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Incorporating Sustainable HCI Research into Design Practice

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ABSTRACT

The rapid replacement cycle of consumer electronics, leading to wasteful use of scarce resources and a growing amount of electronic waste, poses a major threat to a sustainable future. Technological advancements of research, such as in Human-Computer Interaction, contribute to this development and therefore have a responsibility to combat those problems. Theoretical research in Sustainable HCI has developed a variety of design principles and frameworks that can be used to address issues of obsolescence; however, they rarely leave the realm of theory and make their way into design practice. This phenomenon is well-known in the general field of HCI, often referred to as the theory-practice gap.

In this thesis, we explore ways to bridge the theory-practice gap and address the obsolescence of consumer electronics by applying Sustainable HCI theory to product design practice. To lay the foundation of our research and understand people's motivation for replacing products, we conducted a survey and follow-up interviews about the most important factors in people's decision-making process when purchasing consumer electronics. Based on the insights, we took one of the most established frameworks from Sustainable HCI, the Attachment Framework, and asked product designers to include it into their design process. The Attachment Framework offers a set of principles that lead to a deeper bond between an object and its owner, preventing premature disposal and is a particularly powerful tool due to its emotional appeal.

Through a product design activity with two groups of seven designers, one of which was given the Attachment Framework, we conducted a comparative study to gauge the impact of the Sustainable HCI design principles on the product design process and its outcome. The mixed results led us to formulate a set of challenges for the application of theoretical frameworks to design practice, which we sought to investigate on further by implementing two different approaches: A web tool to organize the results of background research called StickyDesignSpace, and a brainstorming app called InspiredDesign. Our final evaluation yields insights into ways how Sustainable HCI design knowledge can be successfully transferred to practitioners outside of the realm of research.

ZUSAMMENFASSUNG

Der schnelle Neuanschaffungszyklus für Unterhaltungselektronik, welcher zu verschwenderischem Verbrauch von knappen Rohstoffen und einer wachsenden Menge an Elektronikschrott führt, stellt eine grosse Bedrohung für eine nachhaltige Zukunft dar. Technologische Entwicklungen der Forschung, wie im Bereich der Mensch-Maschine-Interaktion (engl. Human-Computer Interaction, HCI), tragen dazu bei und haben eine Verantwortung diese Probleme zu bekämpfen. Theoretische Forschung im Bereich der nachhaltigen HCI (engl. sustainable HCI, SHCI) hat eine Vielzahl an Designprinzipien und Lösungsansätze entwickelt, welche das Problem der Obsoleszens adressieren; diese verbleiben jedoch meist theoretischer Natur und finden nur selten den Weg in die Designpraxis. Dieses Phänomen ist im breiten Feld der HCI bekannt und wird gemeinhin als Theorie-Praxis-Lücke bezeichnet.

In dieser Arbeit erkunden wir Wege um diese Theorie-Praxis-Lücke zu überwinden und die Obsoleszens im Bereich der Unterhaltungselektronik zu adressieren, indem wir SHCI Theorie auf die Praktiken der Produktentwicklung anwenden. Als Grundlage für unsere Forschung und um die Motivation der Menschen zu verstehen die Produkte durch Neuanschaffungen ersetzen, haben wir eine Umfrage und Interviews über die wichtigsten Faktoren in ihrem Entscheidungsprozess beim Kauf von Unterhaltungselektronik durchgeführt. Basierend auf den Ergebnissen haben wir einen der etabliersten Lösungsansätze aus dem Bereich SHCI gewählt, das Attachment Framework, und Produktentwickler gebeten dies in ihrem Design-Prozess zu berücksichtigen. Das Attachment Framework bietet eine Auswahl an Prinzipien welche zu einer tiefen Verbindung zwischen einem Objekt und ihrem Besitzer führen, damit frühzeitige Produktentsorgung verhindern, und durch ihre emotionale Bindung ein besonders starkes Werkzeug darstellen.

Durch ein Design-Experiment mit zwei Gruppen mit je sieben Designern, von denen eine das Attachment Framework erhalten hat, haben wir eine Vergleichsstudie durchgeführt, welche uns erlaubt hat den Effekt der SHCI Designprinzipien auf den Design-Prozess und die Resultate zu bewerten. Das gemischte Ergebnis führte uns zum Aufstellen von vier Herausforderungen welche beim Anwenden von theoretischen Lösungsansätzen in der Designpraxis beachtet werdensollten. Diese haben wir in einer Studie mit zwei unterschiedlichen Ansätzen weitergehend untersucht: Eine Website um die Ergebnisse der Hintergrundrecherche einzuordnen (“StickyDesignSpace”) und eine mobile Brainstorming App (“InspiredDesign”). Unsere abschliessende Evaluation liefert Erkenntnisse darüber, wie SHCI Designwissen erfolgreich an Praktiker ausserhalb des Forschungsbereich überliefert warden kann.

RELEVANT PUBLICATIONS

BOOK CHAPTERS

Christian Remy and Elaine M. Huang. **Addressing the obsolescence of end-user devices: Approaches from the field of sustainable HCI.** In: ICT Innovations for Sustainability, Springer, Heidelberg/New York, p. 257 - 267, 2015. (Chapter 2.2)

Christian Remy and Elaine M. Huang. **Communicating SHCI Research to Practitioners and Stakeholders.** In: Digital Technology and Sustainability: Acknowledging Paradox, Facing Conflict, and Embracing Disruption, Routledge, London, 2017 (to appear). (Chapter 6.1)

CONFERENCE PAPERS AND NOTES

Vanessa Thomas, Christian Remy, Mike Hazas, and Oliver Bates. **HCI and Environmental Public Policy: Opportunities for Engagement.** In CHI '17: Proceedings of the 35th Annual ACM Conference on Human Factors in Computing Systems, Denver, Colorado, USA, 2017 (to appear). (Chapter 6.2)

Christian Remy, Silke Gegenbauer, and Elaine M. Huang. **Bridging the Theory-Practice Gap: Lessons and Challenges of Applying the Attachment Framework for Sustainable HCI Design.** In CHI'15: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pages 1305-1314, Seoul, Korea, April 2015. (Chapter 4)

Christian Remy and Elaine M. Huang. **Addressing the obsolescence of end-user devices: Approaches from the field of sustainable HCI.** In ICT4S '14: Conference on ICT for Sustainability, Stockholm, Sweden, 2014. (Chapter 2.2)

JOURNAL ARTICLE

Christian Remy and Elaine M. Huang. **Limits and sustainable interaction design: Obsolescence in a future of collapse and resource scarcity**. In First Monday, Volume 20, Number 8, Special Issue "Limits '15". August 2015. (Chapter 6.3)

DOCTORAL CONSORTIUM

Christian Remy. **Addressing Obsolescence of Consumer Electronics through Sustainable Interaction Design.** In CHI EA '15: Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems, pages 227-230, Seoul, Korea, April 2015.

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Christian Remy and Elaine M. Huang. **Limits and Sustainable Interaction Design: Obsolescence in a Future of Collapse and Resource Scarcity**. In LIMITS '15: First Workshop on Computing within Limits. Irvine, California, USA, 2015. (Chapter 6.3)

Christian Remy and Elaine M. Huang. **Tailoring sustainable HCI design knowledge to design practice**. In CHI '14: Position paper for the CHI 2014 "What have we learned? A SIGCHI HCI & Sustainability community" workshop, Toronto, Alberta, Canada, 2014. (Chapter 6.1)

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Related Supervised Master's Theses

Wanjun Chu. **StickyDesignSpace: Incorporating the Attachment Framework into Product Design Practice.** Uppsala University, Disciplinary Domain of Science and Technology, Earth Sciences, Department of Earth Sciences, 2015. (Chapter 5.1)

Jessica Hediger. **InspiredDesign: A Brainstorming Support Tool for Sustainable Interaction Design**. University of Zurich, Faculty of Economics, 2015. (Chapter 5.2)

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I also had the opportunity to intern at IBM Research India in New Delhi, and while the work itself was independent from my thesis and therefore did not make it into this document, I learned so much – not only in terms of research, but also about what it means to live, work, and carry out research in an entirely different culture. Special thanks to my internship mentor Arun Kumar, as well as Sheetal Agarwal and Saurabh Srivastava.

