethical and technical complexities of Artificial General Intelligence (AGI) remain as ontologically challenging as ever, the AI field has developed an array of powerful computing techniques including Neural Networks, Expert Systems and Machine Learning. Facilitated by a growing abundance of data, cheap computing power, and advanced data science, these techniques—in particular Machine Learning—have become come widespread. Whilst these AIs excel at pattern recognition and prediction tasks, we have not created any 'thinking' machines, however, there are plenty of reasons why we should put time and effort into thinking about them.

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The AGIs that appear in fiction love, live, and fight. These emotive characteristics belie how mundane most applications of AI actually are. AI has become key to national strategies (cf. Hall & Pesenti, 2017; Industrial Strategy, 2017). This is not because super intelligent AGIs are likely to emerge in the near future, but rather that the significant disruptive economic potential of AI has begun to be realised. In light of this we might cast AIs as innovation engines which are fuelled by data, and given this fuel is abundant and cheap it is no surprise the engines are running apace. Notwithstanding the prevailing rhetoric that AI is a proximate future, or 'just around the corner' (Lindley, Coulton, & Sturdee, 2017), applications of AI are already ubiquitous. AI features are integral to activities such as shopping, dating, banking—even the simple act of typing using a predictive keyboard (as in a smartphone).

These ingredients combine to make a cocktail of problematic aspects relating to AI. First, the disconnection between AI's popular vision of intelligent robots, and the reality of faceless and non-cognisant algorithms, is rhetorically dissonant. This reduces the legibility of devices and services which use AI (Gill, 2016). Second, AIs reflect the data which they are trained on, and those datasets are often unrepresentative, inaccurate or biased (Amershi et al., 2015, 2019)—qualities reflected in the AI's trained on them. Third, despite a variety of efforts to make AIs explainable, for most of their users they remain 'black boxes' (Ananny & Crawford, 2018; Ribeiro, Singh, & Guestrin, 2016). Nonetheless AI is employed all around us; AI, and the data which define them, are palpably altering the world in which we live (Lanier, 2013; cf. Morozov, 2013).

In this work we adopt Research through Design (Frayling, 1993; Gaver, 2012)—forthwith 'RtD'—as a means to explore the challenge of AI's legibility. RtD is an apt framework to AI legibility with for several reasons. Prior research and efforts to make AI legible are interdisciplinary. Meanwhile the Design's inherently integrative and generative character (Cooper et al., 2018) provides an opportunity to combine salient aspects of different disciplinary approaches through practice. Issues arising from the adoption of AI form a multifaceted challenge, but it is one that Design-led research is uniquely equipped to deal with by meaningfully combining the theoretical and technical attributes of AI with human-centred and social concerns, and transmuting these varied perspectives into accessible, tangible and novel insights. Integrating the design and research processes through RtD provides a unique opportunity to reify AI's challenges, testing, triangulating, and integrating disciplinary-diverse perspectives. With this in mind it is important to consider that the designs presented in this paper are intended for a research audience as an instrument of RtD, as opposed to design proposals that we intend to be immediately ready for a lay audience or to be adopted in the wild. Operating in this context, RtD processes apply specific design constraints to what Buchannan refers to the "fundamental indeterminacy in all but the most trivial design problems" (Buchanan, 1992). Exploring expansive problem spaces, allowing conception of problem and solution to co-evolve, RtD is uniquely well equipped to make sense out of the overwhelming scope of the problem space. In the case of this research the part of the problem space we explore is the legibility of AI systems and our constraint is to do so by developing a visual language for enhancing AI legibility. We elaborate on both

the concept of legibility and the rationale for developing a visual language in the subsequent sections.

The paper proceeds as follows. In section 2, we have an introduction to different forms of contemporary AI, a brief overview of interdisciplinary AI research programmes, and some notes on what we mean by AI legibility. In section 3 we discuss existing iconography relating to AI and situate our project in relation to semiotics. Section 4 introduces our designs, explaining the design process for the icons and subsequently deploying them in the context of public information signage. In section 5 we conclude with a discussion of the RtD process, highlighting contingent findings, limitations, and future research.

2. What is AI anyway and why should it be legible?

In order to acclimatise readers who are unfamiliar with AI in this section we situate the paper with a brief history and discussion of the state of contemporary AI research. By supposing that the process by which humans learn involves logically processing available data—something which computers do with aplomb—Turing's seminal work became the grand challenge of AI. To achieve the challenge, we'd just require the relevant data, and knowledge of how the learning algorithm works. The famous Turing Test (or 'Imitation Game') was posited as a means to test whether or not AI had been achieved. The game goes thus: in a conversation if a human cannot determine whether they are talking to another human or a computer then we have achieved the grand challenge of AI and proven that, yes, computers can 'think'. Aspiring to pass this test has been a key driver of AI innovation, however it is also somewhat problematic, it suffers as a result of what we term AI's 'definitional dualism'. On one side of this dualism we note the ubiquitous use of AI techniques in narrow use cases—these machines do not think. Meanwhile on the other is the fact that these the techniques were developed in an attempt to create AGI—machines which do think. Although this has been productive, resulting in a many very effective computing techniques which we call AI, at the same time the historic connotations of the term AI evokes un-realistic perceptions and mean that AI is judged by unrealistic criteria (Hayes & Ford, 1995), ultimately resulting in a dangerous rhetorical dissonance (Cave & ÓhÉigeartaigh, 2018).

Confounding the definitional dualism of AI, further factors make a clear delineation of what we mean by AI even harder. The recent proliferation of smart speakers and voice agents (e.g. Siri, Alexa, and Google's Assistant) which are routinely referred to as 'AI', thus evoking the image of an intelligence in one's house (when the reality is that they are fairly rudimentary devices utilising AI for voice recognition) highlights this. Elsewhere Apple's 'bionic' chip is described as dedicated AI hardware, and Huawei highlight AI as a unique selling point in their recent handsets, yet in each case, what is really going is a conflation of the two sides of the dualist equation. Notwithstanding the hyperbole of AI's dualism, for the vast majority of the paper we will be dealing with the mundane and non-fantastical form of AI which ubiquitously exists today.

With AI's dualism codified and the field's history acknowledged, we have still not proffered a

simple explanation for what we mean by AI. This is because such a reductive account doesn't make much sense; there are in fact many interrelated techniques, use cases, and applications which are referred to as AI. While reviewing all of these, and their relationships is beyond the scope of this work, here we aim to give a pragmatic sense of the space by considering its history.

In the 1950s much effort was put into 'symbolic reasoning' an approach which encodes a hypothesis into logic, generating a tree which can then be searched algorithmically. This was thought of as a model for human reasoning. The approach, perhaps inspired by the Turing test, was applied to understanding and synthesising natural language. Later, in the 1970s AI met the physical world and researchers began to try and make robots which utilised AI. However, by the 1980s optimism around AI had subsided; while the various techniques were viable there was not enough available data, storage, or computing power to make them work properly. Around the same time 'expert systems' became popular. Rather than building search trees based on logics and hypotheses, these systems encoded human knowledge into much smaller decision trees. This negated the issues associated with storage and computing power, and in certain domains these systems were hugely successful. By the late 1990s and early 2000s, as predicted by Gordon Moore, computing power had doubled roughly every 2 years and modern computers were fast enough to properly run AI software. At the same time storage became much cheaper, connectivity (e.g. broadband, WiFi, 3G, 4G, etc) faster and more available, many everyday services were digitised, and the Internet of Things (IoT) became a reality. These factors together have precipitated a rapid and widespread adoption of AI. While a wide range of techniques and methods make up modern AI, perhaps the most significant is Machine Learning (ML). The family of techniques which make up ML allow systems to perform particular tasks (e.g. learning to recognise cats) by learning from patterns in data and ML has been so significant for AI that the two terms are now often used interchangeably.

It is the vagaries of ML which have given rise a raft of contemporary AI concerns relating to understanding bias (Rader, Cotter, & Cho, 2018), fairness (Cave & ÓhÉigeartaigh, 2018; Lindley et al., 2019), and transparency (Ananny & Crawford, 2018; Weld & Bansal, 2019). The gravity of these issues is such that they are attracting multidisciplinary research effort. For example, Human-Computer Interaction scholars are striving to develop guidelines for designing AI systems (Amershi et al., 2019), computer scientists are developing technical methods to provably quantify bias (Ribeiro et al., 2016), and emerging design theories such as 'More-Than-Human Centred Design' update our dogmas for a world where technology is entwined in with society (P. Coulton & Lindley, 2019) as well as a number of other dalliances between contemporary Design Research and Philosophy (Lindley, Akmal, & Coulton, 2020; e.g. Redström & Wiltse, 2019).

The interdisciplinary 'Human-Data Interaction' (HDI) field (Haddadi, Mortier, McAuley, & Crowcroft, 2012) is particularly salient for this work as it frames the concept of legibility. HDI proposes three tenets for understanding our relationships with data (and by extension our relationship with AI); agency, negotiability, and legibility. In HDI terms legibility is

quite distinct from transparency and instead refers a user's ability to comprehend how a system works. The agency aspect of HDI is concerned with the capacity for individuals to act, for example being able to decide not to participate based on comprehension. The final attribute—negotiability—explores the broader context in which agency and legibility may manifest, exploring the intricacies of 'societal contracts' relating to data or AI systems. These are expansive issues, but also have significant overlaps, however, in this paper we describe an RtD project which explores the challenge of AI legibility. In addition to combining aspects of the aforementioned AI research, the work also responds to the current lack of legibility for iconography that is currently associated with AI.

3. Iconography and AI

From religious imagery to calligraphy, iconography is a broad term, in this paper we use it to describe the small graphics used in computing to represent programs, features, or options (cf. Ferreira, Barr, & Noble, 2002)—icons. In order to understand how AI (and related concepts such as ML and Neural Networks) tend to be represented we searched a variety of image repositories for icons representing AI. It was evident that definitional dualism is echoed in the image libraries; there is a wide range of brain-like structures, robots, and a proliferation of imagery which evokes conscious, feeling, or thinking machines (see figure 1a, 1c, 1d). There was also a lack of imagery which explains how AI works, or what context it is working in—with two notable exceptions. Neural Networks are commonly depicted as layers or networks of nodes (see figure 1a), to an educated reader this may indicate something about how a particular AI works, however even this gives rise to new questions (e.g. how many layers does the network have, what data are processed, is it an adaptive network?). Similarly, some icons, provide the reader with information relating to the domain of use. In the case of figure 1b we can easily determine that the AI is used to enable facial recognition (however, we have no idea what sort of AI-enabled machine vision system is in use).

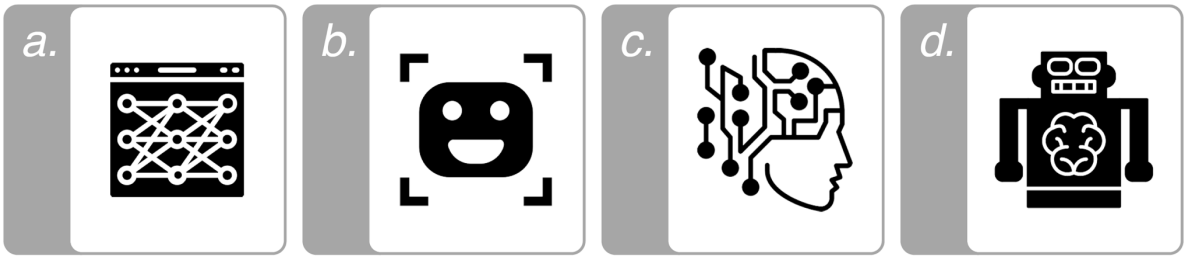

Figure 1 Examples of AI iconography.

Research into icons is diverse; classifying the icon purpose (Ma, Matta, Cahier, Qin, & Cheng, 2015), deconstruction of icon elements (Gittins, 1986), evaluation metrics for intuitiveness (Ferreira, Noble, & Biddle, 2006). Frequently research intersects with semiotic theory such as the Peircean triad. The triad comprises the representamen (a symbol used to represent an idea, e.g. a 'folder' icon); the object (the actual construct being represented, e.g.

individual 'files' organised into a 'folder'); and the interpretant (the sign's implication, e.g. all files in the folder can be moved around together). These constructs are used together to deconstruct different categories of sign (Ferreira et al., 2002). Indexical signs are those where the 'signifier' is the result of the concept appearing on the sign (e.g. smoke signifies fire); symbolic only have meaning by convention (e.g. a 'stop' sign); when the signifier looks like the signified it is described as an iconic sign (e.g. paintbrush tool in graphics software). While this semiotic view of icons is a handy conceptual lens, and provides us with a language to describe the icons with, in reality "is very rare, and some argue impossible, to find signs that belong solely to one category" (Ferreira et al., 2006).

The majority of AI icons have representamen which tie into the fantastical 'killer robot' side of AI's dualism—brains, robots, etc. Hence the interpretant is misleading. On the occasions when interpretant-clarity is increased the sense of the object tends to be sacrificed (e.g. figure 1b is clearly about facial recognition, but with no sense of how or why that system works). Whilst category-mixing is normal in the Peircean view of signs, in the case of AI, the combination of category mixing and lacking conventions or cultural understanding mean that the majority of AI iconography at best indicative and at a worst misleading. These shortcomings in the current state of AI's iconography highlight the space that this RtD exploration seeks to occupy; a visual language for enhancing AI's legibility.

4. Sign Language for AI

Given the complexity of the issues which confound AI legibility we conceptualised our design challenge as developing a visual 'language' for AI, made up of individual modules which can be combined to develop meaning. The design process we describe here broadly falls into four phases. First, drawing upon prior AI research we identified several key concepts that are relevant to AI legibility. Second, we explored how those concepts may be represented in three different visual styles; a pictorial style, a textual style and an abstract style (see figure 2). Third, we focused on a single one of the styles (the abstract style) and iteratively redesigning icons to develop the core concepts of the visual language. Fourth, inspired by 'Design Fiction' (cf. P. Coulton, Lindley, Sturdee, & Stead, 2017), we began to speculate around what regulatory and social changes would be necessary for widespread and sensible adoption of the icons. Figure 2 describes each of the key AI concepts which we incorporated into the visual language and shows how each one manifested in terms of the three visual styles.

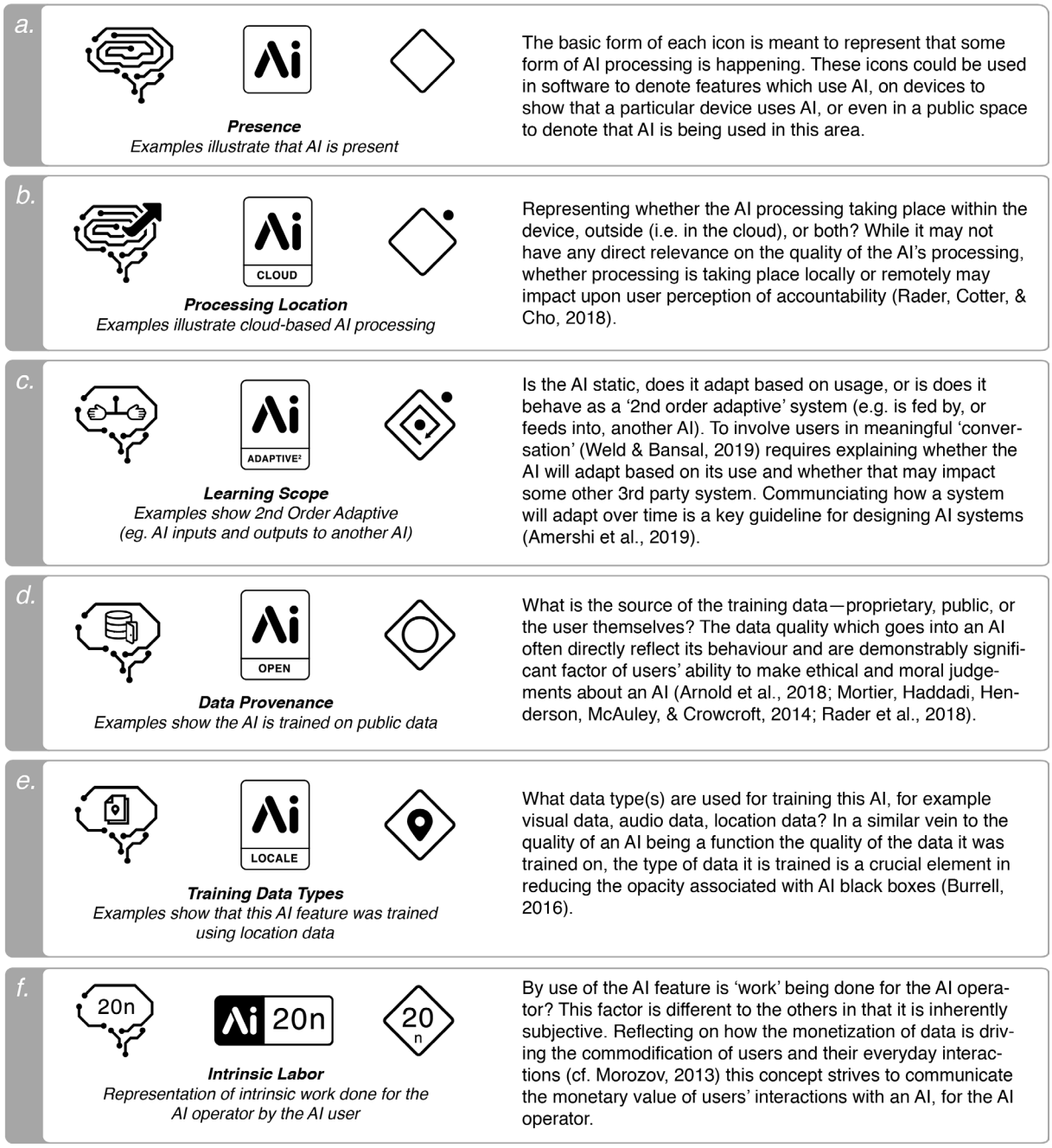

Figure 2 Key concepts for visual AI language.

Whilst the AI concepts we chose to work with could never be an exhaustive account of salient AI issues as shown in figure 2, each concept directly relates and contributes to an ongoing area of AI research; accountability (Rader et al., 2018), transparent adaptation (Amershi et al., 2019; Weld & Bansal, 2019), data bias and quality (Arnold et al., 2018; Burrell, 2016; Mortier, Haddadi, Henderson, McAuley, & Crowcroft, 2014), and broader issues relating to social agency and power (Morozov, 2013).