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RESEARCH ACKNOWLEDGEMENTS

In this thesis, I will report on the research conducted using "we" instead of "I", underlining the nature of research that is almost always a product of collaborative efforts; be it through direct collaboration, instances of supervision, or thought-provoking discussions. Besides the entirety of my research being a result of the invaluable feedback from my supervisor Prof. Elaine May Huang, several projects were conducted in close collaboration with other researchers:

1. Chapter 0: The affinity analysis of consumers' electronics purchasing behavior was a time-consuming effort, and especially towards the end my colleagues Gunnar Harboe and Sarah Mennicken helped with the process, such as discovering potential categories, discussing the resulting themes, and "walking the wall" to elicit implications for design of technology. Besides offering his tremendous wordsmithing prowess, Gunnar Harboe also helped to write up the methodology and results into a coherent structure.
2. Chapter 4: Silke Gegenbauer's master's thesis work was more than just an inspiration for my PhD; while I was interning with IBM Research India in New Delhi, she prepared and conducted the design exercise. The resulting 40 designs from the 14 design students later became the foundation for the comparative study.
3. Chapter 5: After taking first steps towards bridging the theory-practice gap, we were left with several ideas for tools supporting designers, and sought to implement two of them. I feel incredibly lucky to have had the opportunity of supervising two smart and diligent master's students: Jessica Hediger, who developed the brainstorming app "InspiredDesign", and Wanjun Chu, who created the web tool "StickyDesignSpace". Their work included evaluating our existing attachment framework material, translating it into a format suitable for the tool to be developed, and most importantly implementing, piloting, iterating on, and evaluating the respective final application.

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1 INTRODUCTION

Technology surrounds us and entwines our lives in the form of consumer electronics. The family of those devices includes smart phones and mobile phones, desktop computers, portable computer, televisions, video game consoles, home audio systems, and many more [Urban et al. 2014]. Over the past few decades, the amount of consumer electronics has exploded; e.g., the average number of such devices per U.S. household has risen from 2.8 (in 1980), to 13.5 (in 1995), to 25 (in 2010) [Urban et al. 2011]. Recent predictions indicate that new technology, such as the Internet of Things (IoT) or wearables, will continue this trend and see no end to this growth of technology in everyday lives [Bates et al. 2015; Koenig 2015].

This growth of technology is met with growth of undesirable side effects, one of them being electronic waste. The global electronic waste production in 2005 was estimated to be over 20 million tons [Zoeteman et al. 2009], in 2014 that number rose to 41.8 million tons [Baldé et al. 2015], and it is expected to grow further – especially due to emerging markets becoming permeated by technology [Sthiannopkao and Wong 2013]. Despite international regulations [Basel Convention 1992] and existing take back systems, the majority of electronic waste creates an enormous environmental impact, especially in developing countries [Baldé et al. 2015]. Toxic materials pollute not only the air, soil, and water streams, but directly and indirectly cause harm to animals and humans, with many of the effects yet unpredictable as carcinogens and pathogens will lead to severe long-term consequences [e.g., Slade 2007].

Figure 1.1: Four impressions of electronic waste in Guiyu, China. (Courtesy of all four pictures: @baselactionnetwork at flickr.com, CC BY-ND 2.0.)

The resulting effects of electronic waste on the environment can be observed in Guiyu, China; a city that is commonly referred to as the largest electronic waste dump in the world [Baldé et al. 2015]. Several studies report on the environmental impact, such as a high concentration of heavy metals in dust samples [Leung et al. 2008], airborne dioxins [Frazzoli et al. 2010], and water and soil pollution [Zhang et al. 2012]. An estimate of 150,000 workers process the electronic waste; however, the total number of people affected by the impact on the environment could be as high as 45 million [Robinson 2009]. And Guiyu is only one example for the consequences of electronic waste world-wide (Figure 1.1).

1.1 (Planned) Obsolescence

The imagery of electronic waste and its enormous impact on the environment and people living in it raises the question of its origin, and subsequently, how we can address it. Electronic waste is the result of electronic equipment reaching its end-of-life state, i.e., it is no longer being used. In other words, the product has become obsolete, since obsolescence is defined as "[t]he process or fact of becoming obsolete or outdated, or of falling into disuse" [Oxford University Press]. The term obsolescence is sometimes conflated or used synonymously with its related expression "planned obsolescence", indicating that obsolescence is not a naturally occurring phenomenon but an engineered process. This differentiation is an important one, as it bears the question whether or not we can address the obsolescence of products, and if so, how. In the following, we try to shed light on this question.

Growing amounts of waste as a result of planned obsolescence became subject of a major public debate for the first time in the 1950s and 1960s, most notably highlighted by Packard's criticism of consumerism leading to a wasteful society [1960]. This discussion presented a major shift in how planned obsolescence was perceived, and with it terms such as consumerism, growth of economy and ecology of products. Originally, planned obsolescence was conceived as a concept to counter the tumbling economy in the aftermath of the Great Depression [London 1932] and therefore considered as something positive. This view changed in the following decades as awareness about the waste stream grew, and the debate about obsolescence, including whether or not it is engineered, is still current [Burns 2010; Slade 2007].

Despite the evidence of planned obsolescence being an industry invention [London 1932; Slade 2007], there are voices arguing against it being a desirable aspect of modern product design. Most famously marketing experts wrote that "[m]uch of so-called planned obsolescence is the working of the competitive and technological forces in a free society – forces that lead to ever-improving goods and services" [Kotler and Keller 2011:78], stating that obsolescence is a naturally occurring phenomenon of our economy. Along the same lines, a recently published report by the German Federal Environmental Agency concluded that the lifespan of products shortened significantly in recent years, but found no evidence for manufacturers accelerating this effect [Prakash et al. 2016].

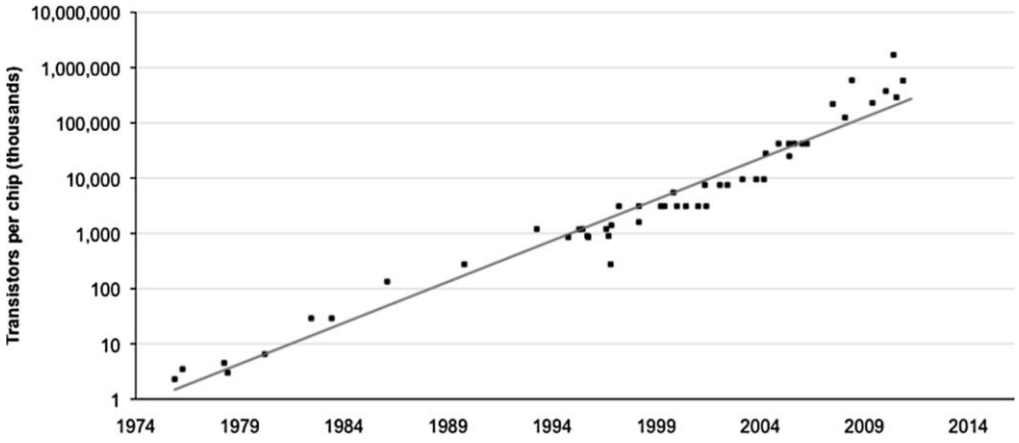

Figure 1.2: Moore's Law [Moore 1965] describes the increase of processing power, roughly doubling every two years, as indicated by the number of transistors per chip in an integrated circuit. (Courtesy of Koomey et al. [2011], © IEEE 2011.)

Those views and study results are opposed not only by Packard's early criticism [1960], but were recently reaffirmed in particular with regard to the history of technology, such as for personal computers [Slade 2007]. Slade acknowledges that technological advancement, highlighted by Moore's Law (Figure 1.2) plays its role in making products obsolete and therefore can be seen as an unavoidable byproduct of our society's progress in technology. However, undeniably there are instances of planned obsolescence to be found as well, such as the incompatibility of software upgrades: "New software is often carefully calculated to reduce the value to consumers of the previous version [...] by making programs upwardly compatible only" [Hindle 2008:147]. In terms of hardware, planned obsolescence is more difficult to prove as the investigation of Prakash et al. [2016] shows; nevertheless, researchers recently found evidence that integrated circuits can be manipulated through malicious software to lose more than 10% of their performance per month [Karimi et al. 2015].