For each concept, figure 2 shows three design approaches. The first (pictorial) design uses a familiar trope of AI iconography—a brain depicted as a network. While clearly problematic

in terms of upholding the issues associated with AI's dualism, the brain motif is a symbolic sign and therefore effortlessly carries some (limited) meaning. The second (textual) design employs typography, and whilst also symbolic (i.e. it has no intrinsic meaning), we deliberately combined a branding element (e.g. the 'AI' symbol) with a more communicative element (e.g. 'cloud-based' AI, see figure 2b). When adopted such imagery (e.g. Fairtrade, the Conformité Européenne—or CE—safety mark) it can become a powerful element of behaviour change (Blythe & Johnson, 2018). The third (abstract) style draws on a design language which hybridises symbolic, indexical, and iconic signs. Whilst some element of convention is necessary to understand these abstract signs, once the core elements of the language are understood this approach has the potential to be interpreted meaningfully (per indexical or iconic signs). For example, if the reader knows that a small dot represents the AI, then a small dot outside the icon represents remote, or cloud-based AI, whereas inside would represent local or edge-based AI (see figure 2b).

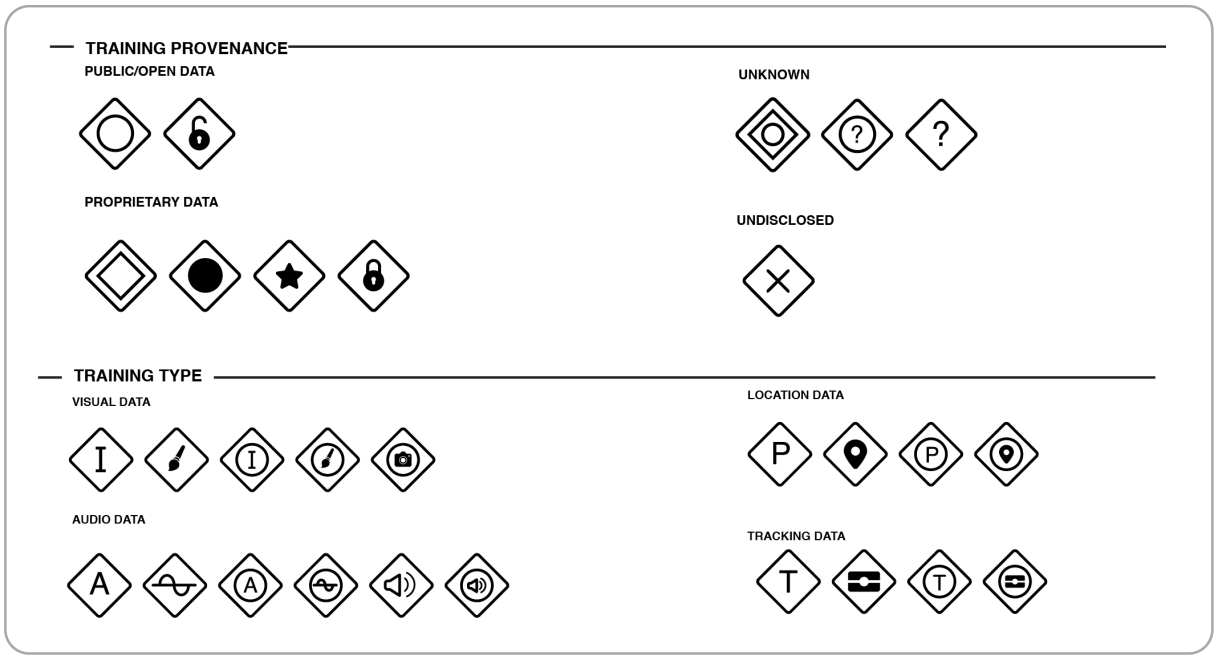

Figure 3 Design iterations of the abstract icon style.

A further exploration of the first two styles will become part of a future co-design research project, but for the purposes of this RtD study we elected to iterate and further develop the third style as it offered the most scope to explore the boundaries of what a visual language for AI could offer. The abstract style offers a unique flexibility, allowing a combination of indexical, iconic, and symbolic elements. The most challenging issue with this approach is how to construct a meaningful grammar about salient elements of AI such as the relationship between data sources, data types, training types, and outcomes. The final iterations of our designs began to address these factors by developing key aspects of a language. For example, 'dots' represent AI processing (figure 4a), 'triangles' represent AI learning (figure 4b), and relationships with data are denoted by an icon inside a circle (figure 4c, 4d).

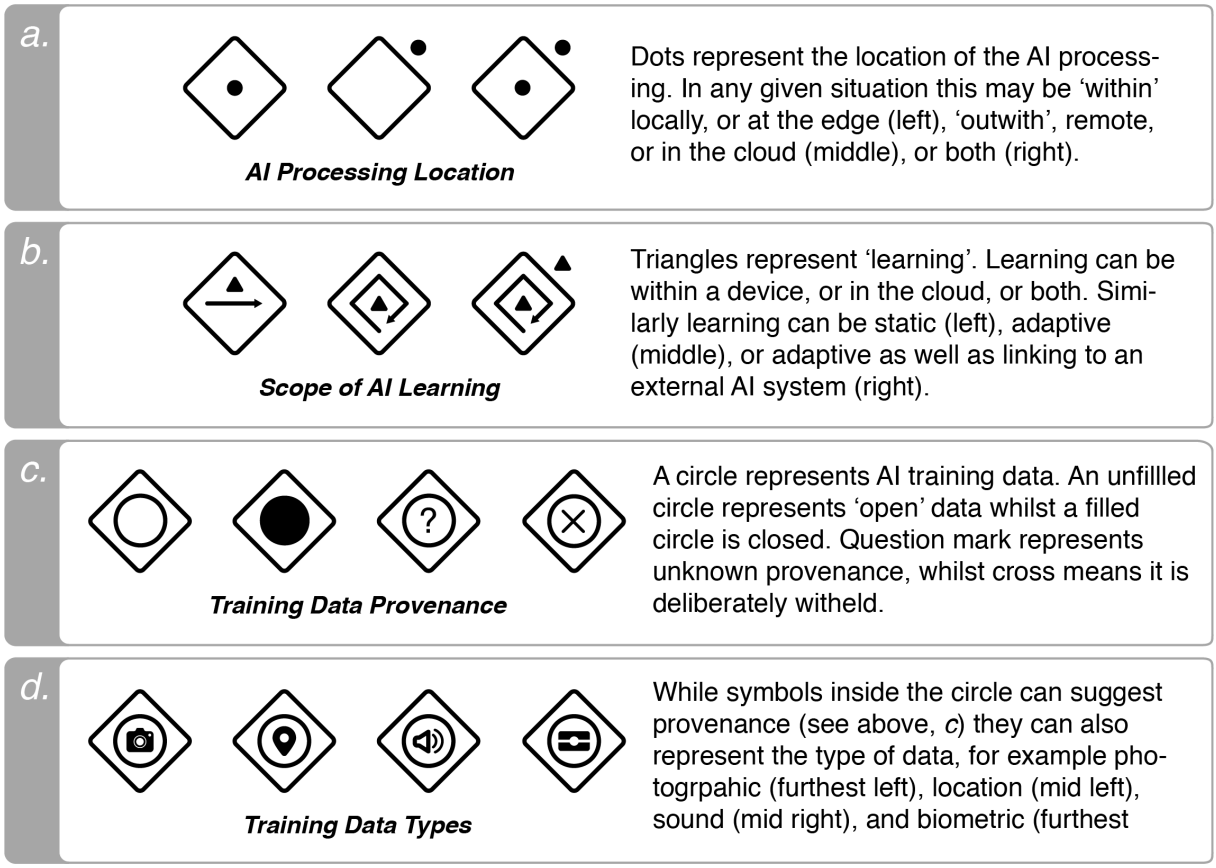

Figure 4 Final iterations of the abstract icon style.

While a study to assess the icons intuitiveness (e.g. Ferreira et al., 2006) and evaluate different designs will produce useful insights and is planned for future work, in this paper we are interested to explore how AI icons may be utilised through practical applications. In order to do this, we employ Design Fiction as World Building. This approach utilises speculative designs as 'entry points' into designed imaginaries (P. Coulton et al., 2017). In this case we build upon the icons discussed thus far and incorporated them into information signs intended to show employees and visitors, in a workplace environment, how AI is used in several mundane contexts; for printing (figure 5), going to the toilet (figure 6), in a computer suite (figure 7), and with security cameras (figure 8). In the speculative world the signs were designed assuming that AI is used ubiquitously and that conventions have been established insisting that uses of AI are signposted in public—these attributes are alluded to in the signs themselves. Each sign follows the same layout. They are cast as generic 'Data Protection and AI Indemnity Notices'. Each one incorporates configurations of our icon designs, used modularly to describe how that service utilises and interacts with AI. Three text-based elements on each sign describe how the AI services use data, what sort of processing takes place, and how users might opt out of the AI altogether.

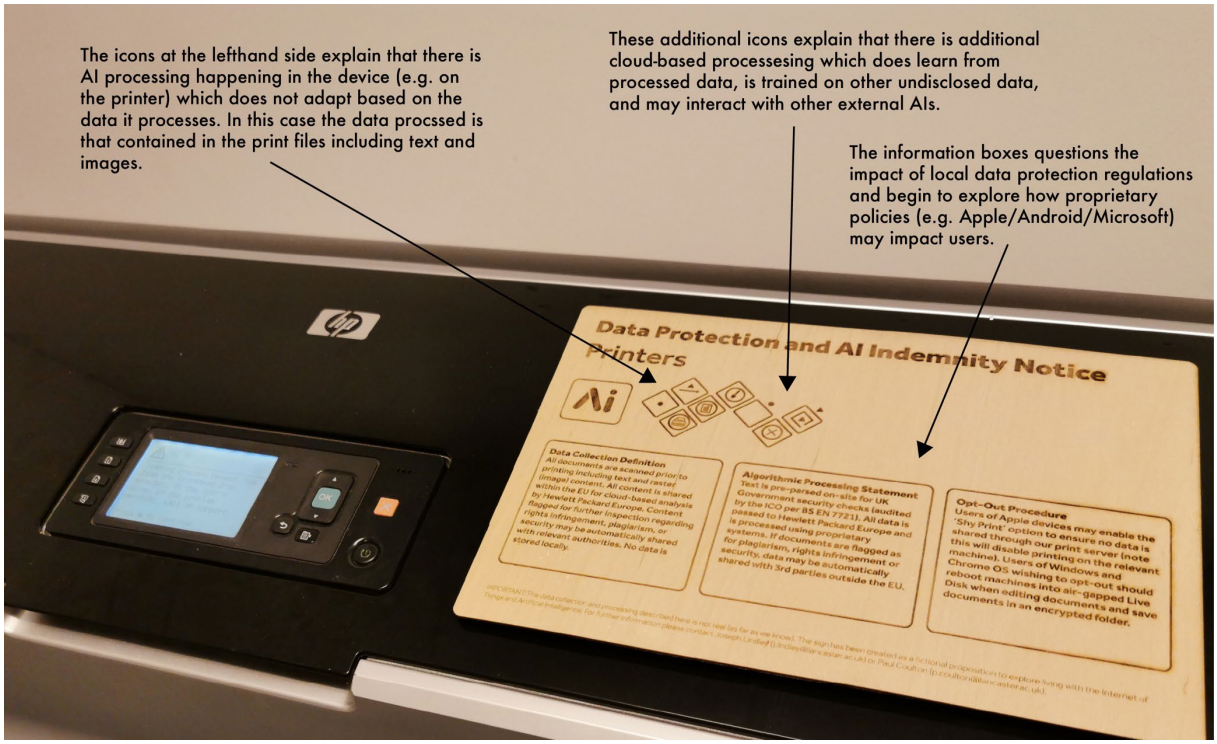

Figure 5 *Sign attached to a printer utilising AI for various purposes including plagiarism checking and copyright protection.*

This printer depicted in Figure 5 evidently sends *all* data that it will eventually print for processing by the manufacturer in order to be checked for copyright infringements. The notice informs us that *no* data is stored locally. A security check is also run before the data is passed, which appears to regulated by the Information Commissioners Office and a European standard, if content is flagged for further security or rights checks then it will be shared outside of the EU (and presumably would not then be protected by the EU's data protection legislation). The opt-out section demonstrates how different manufacturers can choose to implement the ability to opt-out differently, in this case Apple has made an easy to use feature (but if users employ it then they can no longer print), such provisions are not so accessible for users of other operating systems.

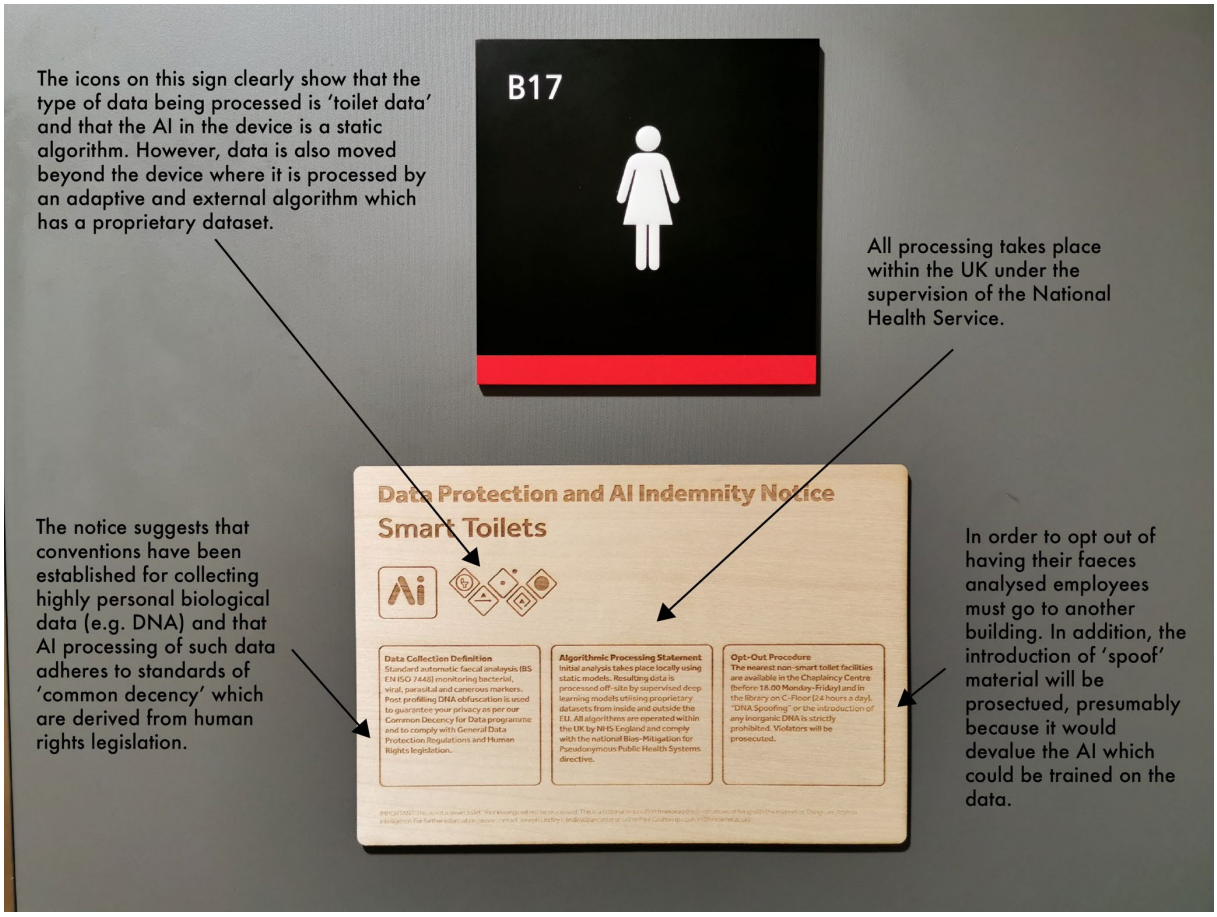

Figure 6 Sign on the entrance to toilets equipped with 'smart toilet' AI processing.

Figure 6 explores the highly personal concept of using AI to analyse DNA, as well as 'bacterial, viral, parasitical and cancerous' markers. The sign suggests that, although opting out is a possibility (protected by a legal right) it is practically hard to achieve for those wishing to use the toilet. The icons show that the primary processing not adaptive (i.e. the system's processing not adapt based on your leavings), however, it also shares data beyond which may be used in proprietary data and AI systems. This configuration may reassure users who consider the 'headline' icons (that the processing is linear and local) but could confuse others that continue to read the icons. It raises the need to explore how a 'grammar' may be used to provide the icons with more semantic nuance.

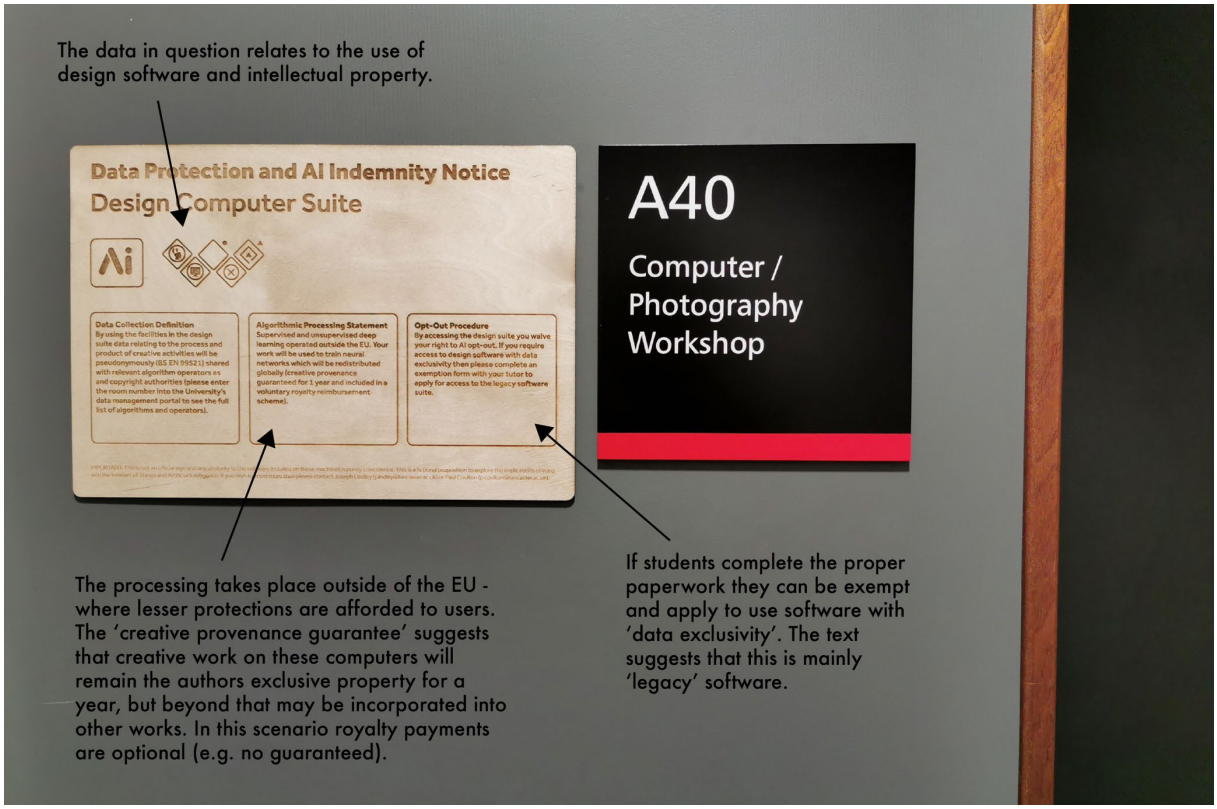

Figure 7 *Creative software packages, such as those used in the photography workshop, may be subject to AI processing as well.*