Regardless of this debate and whether one believes that obsolescence is a construct of industry or a naturally occurring phenomenon as a result of rapid technological development, there is no denying in obsolescence as a major factor contributing to electronic waste. As such, the design of consumer electronics should attempt to mitigate the effects of obsolescence to the extent possible. Even marketing experts who claim that obsolescence is a byproduct of our society's free markets [Kotler et al. 2008:78] state that planned obsolescence should be avoided as it leads to bad consumer experience from a marketing point of view [Kotler and Keller 2011:330]. Therefore, it should be of interest to all parties involved to not only investigate the causes of electronic waste but to actively search for and pursue solutions.

1.2 Sustainable Interaction Design

Among other fields in computer science, research in HCI has contributed to the issue of obsolescence with its technological advancements, in particular in the field of Ubiquitous Computing (UbiComp). The possibilities emerging from more potent technology fuel researchers' pursuit of innovation, and HCI is not only known for following the trends of technology, but leading the field and

establishing those trends [Schmidt 2015]. Therefore, HCI has a responsibility to tackle the problems it is exacerbating itself – and efforts in doing so are to be found under the umbrella of Sustainable HCI (SHCI).

While there were instances of sustainability-related research in HCI before 2007, it was that year's SIGCHI conference [SIGCHI 2007] which saw the field of Sustainable HCI being established due to two important events. First, in a Special Interest Group meeting [Mankoff et al. 2007] the role of sustainability in HCI research was discussed, as well as a potential roadmap and promising avenues for future research. Second, a paper titled "Sustainable Interaction Design" [Blevis 2007] set forth that sustainability should not just be a part of HCI research but become a central aspect in design, and introduced design principles to guide this process. In the following years, SHCI became one of the fastest-growing fields in HCI and saw a surge of contributions on various topics pertaining to sustainability ([DiSalvo et al. 2010; Froehlich et al. 2010; Pierce and Paulos 2012; Brynjarsdottir et al. 2012; Knowles et al. 2014] presented comprehensive literature surveys). In 2011, "HCI and Sustainability" was established as an official ACM community [SIGCHI], and from 2011 until 2013 sustainability was a featured community at the SIGCHI conference series as well.

A significant part of this SHCI research investigated the rapid replacement cycle of consumer electronics [e.g., Woolley 2003; Huang and Truong 2008; Huang et al. 2009] and people's attitude towards technology in general [e.g., Hanks et al. 2008]. Researchers proposed a variety of potential solutions, such as frameworks for more sustainable design [e.g., Hallnäs and Redström 2001; Blevis 2007; Blevis et al. 2007a (a); Odom et al. 2009; Gegenbauer and Huang 2012a (a)], opportunities for re-use [e.g., Blevis 2007; Huh et al. 2010; Maestri and Wakkary 2011; Kim and Paulos 2011; Wakkary et al. 2013], or information about products and their production [e.g., Bonanni et al. 2010; Tomlinson 2008]. However, the success stories of those examples are usually limited to the field of HCI itself, and there is no evidence of its impact on real-world practices. This problem, also referred to as the theory-practice gap, is not unique to SHCI, but well known in the broader field of HCI [e.g., Sutcliffe 2000; Rogers 2004; Goodman et al. 2011; Roedl and Stolterman 2013].

As previously mentioned, the field of HCI has an obligation to tackle issues of environmental sustainability, and its continued efforts are displayed in SHCI research. The lack of application to practice of the developed concepts (or the lack of visibility thereof) limits the impact of the field (or at least its ability to evaluate the impact). Therefore, additional ways to foster SHCI research and its connection to design practice are necessary to bring SHCI and the original idea of Sustainable Interaction Design to its full potential: to make "sustainability [...] a central focus of interaction design" [Blevis 2007].

1.3 Thesis Overview

The goal of this thesis is to explore opportunities for SHCI to address issues of e-waste and obsolescence, with a particular focus on consumer electronics. We started our investigation by studying the consumer's perspective on technology, looking at previous research as well as conducting our own study. Our research was guided by the following research question:

> RQ1: What are the opportunities for Sustainable HCI to make an impact for sustainability on consumer electronics?

As a first step, we reviewed previous research in SHCI to find out about ways to tackle the issues of sustainability in the realm of consumer electronics. We review SHCI, its history, and its different approaches to issues of environmental sustainability in general as well as in particular pertaining to our problem space (Chapter 2.1). A plethora of contributions address the issue of electronic waste through design principles for consumer electronics and their surrounding practices. We analyze how the problem of obsolescence can be mitigated through those approaches and present a set of themes based on obsolescence-related research from the field of SHCI (Chapter 2.2). Besides looking at the contributions from within SHCI, we also highlight how the field can learn from another discipline, namely marketing research, which has insights from decades of experience to offer (Chapter 2.3).

To understand the consumers' perspective of sustainability issues related to consumer electronics, we conducted two formative studies about people's purchasing behavior of consumer electronics and how sustainability affected their decisions. First, we distributed an online survey asking people about recent purchases and ranking factors that played into their decision-making process. Second, we conducted semi-structured interviews to put those preliminary insights into context. We discovered in our analysis that for most participants, sustainability was not a primary factor when purchasing consumer electronics (as opposed to other products). For those participants who wanted to take sustainability into account, they felt that several barriers prevented them from making an environmentally-informed purchasing decision when buying electronic equipment. The study and its results can be found in Chapter 3.

Based on the research from this initial research question, we make the following three contributions:

A survey of obsolescence-related research in SHCI. There is a variety of theoretical contributions in SHCI that offers design guidelines, principles, and implications for design. We categorized the insights from our SHCI literature review based on potential themes addressing obsolescence, offering guidance for future research and development.

Taking a note from marketing research for SHCI. In an excursion to better understand people's purchasing practices as part of our interview study, we expanded into different fields in the spirit of HCI's interdisciplinary nature. The insights we gained from marketing research enable SHCI research to view its

work from a different perspective and make sure to understand the consumer's perspective when talking about the obsolescence of products.

The barriers to influencing consumer electronics purchasing behavior. Our interview study revealed not only insights into the general decision-making process of consumers when purchasing consumer electronics, but also highlighted the difficulties and obstacles when influencing this process. The findings contribute to SHCI as they inform future technology that seeks to support the consumers in their purchasing process by offering information about environmental sustainability.

Based on the insights from our literature review we learned that SHCI had presented many potential solutions to address obsolescence in consumer electronics, but there is a lack of visible evidence for any of those being applied to the practice of designing sustainable consumer electronics. To address this issue, which we refer to as theory-practice gap, we pose the following research question:

> RQ2: How can existing sustainable design frameworks be leveraged to provide assistance in the design process of consumer electronics?

We selected one of those sustainable design frameworks, the attachment framework [Odom et al. 2009; Gegenbauer and Huang 2012a (a)], and observed how designers interpreted its principles in their design process. The attachment framework presents a set of principles that guide the design of objects such that a bond between the object and its owner is created, leading to extended ownership and usefulness and therefore preventing premature obsolescence. The attachment framework is one of the most established frameworks in the corpus of obsolescence-related research in SHCI and offers a particularly strong potential to engage users through design as it works on an emotional level (similar to emotional design [Norman 2004] or ensoulment [Blevis and Stolterman 2007]). In a comparative study with two groups of designers we observed how the framework affected the design process and outcome of a design task, namely to create tablet computer designs that encouraged a strong bond between the device and its owner. The approach and results of this study are documented in Chapter 4.

We summarize our contribution for SHCI arising from this research:

Lessons learned for bridging the theory-practice gap in SHCI research. Our comparative design study with the Attachment Framework showed the importance of properly understanding the target audience, their work processes, and their language, but also highlighted the difficulty of evaluating SHCI design artifacts. We believe that SHCI research needs to properly address those challenges in order to successfully bridge the theory-practice gap and achieve knowledge transfer from SHCI research to practitioners outside the field.

Based on the insights from our initial background research and the lessons learned from our design experiment, we further intensify our effort to bridge the

theory-practice gap by addressing the uncovered challenges, guided by the following research question:

> RQ3: How can an existing sustainability framework be integrated into tools for designing consumer electronics, and what effects does this have on the design process and design outcomes?