The relationship between AI and creativity will inevitably raise dilemmas around authorship and ownership. If an AI aids a creator in their work, does it deserve some form of credit? Conversely, if creative work is used to train an AI which aids in creative work, then should subsequent works which utilise that AI credit the authors of the training works? In this example the icons show how any work done in the computing suite will be subject to external processing of any 'intellectual' data, outside of any EU protection, and with no guarantees that derivative works will credit the original creator. As AI becomes more central to creative workflows, challenges around provenance and authenticity will grow. Our example signs are set in a University context; the dynamic between students' creative acts and intellectual property in Figure 7 raises the questions the prestige of institutions and the types of AI they employ. Would wealthier, higher performing, Universities have access to better and less intrusive AI systems?

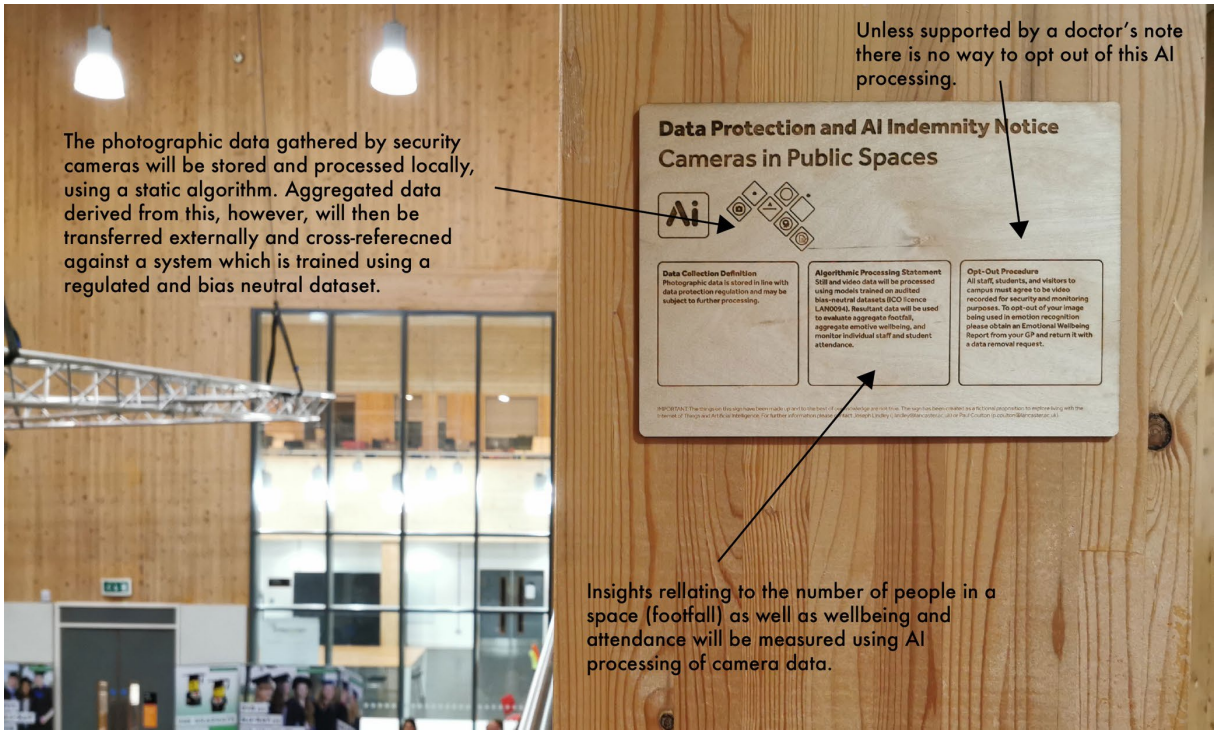

Figure 8 Security camera footage may be processed by AI in order to derive a range of insights.

The ubiquitous capturing and recording of our image is a fact of modern life. Mainly for security reasons most public spaces are under the purview of digital cameras. At the present time, for the most part, these images are simply archived for later perusal if needed. AI technology, however, would provide practicable means to utilise such images in more complex ways. From simply detecting how many people are in a space, through to understanding who is in the space, and the emotional state of those individuals—the array of insights that AI processing of photographic imagery can produce is immense. The sign in Figure 8 suggests that this kind of monitoring is not optional for employees of the organisation in question, or guests attending the building. The only occasion that an employee may apply to opt-out is if they have a doctor's note showing that the surveillance is doing them harm. Whilst there is clearly potential for positive uses of this data—e.g. to optimise the use of space and maximise employee wellbeing—such aspirations must be balanced against a sovereignty of the self. Although our relationship with cameras in public spaces is generally one of reassurance, as AI processing becomes viable, we may need to reassess how we make judgements about our image being captured.

5. Discussion and Future Work

As is common with RtD-based inquiry, this work aspires to produce contingent findings (Gaver, 2012). The spaces that RtD is adept at studying—in this case AI legibility—tend to be in flux, and hence any findings, whilst aspirational, should be interpreted relative to that flux. That is not to say that such findings are not useful, but rather that they are subject to ongoing interpretations—we suggest that the work presented here should be seen on

those terms. Moreover, the principal weight of the research is not carried solely within the designed outcomes, the process, or related literature. The insights, in fact, emerge from considering all three of these aspects at the same time, and the remainder of the discussion reflects on each of them. To that end we reiterate that the target audience for the designs presented in the paper are the AI and Design research communities. Whilst we are confident that there is some merit, in some of the signs, in their current form they are not intended for a general audience, but rather to being the significant task of utilising Design Research to strive towards legible, and responsible, AI innovation.

The volume and diversity of research into AI is representative of its existing and future impact on the world. However, the landscape is unbalanced. Whilst applications of AI continue to be adopted at a pace—largely driven by the private sector—the extensive efforts to develop frameworks, taxonomies, and social standards for the understanding and acceptance of AI a foundering. The difficulties around public perception of AI, which we cast in this paper as it's definitional dualism, confound this challenge. Design Research has key roles to play in both unifying aspects of disparate perspectives (e.g. synthesising both technical and social research) and also framing AI rhetoric in such a way that it reflects gravity and scope of AI adoption. Whilst the prevailing rhetoric places AI as a proximate future, in reality AI is here *now*. To that end, via both the desk-based and practice-based elements of this paper we hope that the unique and important role for design research has been highlighted.

This is early stage work, yet the process of designing and developing the icons and the signs has helped develop a range of insights which apply at various scales. The technologies depicted are all being actively developed, and as such the focal point of our enquiry was not so much the technologies themselves, but the reality which they exist within. In our reality, although the use of AI is quite intrusive (e.g. analysing faecal matter or scanning printed documents) the intrusion is conducted within a strict regulatory environment. The multiple authorities involved (e.g. information commissioners, standards organisations) and inter-related policies (e.g. healthcare legislation, data protection law, local organisational policies) make the otherwise intrusive use of AI seem more innocuous, however the practicalities of implementing such a complex regulatory environment are not insignificant. Similarly, an assumption within all of the signage we created is some kind of agreement, or didactic ruling, about what AI actually is—what classes of AI need to be regulated, and in what contexts? Should AI-based processing of printed documents in a workplace be held to the same standard as analysing employees' poo? In addition to the broader context that AI signs exist within issues relating to the minutiae of the problem also arose. While we focused on a modular and abstract icon design, the food industry demonstrates a huge variety of iconographic ways of communicating about the product; emblems and logos tell us whether food is organic, fair trade, vegan, all natural, high in protein, etc. Prior research suggests that in some circumstances the very presence of these signs reduces critical engagement with the issues the sign is addressing (Blythe & Johnson, 2018). Supported by our own experience of attempting to craft signs that were legible, we considered that even if a mandate for public signage existed, establishing if signs are efficacious may be a complex and ongoing task. To

draw upon the terminology tactfully offered by one reviewer of the paper, even if the signs are carriers of information how do we know if they are carriers of meaning—establishing this is difficult and may call upon a collaboration between design and other research communities. It would, perhaps, be through such a process that iterations of a visual language for AI legibility would move from being purely a research instrument to a viable or implementable product[1].

This research does not aspire to provide definitive answers to explicitly defined research questions, but rather provide contingent insights relating to the ongoing impact of AI's adoption. The contributions of this paper are multiple. First, by reviewing a range of AI-related literature we highlight the cross-sectoral and multi-disciplinary challenges that AI poses. Next we introduce the crucial integrative role of design-led research can play by making aspects of other research programmes tangible and providing a sensible framework to reflect on them. Finally, though the reflexive process of designing icons and signage aimed at AI legibility we begin to frame questions and pathways for future research. Ongoing work in this area must be multifaceted. Clear avenues include empirical assessments and iterative developments of visual cues to support AI legibility. Further speculative design work, incorporating participatory and co-designed aspects, will develop practical means to integrate AI research, helping create coherent research programmes out of disparate research projects and in doing so, help to develop research instruments commensurate with the challenges posted by AI.

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1 Note that, as eluded to by one of our reviewers, were such an implementation to be pursued cultural nuances vis-à-vis semiotics—which are currently entirely omitted from this study—must be considered.

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About the Authors:

Joseph Lindley is a Research Fellow interested in how Design Research can contribute towards radical-yet-responsible applications of contemporary technologies including Artificial Intelligence and the Internet of Things.

Haider Ali Akmal is a doctoral candidate and practicing visual artist. His research focuses on the intricacies of human experience as it relates to digital and physical interactions. His work combines Speculative Design, Philosophy, and Play as instruments of research.

Franziska Pilling is doctoral candidate with a research focus on Artificial Intelligence as a Material for Design and employs Speculative Design, Design Fiction and Experience Design to research alternative perspectives on Artificial Intelligence.

Paul Coulton holds a chair in Speculative and Game Design at Imagination Lancaster. Having allegorically achieved his goal of becoming the first Professor Applied Triviality he is curating a 'Caravan of the Future' in order to deliver research impact in hard to reach communities.

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Data Science for Service Design: An exploration of methods

Youetta KUNNEMAN[a]*, Mauricy ALVES DA MOTTA FILHO[a]*

[a] University of Twente, Netherlands, The
*Corresponding author e-mail: yj.kunneman@gmail.com
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Abstract: This research identifies the opportunities for data science to support the service design processes through explorative development of a guide to data science methods for service designers. Designers and their teams search for data science techniques from their perspective as designers, while current literature is fragmented and technical. The present research explores methods that can help designers get started with data science. It evaluates if the techniques meet the designer's needs and fit the design process with user-centred activities; as a result, the methods contribute to the diversity of the designers' methods toolkit. These methods increase the validity of user research, make hidden information accessible with specialised user research tools and help designers in their creative process through relevant resources, inspiration and/or an alternative perspective. Together these results encourage organisations to mature data science resources for design projects so that their services benefit from more informed designers.

Keywords: service design; data science; process mining; mixed methods

1. Introduction

Services are central to value creation (Vargo and Lusch, 2004; Grönroos, 2011; Secomandi & Snelders, 2011) and service innovation has a crucial role in economic and social development (Patrício, Gustafsson & Fisk, 2018). The growing consumers' demands and increasing complexity of technology puts pressure on service providers to improve the quality of their services (Spiess, T'Joens, Dragnea, Spencer & Philippart, 2014). Service design has the potential to foster the development of superior services experiences, supporting the value co-creating interactions between the service provider and user (Costa, Patrício, & Morelli, 2018; Patrício et al., 2018; Kimbell, 2011). The growing demand for service quality and technological advancements also puts pressure on the service designers, and academia and industry call for interdisciplinary methods to support the development of superior service experiences (Patrício, Fisk, Falcão e Cunha, & Constantine, 2011).

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Data science offers opportunities for designers, as it helps extract meaningful knowledge from data (van der Aalst, 2014) in a context where the amount of data from and about consumers grows - e.g., consumer-generated content (Xiang, Schwartz, Gerdes Jr, & Uysal, 2015). Discipline such as marketing (Murray, Agard, & Barajas, 2018; Tan, Steinbach, & Kumar, 2006), product design (Köksal, Batmaz, & Testik, 2011) and ethnography (Weibel et al., 2013) already apply data science quite extensively. Data science techniques have also proved useful for projects closer to service designers, such as, among others, mapping the customer experience (Bernard & Andritsos, 2017), and understanding social and economic behaviour (Xiang et al., 2015).

Yet, although these studies provide useful insights, literature is fragmented over multiple areas such as process mining (van der Aalst, 2011, Bernard & Andritsos, 2017) and natural language processing (Balazs & Velásquez, 2016; Poria, Cambria, & Gelbukh, 2016). Furthermore, to our knowledge, these studies are not specifically focused on service designers, nor they explicitly address designers' needs. Many design agencies, service designers and their teams look for ways for utilising these data science techniques from their perspective. This research aims to provide key information in an overview of when and how data science is useful to support the service design process. The explorative, qualitative research process resulted in a guide to service design methods based on data science techniques.

1.1 Research focus

This research brings service design and data science together to explore the possibilities and answers the following research question*: When and how can data science be used to support service designers?* The objective of this research is to help service designers navigate and select data science techniques for their projects. As such, it is essential that the research meets the needs of the designer and fits the service design process. More specifically, we refer to the difference between a technique as a way to execute (doing it right) and methods as procedures to achieve an objective (doing the right thing; Junginger, 2015). The data science techniques are addressed by this research on the feasibility and theoretical background. However, the focus of this research is how they apply as a method for designers to accomplish their goals.

Accordingly, this research (1) includes both academic and practitioners (i.e., digital agency Mirabeau[1]) perspective; (2) conducts an explorative and qualitative research from the perspective of the designer (e.g. test desirability); and (3) examines data science techniques/ tools, custom build projects and data experts (e.g. indirect use by tool).

1.2 Background

Service design offers a unique perspective to service innovation and development, focusing

1 Mirabeau is a digital agency with clients in multiple fields, such as B2B, finance, retail and travel (Mirabeau, n.d.), and practises (digital) service design.

on the service offering, and on the value co-creating interactions between the service provider and users (Costa et al., 2018; Patrício et al., 2018; Forlizzi & Zimmerman, 2013). Therefore, service designers model the holistic experience and the service environment (Yu & Sangiorgi, 2014; Zomerdijk & Voss, 2010), which contains social, material, relational elements (Zomerdijk & Voss, 2010; Kimbell, 2011). Service designers work typically with user-centred methods, where multiple stakeholders from different organizational silos collaboratively to-develop the design solution (Evenson & Dubberly, 2010; Stickdorn, Schneider, Andrews & Lawrence, 2011).

On the other hand, the growth and significance of data in our world is clear. Data is a valuable resource that produces new insights and competitive advantages because it originates from the customer (Witten & Frank, 2005). Data science embodies the fundamental principles that support and guide the extraction of knowledge from data (Provost & Fawcett, 2013). It is a tool for explaining data and making predictions. Data science contains mining techniques and contextualising fields (e.g. visualisation) (van der Aalst, 2014), and is the process of automatically discovering and describing meaningful patterns in big tabular data (Tan, Steinbach & Kumar, 2006; Witten & Frank, 2005) or data logs (van der Aalst, 2014).

1.3 Stakeholders

This research is aimed at the service designer that practises service design as defined in the previous section. They work for e service providers, its stakeholders and users with a solid base in the philosophy of human centeredness. We also include “digital designers” and other designers that deal with, for example, both service and interaction. Nonetheless, the presented techniques and methods could still be interesting for managers and other professionals interested in the techniques and methods of service design.

This paper acknowledges the differences between data roles, such as data scientist, data analyst and quantitative researcher. In this realm there are variations on the technical level and expertise. For example, the data scientist should have higher data management skills than an analyst (Davenport, Barth & Bean, 2012). The quantitative user researcher is not specified on this scale and is specialized on processing user related data. This paper will not elaborate further on the differences between these roles. The focus is on applying data sciences techniques in a broad scope from custom to indirect in a tool. Therefore, methods are not limited to the technical level of the data role; which role is desired depends on the method and available/required resources.

2. Research process

This research examines how data science can support service designers by mapping methods based on data science techniques through an iterative research process where both academic and practical designers were involved in user-centred activities (Saikaly, 2005). The research process alternated between converging and diverging activities and is divided

into three main phases: exploration, ideation and evaluation. Throughout these phases, the research explored the methods by emerging, splitting, merging, terminating and changing.

Figure 1 *Photo of the pilot evaluation workshop. The participant compared personal and data science methods.*

The first phase of the research, namely exploration, focused on the characteristics, possibilities and opportunities for the intersection between the fields of data science and service design. The goal of this phase was defining the research areas, understanding designers and data scientists, and creating a mental structure of the designers' needs and data science strengths. Key activities at this phase included shadowing, interviewing, and literature review.