Insights not only from our studies but also previous research [e.g., Dourish 2010; Khan 2011; Mankoff 2012] emphasize that attempting to incorporate SHCI design knowledge a early as possible into the design process offers the best chance to maximize success. Therefore, we turn our attention to two popular activities that are present in almost every product designer's process: background research and brainstorming. We developed two prototypes that were tied to the specific activities and evaluated with designers in a process reflecting their real-world design practice.

The first prototype is StickyDesignSpace, a design space that helps designers organize material gathered in the beginning of a design task to explore previous solutions and get inspiration for potential design solutions. The second prototype is InspiredDesign, a tablet application that provides brief messages as additional input in a design brainstorming session. We evaluate both prototypes on its own merits in Chapter 5, but also reflect on the overall lessons learned in comparison to our earlier research and draw insights for the general topic of applying theoretical SHCI knowledge (and even HCI knowledge) to design practice in Chapter 6.1. For the problem of obsolescence in particular, there is a tension between sustainable design and economical motivations. We will discuss this tension, but also highlight how future developments might potentially change the debate and impact the focus of sustainable design, in the remainder of Chapter 6. An outlook into potential future work concludes this thesis with Chapter 7.

The final step of our research results in the following contributions:

Tools that showcase successful SHCI design knowledge transfer. StickyDesignSpace and InspiredDesigns are two examples of how SHCI design knowledge can be transferred into product design practice. Our applications therefore contribute to SHCI research by showcasing for future research how to bridge the theory-practice gap and achieve knowledge transfer, increasing SHCI's outreach to a much broader audience.

SHCI design knowledge and its importance in a future of limited resources. Research in HCI oftentimes investigates current practices and creates solutions addressing the current situation; however, in future scenarios the circumstances that influence and shape research might differ significantly. We contribute with a discussion of obsolescence-related research projected onto one of those scenarios: a future of limited resources and changed economical and societal circumstances which affect SHCI research and people's everyday life alike.

To establish the background and motivation for our research, we start by discussing previous research from the field of SHCI in the next chapter. This chapter provides an overview of SHCI research, its history, and the different branches of contributions, as well as related work within SHCI that addresses issues of obsolescence. For the design studies in subsequent chapters, especially chapter 4, 5.1, and 5.2, we will discuss related work separately in each chapter, which allows us to better contextualize the treatment of related work for each of the design activities.

2 Background and Motivation

Laying the foundation of our research, we investigate the existing situation regarding people's acquisition, use, and disposal of technological equipment. The first section of this chapter presents an overview of SHCI, including the historical development of research in this field. Focusing on the core issue that his thesis aims to address, electronic waste and obsolescence, section two follows with an overview of obsolescence-related research in SHCI. We conclude our background research by offering insights from another discipline, marketing research, and how SHCI can learn from its decades of experience regarding similar questions, albeit different goals.

2.1 Sustainable HCI and its Two Branches

After SHCI was established as a field following the SIGCHI conference in 2007, the topic of environmental sustainability gained much popularity and importance for many researchers within the domain of HCI research. A search on the ACM's Digital Library [ACM, Inc.] for author keyword "sustainability" in publications at the SIGCHI conferences reveals one extended abstract in 2004 and 2006, respectively.

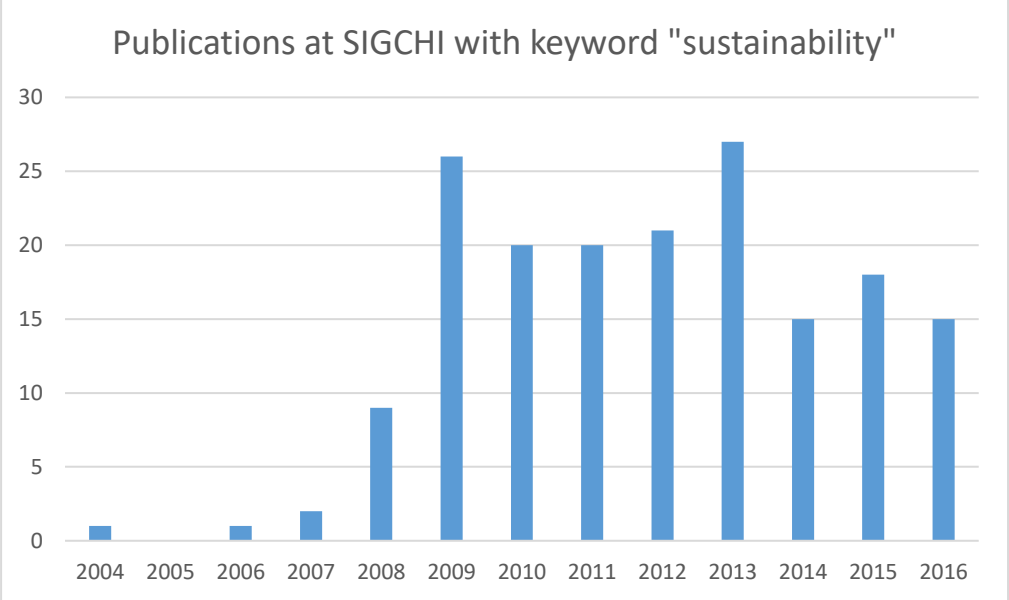

Figure 2.1: Number of publications at the SIGCHI conference series with author keyword "sustainability". The decline after 2013 might be due to the inception of other thematically similar venues (e.g., ICT4S, LIMITS).

Searching all of ACM's database for any publication with both keywords "sustainability" and "interaction design" results in thirteen hits before 2007. The SIGCHI 2009 conference [SIGCHI 2009] alone saw 26 contributions tagged sustainability (Figure 2.1). Note that those numbers are only from one conference; other venues such as Designing Interactive Systems, UbiComp, and INTERACT have seen submissions addressing sustainability as well. Recently, new venues have been created that focus on topics at the intersection of sustainability and computing, such as the ICT4S conference (since 2013) and the LIMITS workshop (since 2015). While those numbers highlight the increased

attention for sustainability-related topics in recent years, the content of the publications behind those numbers show a great deal of diversity in tackling issues of environmental sustainability. For a more nuanced distinction of the various research topics, DiSalvo et al. [2010] provided an overview of the different genres within SHCI; but here we focus on a high-level separation into two main branches of SHCI as identified in the Special Interest Group meeting at the CHI conference [Mankoff et al. 2007]: Sustainability in design and sustainability through design.

Mankoff et al. define *sustainability in design* as addressing "sustainability as part of the material design of products" [2007], for example by reducing the environmental impact of a product or increasing its energy efficiency. As DiSalvo et al. [2010] point out this affects both hardware and software products; although most examples in SHCI initially regarded physical objects in conjunction with software [Blevis 2007] recent trends such as cloud computing highlight the importance of sustainability in design for software on a different level [Preist et al. 2016]. *Sustainability through design* is defined as supporting "sustainable lifestyles and decision-making through the design of technology" [Mankoff et al. 2007]. Examples include, but are not limited to, products that promote environmentally conscious behavior, such as devices and applications that provide information about issues of sustainability. In the years after SHCI's inception in 2007, in particular so-called eco-feedback technology became an increasingly popular research topic in the field; it encompasses the design of hardware and software that offers information about people's behavior or their environment, usually with the goal of raising awareness and ultimately changing people's behavior. Several surveys highlight those efforts [DiSalvo et al. 2010; Froehlich et al. 2010; Pierce and Paulos 2012] but also point out that oftentimes such eco-feedback technology does not lead to long-term behavior change, which has led to a debate on how to address those issues and move the field forward [Brynjarsdottir et al. 2012; Silberman et al. 2014; Knowles et al. 2014].

This distinction is important to highlight the two different categories of solutions for the issue of obsolescence. Sustainability in design can be considered a more direct approach for which the solution is part of the design itself, whereas sustainability through design means that the resulting product needs to lead to a change in people's behavior, practices, or actions. In the following section, we take a closer look at the existing research that suggests solutions to the problem of obsolescence. Most of those solutions can roughly be attributed to sustainability in design, since they mainly suggest changes to the design of technology itself. Therefore, the last section of this chapter discusses opportunities for sustainability through design to counter obsolescence. For SHCI research to be able to tackle those issues, one needs to understand people's motivation, needs, and requirements first, which is why we conducted a study about people's electronics purchasing practice, investigating the factors influencing the decision-making process and how environmental aspects play into it.