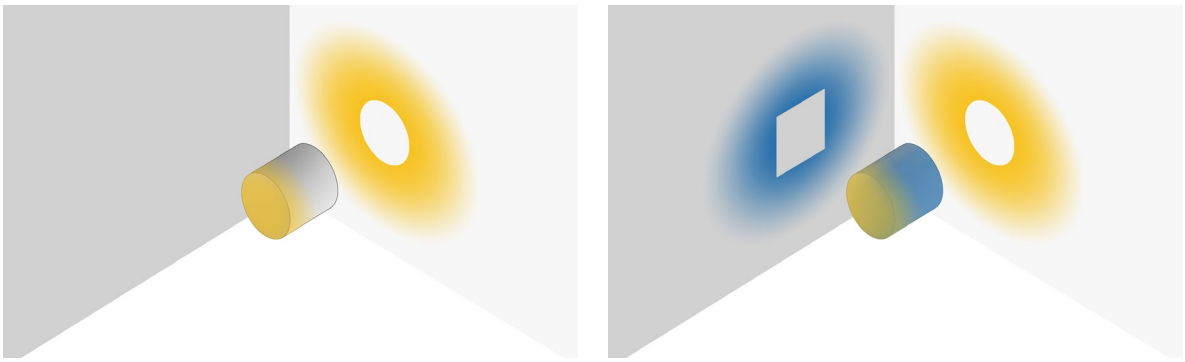
As the opportunities for the use of data science in supporting service design grew, they were pruned in the ideation phase, resulting in a guide to methods that use data science and collaboration. At this point, case studies and speculative cases helped to refine the ideas with the help of design practitioners. Main activities in this phase consist of brainstorm methods and feedback sessions with designers.

The evaluation phase aimed at testing the usability and desirability of the methods and gathering overall findings from the design research. Workshop sessions with designers (Figure 1), self-reflection, discussions and a panel interview substantiated this phase.

3. Service Design and Data Science

3.1. Opportunities

Most opportunities for data science to support service designers are based on providing easier, new or different sets of information. Designers use research and analysis methods to "organise, share, discuss and make sense of the data they collect to generate insights" (Costa et al., 2018, p165). The variety of methods is essential to support designers to achieve holistic and valid observations, and to ensure applicability and quality in a range of projects. Moreover, because every method has weaknesses and limitations, triangulation can help mitigate blind spots in the research process (Figure 2), increasing the reliability and validity of the findings (Jick, 1979; Creswell, Plano Clark, Gutmann, & Hanson, 2003).



Similar to a light beam, a single method reflects only one side.

However, method triangulation observes from multiple angles.

Figure 2 The reliability and validity increase with method triangulation.

Applying data science in a design context may provide new and advanced methods to the existing method toolbox of service designers. Service designers gain insights based on the combination of qualitative and quantitative information (Stickdorn et al., 2011). The data science techniques are mainly quantitative-based and complement with the designers' traditional use of qualitative methodologies. Next to additional quantitative analyses, data science contributes new perspectives to designers with another way of working. Various knowledge representations and learning techniques can result in alternative conclusions. The learning techniques make it also possible to predict or pick up seemingly small signals from the data or process large amounts of data.

3.2 Challenges

Changing the way of working in the organisation is a complex and difficult feat. This transformation can be assisted by a maturity model that identifies the steps in the process of embedding new methods (Corsten & Prick, 2019). This research proposes extending the service design maturity model of Corsten and Prick (2019) to the ability of combining data science and design in relation to methodology-independent stages (Table 1).

Based on these stages, the research identified three types of challenges: technical, determining business value and capabilities.

Table 1 Stages of the Maturity Model. Extracted from the Service Design maturity model of Corsten and Prick (2019).

Explore	**Prove**	**Scale**	**Integrate**	**Thrive**
This first stage is about trying the new methodology and starting the initiative.	The second stage should create evidence of value and lay the foundations.	Next, the capabilities spread outside the initial team and through the organisation.	This stage systematically integrates the methodology in the way of working.	Ultimately, the methodology ingrains into the company culture and pushes the field.

In the early stages (Explore and Prove), some *technical* data-related challenges arise, such as the lack of data availability, the data quality or access to the data. Furthermore, finding suitable data is a significant challenge since the needs and specific wishes of the designer change during the project process. In the Scale stage, the capabilities spread outside the initial team. Applying more and particularly more complex quantitative methods will demand different skills from the design team. Team members will need a shared knowledge base, and the user researcher might need additional skills in data science or quantitative research. Finally, throughout all stages, showing the value of the transformation is essential (Corsten & Prick, 2019). However, proving business value might be most difficult when the value still depends on individual projects.

3.3 Service Design Process model

The design process is a non-linear iterative process of diverging and converging. Although it is circular, different phases can be represented in a general structure (Stickdorn et al., 2011) similar to the double diamond model of British Design Council from 2005 (Yu, 2017). In this paper, we adapted the double diamond (DD) into the holistic double diamond (HDD). This adapted model contains two diverging and converging diamonds similar to the DD, but it also considers a broader timeline that supports mapping the data science methods for the service design process in a clearer way.

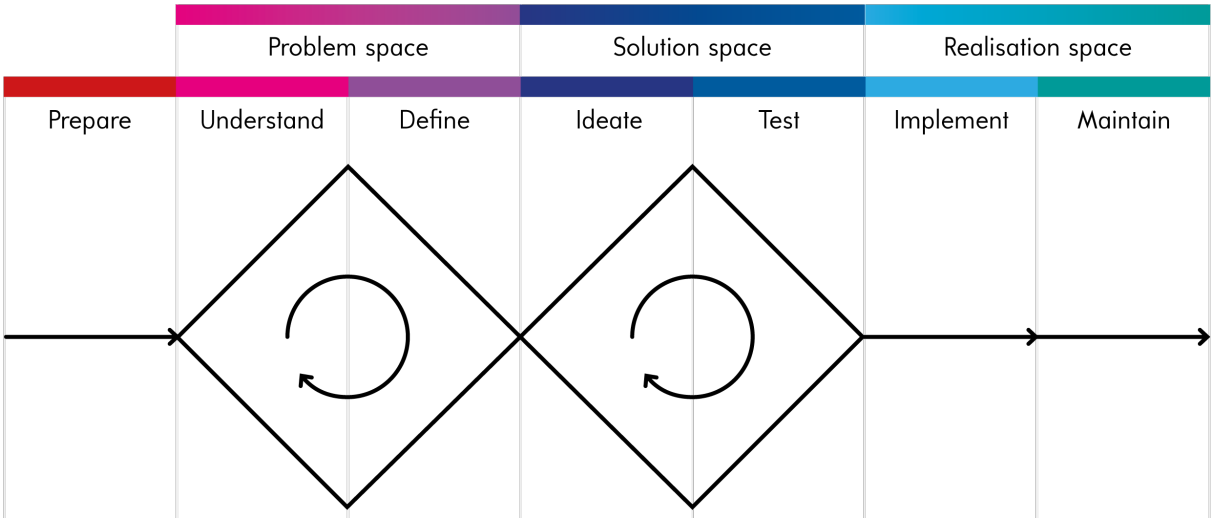


Figure 3 The Holistic Double Diamond model.

The HDD model places Implement out of the second diamond and accommodates an explicit Test phase. This research makes testing explicit to demonstrate the different needs and possibilities for designers. Additionally, ideation is a diverging process, while testing is not. Testing is converging, and the DD does not address this contrast. Secondly, the HDD includes the designer's activities and involvement outside the scope of the DD and similar models; the outer phases Prepare and Maintain.

Prepare: Prepare is the phase that involves the activities of the service designer before kickstarting the project, such as preparing the service design process and perhaps explaining what service design is to the client (Stickdorn et al., 2011). In this phase it is decided that and in which direction the project takes place. The main goal of this phase is preparing for the process and project, e.g. with pitches and stakeholder convincing.

Maintain: The end phase is Maintain, where designers continue assisting the services without starting a new project. After implementing the service concept, design activities take place to continue and improve the service. In this phase, the service is measured to learn and increment.

Table 2 *Design phases of the Holistic Double Diamond model. Horizontal axis: phases over time; Vertical axis:* **Phase***, description, phase in similar models.*

Prepare	**Understand**	**Define**	**Ideate**	**Test**	**Implement**	**Maintain**
This phase prepares the process and project so that there are directions and resources to start.	The designer explores the problem space for the true problem and creates a holistic view.	Findings from the analysis are concluded in the creative brief. The problem is (re)framed.	Concepts are developed with an iterative process for creating and refining solutions.	Testing is essential to evaluate the trials with prototyping, user tests and reflection.	The service concept is realised and launched.	This phase continues and improves the service(s) after implementing the service concept.
Kick-start	Discover, Analyse, Explore, Research	Frame	Develop, Generate, Create	Prototype, Reflect, Evaluate	Deliver, Launch	Optimize

4. Data science methods for service designers

Through practice-based design research (Saikali, 2005), this research explored how data science may support service design processes through the identification and analysis of concepts of data science methods for service designers. The methods are categorised into four groups: 1) user research tools, 2) analysing complex systems, 3) inspiring and insightful generated materials for serendipity, and 4) joining forces with data scientists in collaboration. Because designers experience different needs during a project, and data science offers new ways of providing insights, analysis, inspiration and collaboration. The methods connect with these different needs and excel at different phases in the design process which are discussed in Section 3.3. (Figure 4).