2.2 Survey of SHCI Research Addressing Obsolescence[1]

In this section, we analyze the current state of SHCI research that has dealt with and appealed to the problem of obsolescence for technology. Our approach was to consider all publications related to both HCI and sustainability that address obsolescence. In the literature review process, our focus was to gather insights through two primary approaches: first, identifying common themes in the solutions proposed for interaction design; second, highlighting challenges mentioned in SHCI research emerging from previous work. In the following sections, we present the results of our analysis of the field, categorized by three themes that emerged as high-level categories in our analysis: values in design, re-use, and longevity. These three categories represent three equally important dimensions along which obsolescence-related SHCI research can be oriented. For each of these themes, we highlight a number of design considerations that have emerged from SHCI research and discuss them in light of their significance to issues of obsolescence and potential challenges in application.

2.2.1 Values in Design

Many approaches to address obsolescence can be attributed to conveying value in design. The common idea is that an object whose design expresses or comprises a certain quality (e.g., in terms of aesthetics, interaction, or usefulness) is less likely to be replaced, thus creating a resistance to obsolescence. In his definition of sustainable interaction design, Blevis incorporates values as one important aspect in design [2007], highlighting different aspects of design values as presented in previous literature and design practice. For example, design can be about "features and functions of objects", "affective aspects of objects", "interactions between people and environments", or "choices that lead to sustainable futures". Similarly, SHCI research presents different concepts of values in design.

2.2.1.1 Pleasure Engineering

Even before sustainability became a major subject within the domain of HCI, Woolley [2003] related the rapid replacement of products with a shift from pleasure (upon purchase) to dissatisfaction (long-term use). He therefore calls out for *pleasure engineering*, creating designs that enable long-term pleasure, and ultimately defer or even avoid the dissatisfaction over time. Four strategies are proposed to achieve such a long-term satisfaction: future-proof design in functionality and appearance; price reduction incentives; no incremental changes but fewer and larger steps in technological advancement (cf. Moore's Law – contracting steps); and as a last resort, governmental regulations. Some of these strategies, e.g., regulations or a product's price, cannot be addressed by HCI approaches directly. The design of services and technology that support everyday work practices of various stakeholders outside of HCI offers opportunities for interaction designers to indirectly achieve an impact on practices that lead to more sustainable actions.

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[1] Contents of this chapter have been published in a book chapter [Remy and Huang 2015a].

2.2.1.2 Achieving Heirloom Status

The research of Hanks et al. [2008] considers the attitudes of young adults towards sustainability, specifically regarding ownership of objects. Through a survey of college students, they discovered that students did not believe that they would pass electronic devices down to their children. They argue that interaction design should strive to *achieve heirloom status*, turning electronics into objects that are worthwhile not only to keep, but even to inherit. While heirloom status is a design value mentioned by many researchers in SHCI [Blevis 2007; Jung et al. 2011; Pan et al. 2012], it is difficult to design for and difficult to study as it only develops over time. Studies of objects that people hold on to for a long time can provide hints as to how design technology to achieve a similar impact [Odom et al. 2009; Gegenbauer and Huang 2012a]. In the specific case of electronics, heirloom status might not only apply to physical material, but also the digital dimension of products (see *value of the content, not the device* as reason to keep objects [Gegenbauer and Huang 2012b]). This interplay of physical and digital properties might create new opportunities for HCI to support the process of establishing heirloom status, if not only the physical product itself becomes an heirloom, but the software, applications, or content on it is perceived so valuable that people want to pass it on.

2.2.1.3 Ensoulment

By studying people's attachment to objects they would not discard, Odom et al. [2009] identified *histories* as one reason for holding on to products – the object helps the owner to preserve a memory. In a study focused around electronic waste, Zhang and Wakkary [2011] made a similar observation by highlighting *emotional connections* as one reason why owners do not dispose of their electronics. Those are two examples of *ensoulment* in practice; a term introduced to HCI by Nelson and Stolterman [2012] and later on applied to SHCI [Blevis and Stolterman 2007]. It refers to the notion that a product, due to its design, is perceived by the owner as having a soul, establishing an emotional bond that prevents disposal and encourages longer ownership. Related terms are *emotional design* [Norman 2004] and *attachment* [Odom et al. 2009; Gegenbauer and Huang 2012a; Gegenbauer and Huang 2012b]. Furthermore, Odom and Pierce [2009] suggest fostering such a connection through *narratives* and *character*, and provide the example of an MP3 player resembling a musical passport which, each time the owner enters a new country, allows to be virtually "stamped", creating a memory and accumulating a travel history over time.

2.2.1.4 Slow Design

Based on the *slow movement* which proposes a cultural shift towards a new lifestyle with slower pace and increased awareness of one's environment, *slow design* is an approach that targets a person's everyday life beyond just the interaction with one product. Slow design aims to slow the metabolism, resource consumption, and flows of people's lives, engendering a positive behavior change. It can be seen as not only addressing obsolescence through the design of products itself, but calling for a change in people's lifestyles in general. Hallnäs and Redström [2001] argue that products conveying slow design cause their owners to be more reflective of their interactions and practices, and Strauss and

Fuad-Luke [2008] pointed out that slow design principles have a positive impact on the design process itself as they open up new perspectives about the potential of designs and their message. A recent slow design case study supported these insights with similar responses from both designers and evaluators [Grosse-Hering et al. 2013]. The core idea is that products conveying slow design contribute to a lifestyle embodying more reflection and awareness, ultimately increasing individual wellbeing, both on an individual as well as on a societal and cultural level.

2.2.1.5 New Luxury

Blevis et al. [2007b] discuss *new luxury* as an additional opportunity for sustainable interaction design to promote a shift to a more sustainable design of consumer electronics. The concept of new luxury as a contrast to more expensive and exclusive definition of traditional luxury is defined as "products and services that possess higher levels of quality, taste, and aspiration than other goods in the category but are not so expensive as to be out of reach" [Silverstein et al. 2003]. Blevis argues that this level of quality introduced by new luxury can contribute to SHCI efforts, for example, by promoting "services over new physical materials", "upgrades of existing products", or "concern for secondary markets". Several authors have noted that luxury and material success are obstacles in tackling obsolescence [Blevis et al. 2007b; Blevis 2008; Hanks et al. 2008] since some consumers – commonly referred to as early adopters – always like to have the most novel technology [Hanks et al. 2008]. New luxury might be leveraged to turn this traditional notion of material success and luxury against itself to promote more a more sustainable behavior, for example, by shifting the societal paradigms such that owning a device for a longer amount of time becomes more desirable than buying a new one.

2.2.2 Re-Use

Another approach to extending the lifetime of electronics – partially or for the whole device – is to design for reuse. These concepts all have in common that some aspect of the relationship between the owner and its device changes, such as changing the owner of the device (transferring), changing the device itself (repairing or recycling), or changing the way people interact with it (repurposing) [e.g., Blevis 2007; Huh et al. 2010; Maestri and Wakkary 2011; Kim and Paulos 2011; Wakkary et al. 2013]. While the conceptual design of the device itself can encourage and support reuse, it is often difficult to anticipate what will lead to successful practices. However, interaction designers can also offer support for reusing existing devices, such as by creating tools to share ideas and examples or encourage and support practices of reuse.

2.2.2.1 Transferability

The lifetime and usage of consumer electronics can be extended if the design of such devices supports and encourages *transferal of ownership*. Hanks et al. [2008] propose a rethinking of design such that electronics keep their value of functionality, similar to automobiles. Blevis's rubric [2007] also names transferability as an important aspect of sustainable interaction design, calling for "reuse as is". In a study comparing mobile phone transferability in three different countries, Huang et al. [2009] discovered that there are different

attitudes towards transferal of ownership. While in Japan privacy concerns were an issue, leading people to manually destroy and discard their phones rather than selling them, several Northern American participants were unable to transfer their phone due to them being locked to one service or contract. This highlights that depending on context there are different barriers to transferability and different ways of addressing the issue; for example, while the issue of privacy is a matter of decoupling digital contents from a device and making this trustworthy and transparent to people, contract or service issues are an external issue that can only be addressed indirectly by interaction designers. In the same study [Huang et al. 2009], German participants mentioned that it was economically advantageous and thus often preferred to pass on phones to acquaintances or sell them upon acquisition of a new phone, showcasing an example of encouraging transferal of ownership. Interaction designers can leverage this knowledge by designing services to support these ownership transfers, creating a desire for more opportunities for transferability and thus indirectly making an impact on existing policies and roadblocks to transferability such as contract or service locks. Additionally, designers to support transferability explicitly through the design of devices themselves and their software.

2.2.2.2 Repair

One of the innate characteristics of obsolescence is that devices break and stop functioning – be it through purposeful design or through unintended malfunctioning. Maestri and Wakkary [2011] studied how laypeople repair broken objects, including but not limited to electronics. They argue that interaction design should support the manufacturing of products that allow for them to be repaired without specialized knowledge; a concept they call *everyday design*; the implication is that everyone is a designer or, in the context of their study, a repairer. In an extension to the first study Wakkary et al. [2013] provide additional examples and conclude that the material of a product should allow for repair by laypeople based on people's expected competence in repair, and the product's design should allow for repair without the requirement of special tools.

2.2.2.3 Re-use of Materials

Through an online survey about electronic waste re-use examples, Kim and Paulos [2011] developed an extensive design reuse vocabulary for material properties, shape properties, and operation properties of electronic waste. Their framework provides designers with actionable guidelines for the design of electronics that allow for re-use through partial or complete disassembly. But it is not only the materials themselves that are important to consider for re-use of technology; in a study of electronic waste recycling practices, Zhang and Wakkary [2011] identify that the disposal of electronics and the information about available electronic waste for re-use needs to be organized. They suggest local recycling information networks to support electronic waste re-use practices. In a framework for sustainability assessment by Dillahunt et al. [2010], several criteria call out for a better re-use support as well, such as *modular devices that can be taken apart easily*, materials that can be *replaced*, *reused*, or

recycled. The latter two criteria also appear in Blevis's rubric [2007] as *recycling* and *remanufacturing for reuse*.

2.2.2.4 Augmentation

A rather difficult design proposal but one that, as studies show, can be very successful to extend the lifetime of a product, is to allow for an object to be augmented beyond its intended use. Odom et al. [2009] call this augmentation; further examples for augmentation can be found in the follow-up study by Gegenbauer and Huang [2012a], e.g., "an alarm clock to which the owners had attached a light" or an embroidered chair. An impressive and exceptional example in the domain of consumer electronics is that of a combination of 30-year-old computer technology currently being used by children in Indian communities [Lomas et al. 2013]; this use is only possible due to the design of the original technology itself that did not prevent or constrain such repurposing of the device. Huh et al. [2010] present a similar observation for more recent devices, when PDAs acquired through eBay were used as e-book readers or a cheap alternative to GPS devices. Note that both these examples reflect aspects of transferability as well since they include change of ownership; but the key aspect that enables an extended lifetime is the repurposing and augmentation of devices beyond their intended use.

2.2.3 Longevity

One theme in SHCI to address obsolescence is that of achieving real durability and longevity. This differs from reusability as it aims for longer ownership without changes in the relationship, tackling obsolescence at its core. Therefore, its largest barrier is planned obsolescence, which is the exact opposite of durability; instead of designing a device to break, durability argues that a device should be designed to last longer. Interaction designers can contribute to solutions for issues of obsolescence by laying the foundation of longevity through functionality and motivating longevity of use among consumers.

2.2.3.1 Longevity of Functionality

Gegenbauer and Huang propose a design principle called *sufficiency*, defined as the "extent to which an object continues to be used or kept because it is capable of serving its intended purpose" [2012a]. Odom et al. [2009] present a similar notion by defining the design criteria of *perceived durability*, encouraging the design of long-lasting objects due to their functionality, simply inherent longevity, or both. Designing for longevity is particularly challenging as it requires thinking about not only whether design is usable and useful now, but also predicting whether it will be in the future. However, the important premise of this approach is to make sure that the core functionality of the object will work in the long-term, as this is a requirement to achieve longevity in the first place.

2.2.3.2 Intrinsic Motivation for Longevity

Another aspect of longevity is that of raising awareness of the benefits of holding on to one object rather than engaging in a rapid replacement process. The concept of slow design as highlighted by an exemplary design concept study [Grosse-Hering et al. 2013] creates an intrinsic motivation for people to continue

using a device, as it causes people to reflect on their interaction with technology [Strauss and Fuad-Luke 2008] and ultimately can contribute to a change in lifestyle with regard to their attitude towards technology. Similarly, Hanks et al. [2008] argue that some people prefer longevity of use for devices, fully aware of and making reference to the environmental concerns connected with rapid replacement. The combination of awareness of longevity and incentives (often intangible, almost metaphysical) can lead to a strong appeal of longevity.

2.3 The Consumers' Perspective: Taking a Note from Marketing Research[2]

Understanding people and studying practices is one of the foundations of HCI, and in 2013 the field's premier journal, ToCHI, released a special issue on practice-oriented approaches for SHCI [Pierce et al. 2013]. However, HCI and in particular SHCI has not a long standing history of research looking into the purchasing decision process – unlike other disciplines, as a literature survey revealed. In particular, we came across a field which has been studying the purchasing decision process for several decades: marketing research. Marketing research has borrowed methods from psychology to study consumers and analyze their practices, using the results to inform the design of products and the dissemination of information to maximize the benefits for the interested stakeholders. Marketing research is often dismissed or overlooked in the HCI research due to the perception of it as primarily prescriptive rather than descriptive in regard to the relationship between consumers and products. However, marketing research also focuses heavily on conveying information to consumers to influence their behavior, and as such its goals align to some extent with those of persuasive technology, a major thread of sustainable HCI research. Therefore, we believe that an understanding of and familiarity with models and concepts drawn from the field of marketing research can enrich and inform research in sustainable HCI by putting a new lens on the existing body of research, offering potentially useful tools, and highlighting new or previously overlooked aspects.

Figure 2.2: Five Stage Model of the Buying Decision Process (adapted from Kotler and Keller [2011:166]).

Marketing research offers a wealth of concepts of potential value for sustainable HCI. As one such example, Kotler and Keller's [2011:166] Five Stage Model of the Buying Decision Process (Figure 2.2) is well-established and has been refined over many years. Focusing on consumer electronics purchases, we apply this model to sustainable HCI and shed light on new opportunities for research and valuable framings for existing and ongoing work in the field.

[2] Contents of this chapter have been published in a magazine article [Remy 2012].

2.3.1 Problem Recognition

As a first step before every purchase, there is the initial desire to buy something. Marketing research calls this step *problem recognition*, with the problem being the consumer's lack of a certain product. The purchase intention can be triggered by many factors – basic needs such as hunger or thirst, but also external triggers such as seeing someone else using a certain device or looking at an advertisement. This need for a purchase can also be depicted by two different states: an actual state, which is the current state of the consumer, and an ideal state, which is the desired goal that can be reached by making a purchase.

For consumer electronics, the past has shown that the actual state is in constant elevation. After the purchase of a new device, the ideal state never lowers, but rather becomes the new actual state. This leads to a rapid turnover cycle and subsequently contributes to the *disposable technology paradigm* [Huang and Truong 2008]. The questions that arise here for sustainable HCI research are: How can we design to address the feeling that the actual state lowers over time, while raising the actual state as perceived by the consumer? And additionally, is there an alternative way to get from actual to ideal state other than by replacing entire devices all the time? To some extent, research has tried to answer these questions—replacing parts of devices and upgrading hardware or software might reduce the need to buy a new device, addressing the second question. Answering the first question, however, might be even more promising, as it concerns the more fundamental question of perceived need. To address this, sustainable HCI research needs to further investigate, with the help of marketing research, the underlying question of how attachment to devices is being formed and what would encourage longer use rather than a rapid replacement cycle.