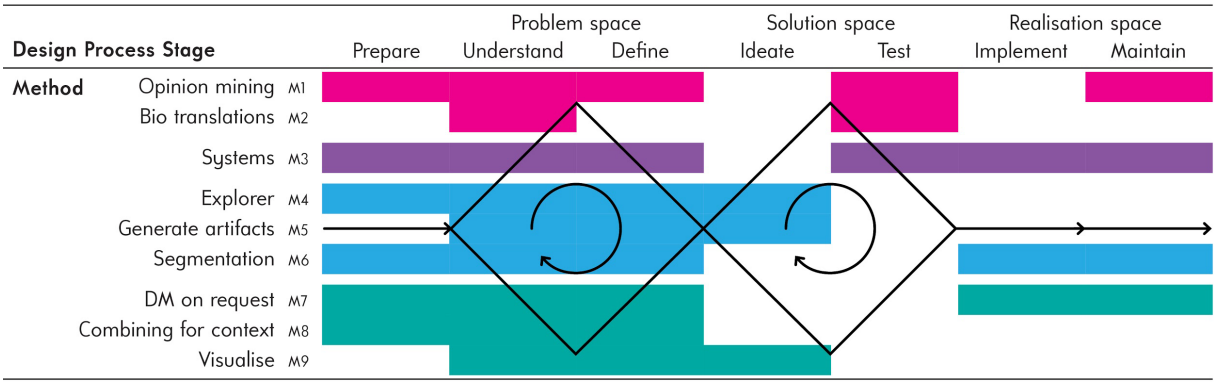


Figure 4 *Methods in the service design process. The most relevant phases of each method are highlighted. The design process model is a modification of the 'double diamond' by british design council in 2005 (Yu, 2017).*

4.1 User research

Data mining can make hidden information accessible to designers with specialised user

research tools, and therefore designers can measure more factors of users. For example, the following two methods (M1 and M2) can be particularly useful to uncover users' insights.

M1: *Opinion mining* analyses sentiment and correlations in consumer-generated content that is relatively easy to obtain such as social media, reviews and customer feedback. The method informs the designer about the users' satisfaction, frustrations and celebrations. For example, text can be classified as positive/negative and other emotional states (Balazs & Velásquez, 2016) or analysed for relations between extracted factors and ratings (Xiang et al., 2015). The advantages compared to interviews and surveys is that no explicit participants are needed, and the opinion is provided in a non-experimental setting.

M2: *Bio translations* is a group of research tools that analyse the inner state of users by interpreting (seemingly unmeasurable) signals. Depending on the recording device (from EEG to facial recognition), the technique can be noise sensitive or intrusive in use. For example, Zhou et al. (2017) used passive RFID tags and classification models to detect customer actions on clothing, such as pay attention to, pick out and turn over. This way, they detected how customers browse stores. During the evaluation workshop, an abstract layer with classified mental states was preferred over factual data.

4.2 Systems

Process mining can support designers to understand and test system models, such as mapping the actual and expected customer journey.

M3: Processing mining can generate, analyse and test models of complex systems such as the actual and expected *customer journey*. Designers can with this approach 1) extract information from the real world, 2) gain insight into the common and specific cases and 3) simulate environments through virtual models. For example, Harbich et al. (2017) extracted individual journeys from event logs of the daily activities of Chicago citizens to detect the most likely and also alternatives/divergent journeys.

4.3 Serendipity

Data science can help designers in their creative process through relevant resources, inspiration and an alternative perspective. The materials involved in the design projects (e.g. artefacts and insights) can be analysed for high-level or cross-domain insights or generated by machines.

M4: *Data-driven* techniques can assist with finding and exploring relevant patterns and resources from projects, clients and designers. Build into a data-driven system; designers can analyse their materials and insights for higher-level or cross-domain insights and spread knowledge faster through the organisation. The performance depends highly on the quality of the content. The system can be used for kick-starting, on-boarding, inspiring and data-driven design projects.

M5: *Generating (parts of) design artifacts* by machine learning helps designers with

inspiration, additional information or efficiency. It can produce an alternative perspective or autocomplete for prototypes, testing and personas. The difficulty with generating personas is defining their attributes and selecting the matching data sources.

M6: *Segmenting* can reveal patterns and form groups based on non-predefined characteristics. This provides an alternative view on the users or products because unexpected or previous unknown user behaviour can be found. The results as qualities (sexting correlates to user blocking[2]) and quantities (80% of users spend more than 10% of their total clicks on blocking events[2]) are useful for the designer as an insight but also evidence and foundation for non-traditional segments. The technique requires that the data is rich enough to capture underlying behaviours and prevent self-fulfilling prophecies. During the evaluation workshop, designers showed the most interest in behavioural- and emotional-based segmentation.

4.4 Collaboration

The design team can work together with data scientists more effectively with these collaboration methods that are not based on specific data science techniques.

M7: When collaborating in a team, the designer can *request information from the data scientist* in a broad sense (explorative) and for detailed information and validation.

M8: The effectiveness and meaning of data science techniques can be increased with the skills of service designers, such as to design value-creation and acquire a holistic view.

M9: *Visualisations* are a familiar tool for designers and service design has a highly visual approach (Costa et al., 2018). Relevant data can also be visualised for effective communication, organising, understanding, reasoning, decision making and displaying correlations (van der Aalst, 2014a; Costa et al., 2018).

5. Discussion

This qualitative, explorative study resulted in a guide to data science methods for service designers that contribute to the diversity of the designers' methods toolkit, and the main findings include:

- Integrating data science techniques requires organisational maturity.
- Data science techniques can increase the validity of user research with method triangulation.
- Data science can make hidden information accessible to designers with specialised user research tools and methods.
- Data science can help designers in their creative process through relevant resources, inspiration and an alternative perspective.

Together these results have the potential to enhance the methods toolbox of service

2 Segmentation insights from Whisper app by (Wang et al., 2016, p. 226).

designers and encourage organisations to mature their data science resources and capabilities for design projects. Service design and user-centred design fields can benefit from these developments, by becoming more informed about the users, stakeholders and applications. Furthermore, new challenges, employment and consulting for data scientists arise to support the advancing designers' needs.

5.1 Integrating data science and design projects

Integrating data science into design projects will change the roles within design teams and user research. Since a knowledge base on quantitative research skills is added to the team, they might need to acquire new specific (quantitative) research roles. The increasing diversity of skill sets will improve the available methodologies, but also requires a new way of working.

Furthermore, integrating data science techniques requires organisational maturity in data science. This will require investments and will lead to new opportunities for growing teams and companies. With the advancement of maturity, the availability and quality of data for service designers will grow and improve the designs they make. Addressing the maturity of clients is also essential for (design) agencies. Because they depended on the data and resources of their client, the agency can consult on data, data science and the integration with design.

5.2 Robust user research

More advanced user research tools become available, and design teams can create a better understanding of user behaviour and their inner states. Also, the implementation of services could be improved with a better comparison between the actual and expected journeys. Design teams should critically look at their user research and check if data science can fill their triangulation gaps and make their research more effective. For example, the design team should fully cover the behavioural-attitudinal and quantitative-qualitative axes. As a result, the designers' insights and methodologies are more robust.

5.3 Creative design process

Data science can help designers in their creative process with new user insights, generative design and alternative perspectives. With generative design, more digital creative tools become available, such as an autocomplete, and stimulate for a more efficient design process. The data-driven analyses result in new higher-level insights about the users and designers, while other data science analyses of users provide insights based on a different perspective. For example, non-traditional segments based on behavioural patterns provide alternative user-groups. This will improve the service design process itself as designers utilise more and/or better resources. Therefore, the design process will be based on more data and more diverse perspectives.

6. Conclusion

This research aimed to identify the opportunities for data science to support the service design processes. The iterative research process resulted in a guide to concepts of data science methods for service designers. The development of these concepts covered both fields in academic and practice. Moreover, it included the participation of designers in workshops. By analysing these concepts, this research has shown an overview of the diverse ways data science can support the service design process.

Service designers use particular methods to collect and analyse information for creating a holistic view of the users and stakeholders. Data science contributes by adding techniques for accessing new insights and/or increasing validation by supporting method triangulation. The techniques analyse for patterns, correlations and/or answer contextual or specific questions.

As shown on Figure 4, data science can be applied during the whole design process. It makes sense that data science techniques fit research-heavy phases of the service design process. However, this research showed that data science has the potential to support designers outside that scope extending to the whole project by, for example, helping stimulate inspiration during the ideation phase.

Data science supports user research in both foundational and directional research. User research is vital for analysing the holistic experience, and service designers benefit from specialised research tools to reveal new information about the users. Secondly, data science can help with the fast collection of materials that designers gather and build by finding patterns, highlighting elements and analysing insights. This approach is useful to support cross-team knowledge.

Challenges for using these concepts and methods seems to be mainly related to organisational maturity. Selecting a matching technique (including the data) depends on many factors, which are described in the detailed method description. For example, the required capabilities, such as skills and data, differ per technique.

This research was an explorative study and presented a broad overview. The concepts were related to the needs of designers and available project resources. The results were useful to orient and select data mining techniques for service design projects, but the findings can’t be generalised.

These data mining techniques were evaluated with designers from the company Mirabeau, an agency that practises service design. Future research investigates with practitioners from other organisations (e.g. in-house vs outsourcing). Future studies could also continue to examine the viability, practical application and hands-on information of the methods.

To conclude, an overview was provided of data science techniques for service designers and their design process. Where fragmented literature might provide useful insights, this study offers validation with service designers or explicitly addresses their needs. The overview and the methods assist design agencies, service designers and their teams in organising, selecting and utilising these data science techniques.

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About the Authors:

Youetta Kunneman switched sides from machine to human. She explores and creates value by combining her backgrounds in Artificial Intelligence and Design. Her focus is on how designers achieve their goals and how to improve this.

Mauricy Alves da Motta-Filho is an Assistant Professor at the University of Twente. His research interest lies at the intersection of brand, business and service design.

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