2.3.2 Information Search

Once the intention to make a purchase has been formed, many consumers actively search for information. Marketing research classifies this information into four different categories: *personal* (recommendations or advice from acquaintances), *commercial* (advertisements, but also information sheets both in retail stores and online), *public* (reviews or news articles), and *experiential* (going to a store or a friend who owns the device and trying it out). Information from these sources is perceived differently. While quantitatively, most information comes from commercial sources, public and personal information is considered to be the most influential; information from these sources is often used to verify and validate information from commercial sources. The increased amount of information that is available, in particular because of the growing body of knowledge on the Internet, does not make the decision easier. To the contrary, more information often makes the choice much harder, leading to more complexity [Remy and Huang 2012] and choice paralysis. Therefore, simplification of the information search process is an important task for sustainable HCI research. Simply providing new and more information, especially about the environmental impact of a potential purchase, does not help but rather complicates a buying decision. Projects such as *SourceMap* [Bonanni et al. 2010], which make extensive use of information visualization, are just a first step. How can we offer filtering of information and provide consumers with only the information that is directly relevant to their decision? To do this, every

consumer must be treated as an individual to learn what specific information she is looking for, to determine which information can be left out and how the remaining important information can be conveyed with maximum readability.

2.3.3 Evaluation of Alternatives

When buying a product, the consumer has certain expectations about some of the properties and features of said product. The information gathered during the decision-making process is evaluated in light of the consumer's expectations, attitudes, and beliefs. This process can be formalized for the purpose of marketing insights to anticipate or reconstruct a certain decision; however, it can be unpredictable and subject to many factors that are often difficult to quantify, such as a person's beliefs or expectations.

Interfaces and applications for making purchases currently offer consumers the ability to evaluate alternative products under consideration through information specifically geared toward supporting comparison, such as feature charts or star ratings. There has generally been little mainstream inclusion of sustainability information, however. What might it mean to design tools that incorporate sustainability into this evaluation, or beyond that, even make sustainability a central focus of comparison? If issues of sustainability conflict with other consumer priorities, what kinds of support might be offered for allowing consumers to evaluate alternatives by optimizing their priorities? There are attempts within sustainable HCI on visualizing impact [e.g., Bonanni et al. 2010; Tomlinson 2008], but questions remain about how to facilitate explicit evaluations of alternatives. Marketing research identifies this evaluation of alternatives as a critical aspect of purchasing, and we believe it is one that warrants exploration in sustainable HCI.

2.3.4 Purchase Decision

Some consumers do not actively search for information, instead making spontaneous purchase decisions without a preceding phase of information collection. Especially if the initial trigger was a device they saw and liked, their mind might already be made up, and there is no need for information search and evaluation. However, regardless of whether the evaluation phase was skipped, once the consumer has made a choice for a particular device, there are still factors that can influence the decision. A sign in the store, an advertisement on a website, shortage of money, unavailability of the device at the retail store, or last-minute advice from a friend. These factors may trigger change, postpone, or even cancel a purchase.

The takeaway for sustainable HCI research is that information counts until the very last second, and it can indeed be very powerful. That is not to say that this way of conveying information should be the main target in communicating sustainability issues, but it is one that needs more attention. There is already a significant body of research about sustainability information, but how do we make this more accessible to consumers who do not actively search for it? How can sustainable HCI offer support for last-minute decisions, and what does it mean to address consumers at this stage? Looking to marketing research may provide direction to help close the gap between the huge amount of information

that is available for long-term decisions and the lack of support for more spontaneous consumers.

2.3.5 Postpurchase Behavior

After the consumer has bought a product, he might recommend it to other people, or simply by using it spark interest and trigger a purchase desire in someone else, closing the loop. Postpurchase action (how the device is used and maintained) and disposal (how it is disposed of) are also issues of concern at this stage of the model that suggest directions for sustainable HCI research.

Facilitating news dissemination about a sustainable purchase, creating incentives for and guidelines on using a product sustainably, and offering assistance in proper disposal are just some of the options that need further exploration and action in research. Combining these problems with knowledge from marketing research highlights new challenges and leads to questions such as: Can sustainable HCI researchers create support for designers to help them generate more designs that lend themselves to more sustainable use? What does sustainable design even mean regarding the entire life cycle of a product—manufacturing, use, and disposal—and how can such design foster more sustainable behavior for the owners of the products?

2.3.6 New Avenues for Research

It needs to be noted that this five-stage model is an abstraction of an extremely complex and diverse process. Some consumers might repeat several steps multiple times, while others might just skip to the fourth stage. However, the model depicts an abstraction of a body of knowledge that was acquired over a long period of time studying consumers and their decisions; sustainable HCI can benefit from this knowledge. The model can be applied to the research field to draw conclusions about how to better understand not only consumers' practices and routines, but also their needs and desires. It helps to look at our research field from a new perspective, provoking thought and providing inspiration for new ideas. Sustainable HCI is a relatively young field of research, and as such we believe it can greatly benefit from looking at other fields, learning from their insights, and applying their methods and models. The five-stage model presented here is an example—just one—of a concept drawn from marketing research that can inform sustainable HCI research and point to new directions for research.

3 Factors Influencing the Electronics Purchasing Decision-Making Process[3]

In the spirit of sustainability through design, one potential approach to address environmental issues such as obsolescence is to provide people with information, raising their awareness of those issues and hopefully achieving a change in behavior, leading to more sustainable practices. One of the first steps in designing such technology is "understanding users" [Nielsen 1994:73; Preece et al. 2002:73], and in particular in SHCI recent scholars have stressed the importance of studying practices [Pierce et al. 2013].There is a variety of research that sought to gain a deeper understanding of consumers' practices and behavior. Woodruff et al. [2008] investigated how inhabitants of 35 US households changed their accommodation and lifestyle towards being more environmentally responsible. Among other findings, they propose a set of design implications that stress the importance of introducing choices suited for users and adapting their surrounding environment to enable more sustainable lifestyles. Also on the environmental impact of homes, but targeting resource consumption, Chetty et al. [2008] looked at the resource management practices of 15 households and derived how the UbiComp community can enhance and support more sustainable behaviors for water, electricity, and natural gas usage.

In our work, we are focusing more on the environmental practices of people with regard to consumer electronics. A large-scale quantitative study with 435 participants conducted by Hanks et al. [2008] touches upon this issue; among other findings, they report on purchasing and replacement behavior and how this is correlated with other factors within their sample population. Huh et al. [2010] examined purchases of used computing devices purchased on eBay by interviewing the buyers and identified different notions of sustainability. Huang and Truong [2008] investigated a similar but more focused topic when they conducted interviews to find out about the replacement cycles of cell phones and proposed measures and design implications to avoid the rapidly accelerating cycles of purchasing new devices.

Our study focused on the electronics purchasing process, the decision process when nearing such a purchase, and which factors are influencing it. In particular, we were interested in the information that is available to consumers in this situation and how they interpret and apply this information – but also, which sought-after information might be missing. Our initial research plan was to use a survey to identify individuals who make an effort to use environmental information in electronics purchasing processes. We planned to study their practices to learn what types of information they use, how and from where they acquire it, and at what points during the process they use it. Our intent was to adapt their approaches to create systems that would make relevant information

[3] Contents of this chapter have been published in a workshop paper [Remy and Huang 2012].

available at appropriate points in the purchase process, to enable less-motivated individuals to make similarly sustainable purchases with low effort.

However, upon receiving the survey responses, we were surprised to find that even participants who identified themselves as "environmentally concerned" did not have strategies or trusted information sources for making sustainable choices in purchasing consumer electronics, suggesting that the information gap in this domain may be greater than we initially surmised. As a result, we refocused our research to encompass a broader set of issues, including how people use environmental information when making purchases of goods in general, how electronics buying practices differ from the purchase of other types of items, and how the use of environmental information in other types of purchases may inform the eventual integration of such information into electronics buying. In the following, we report on our initial survey that identified the disconnect between environmental information and electronics purchasing, our subsequent interviews considering how people use information in making purchases, and discuss the results in light of opportunities for SHCI to address obsolescence.

3.1 Preliminary Survey: Recent Electronics Purchases

To gain an initial understanding of people's practices when buying consumer electronics, we conducted an online survey asking for their experience in past purchases. The main goal was to get an idea of how, where, and to what extent consumers use information about environmental sustainability in their purchases. It consisted of up to 19 questions, starting with four initial demographics questions and concluded by an open-ended question for further comments and a (voluntary) contact information field. In the main part of the survey, we asked participants to provide a list of their last three consumer electronics purchases, followed by a detailed set of questions for each device. These were: a list of factors that people took into account in making their purchase decision (from a list of 14), a ranking of the up-to-five most important factors, an open-ended field for annotations about the device being replaced by this purchase, if any (reason for replacement, lifespan of the old device, and its whereabouts after replacing), and a conditional open-ended question to elaborate on environmental factors that participants checked. This last question was only visible if participants checked a factor that could potentially be connected to ecological concerns, and the answer helped us to distinguish ecological from economical or other rationales for these five factors.

The 14 factors were as follows:

- Price
- Technical features
- Aesthetics, design
- Physical dimension
- Environmental sustainability*
- Brand
- Energy consumption*
- Promotion/sale

- Manufacturing country*
- Overall product quality
- Customer service
- Battery life*
- Recyclability*
- Other (specify)

The five factors that triggered the inquiry about possible environmental rationales are marked with an asterisk. The full survey can be found in Appendix A.1.

The survey was distributed using snowball sampling; as our purpose was not a quantitative study, we did not attempt to achieve a random or representative sample. Our goal was rather to gather the input of a reasonable amount of environmentally engaged people, by sending the survey out to mailing lists and other contacts that were connected in some way to sustainability. A total of 79 participants completed the survey (29 female and 50 male), with almost all of them living in Central Europe (75). The participants were aged between 18 and 55, with the largest group aged between 26 and 35, consisting of 39 participants. Altogether we gathered information about 225 consumer electronics purchases.

Factor	Participants	Percentage	Devices	Percentage	Ranked #1	Ranked #2	Ranked #3	Ranked #4	Ranked #5	Not ranked
Price	76	*96.2*	176	*78.2*	82	55	20	13	6	0
Technical features	71	*89.9*	178	*79.1*	83	47	22	8	7	11
Overall product quality	60	*75.9*	125	*55.6*	18	40	30	12	16	9
Aesthetics, design	56	*70.9*	105	*46.7*	11	23	24	23	13	11
Brand	53	*67.1*	93	*41.3*	9	16	15	32	12	9
Physical dimension	45	*57.0*	79	*35.1*	3	13	30	13	11	9
Battery life*	38	*48.1*	47	*20.9*	3	10	6	9	6	13
Promotion/sale	26	*32.9*	37	*16.4*	6	9	6	4	6	6
Energy consumption*	25	*31.6*	36	*16.0*	0	3	11	6	11	5
Other	14	*17.7*	22	*9.8*	8	7	3	2	2	22
Customer service	10	*12.7*	14	*6.2*	0	0	5	0	4	5
Manufacturing country*	9	*11.4*	12	*5.3*	0	0	1	1	0	10
Environm. sustainability*	8	*10.1*	10	*4.4*	1	1	4	0	1	3
Recyclability*	2	*2.5*	2	*0.9*	0	0	0	0	2	0

Table 3.1: Results from online survey about the three most recent consumer electronics purchases. Based on data from 79 participants (225 device purchases). For each factor: how many participants ever indicated that factor, how many device purchases it was indicated as a factor for, and how many times it was ranked as one of the top five factors.

3.1.1 Survey Results

An overview of the survey results is shown in Table 3.1. For 76 participants (96.2%) *price* was an important factor for at least one of their purchases, and in more than 60% of the cases (137 of 225) it was the most or second most important factor. A closer look at the individual results for all the devices shows that *technical features* is a similarly prominent factor, being mentioned 178 times (79.1%), compared to price with 176 occurrences (78.2%). Other frequently mentioned factors were, in this order, *overall product quality*, *aesthetics and design*, *brand*, and *physical dimension*. Only in seventh place does an entry potentially related to sustainability concerns occur: *battery life* (or lifetime), which is followed by *energy consumption* in ninth place. *Manufacturing country*, *environmental sustainability*, and *recyclability* take the last three spots, being mentioned 12, ten, and two times, respectively.

(We could not find any patterns to connect decision factors with any of the demographic data; the few cases where environmental factors played a role were scattered evenly across gender, age groups, etc. Since the survey is not based on a representative user population, any correlations would not be statistically meaningful in any case.)

These results surprised us. We specifically targeted the survey at environmentally engaged participants, yet according to their own responses, environmental factors play only an occasional, marginal role in their choice of consumer electronics: out of the 107 times that one of the five environmentally relevant factors was mentioned by any participant, only 40 made it into the top three of their considerations, and only four times was one rated as the primary consideration.

Where were people who self-identified as environmentally concerned assigning low priority to environmentally relevant factors in their purchasing decisions? Were they not, after all, interested in the environmental sustainability of their consumer electronics purchases? Were other factors simply more important to them? Or are there barriers that keep people who are concerned with environmental issues from taking action based on those factors?

A look at some of the answers to the open-ended questions suggests that these explanations all play a role. Many did not bring up environmental sustainability at all, and even when they did, other considerations often took priority. For example, one survey responder mentioned: "*It is important for me that the device is environmentally friendly and cost-effective*", but in her purchase decision *price* was the primary concern ahead of *energy consumption*, while *recyclability* only came fifth (after *overall product quality* and *brand*). At the same time, some participants complained about the difficulty of acquiring the sustainability information required to make an informed choice (e.g., one participant complained that "*the information you need is always hard to find.*").

Considering such comments and the survey data as a whole, we are faced with some interesting questions: Why would environmentally engaged consumers dismiss or discount sustainability as a concern in buying consumer electronics? What are the problems that stop people from accessing and making use of environmental information for consumer electronics? And in order to

understand the situation in context, how do they make environmental purchases in other domains, and what makes purchasing consumer electronics different? To answer these questions and gain a deeper understanding of the topic, we designed a set of in-depth interviews.

3.2 Interview Study: Factors in the Electronics Purchasing Process

Given the meager evidence for sustainable behavior when purchasing consumer electronics among our survey participants, we felt a follow-up interview on the same topics with only participants from this sample would not be promising. Instead we decided to delve deeper into the motivations behind environmentally informed purchases, also in other domains, and at the same time investigate the exact decision-making process prior to consumer electronics purchases. By connecting this information, we intended to find out how exactly these practices differ and what the reasons for the different processes are.

We advertised online for potential participants, who entered their contact information in a short web form alongside an open-ended question where we asked them to elaborate on their commitment to the environment and which of their purchases sustainability plays a role for. Based on their answers, we selected 11 participants who seemed to have a strong interest in more than one product domain. The participants were aged between 21 and 42 (mean = 29.3, sd = 5.6), five female and six male, ten living in Switzerland and one in Germany. There was a variety of different backgrounds among the participants, including students, physicians, artists, IT consultants, a social worker, and academics.

The interviews lasted for 43 minutes on average (between 31 and 53 minutes). The semi-structured interview protocol focused on the story of their purchases, from the initial thought of buying an electronic device through acquiring information, how they did the product research, up to where and how they bought it. We probed for sources of information that helped during the decision-making process, but also for negative experiences and incidents where something went wrong. Furthermore, we were interested in environmental information they had and actively used when purchasing any other product, and asked them to tell us about a specific sample purchase. To get a more detailed impression of their take on technological artifacts, we asked for devices that they replaced recently, devices that they had for a long time, purchases of used devices, and the whereabouts of old devices that they no longer used (see Appendix A.3 for the full interview protocol).

Except for one interview that was conducted in English, all were held in the participants' native language (German). After partial transcription, all interviews were translated to English, though the original data was kept next to it to avoid loss of meaning or possible misinterpretation due to translation mistakes. We then analyzed the data using affinity analysis [Beyer and Holtzblatt 1998]. Affinity analysis is a process in which paper notes containing small text samples, in our case interview excerpts, are clustered in categories identifying a common message – their affinity. Our first research question ("What are the opportunities for Sustainable HCI to make an impact for sustainability on consumer

electronics?") served as a basis for the affinity analysis to derive the categories from our roughly 400 interview notes (Figure 3.1).

Figure 3.1: Overview of the final affinity diagram.

The term sustainability has a variety of different facets and interpretations in research, and its understood meaning also varied significantly among the interview participants. We use it as defined by Blevis [2007], with a particular focus in this paper on the ecological impact to the environment, in all stages of the product cycle. Our participants variously took it to include factors such as treatment of animals, conditions of manufacturing workers, social relationships between customers and vendors, and personal health effects from use of the products, and we encompass these perspectives.

3.2.1 Interview Findings

The interview study yielded a variety of insights about the use of environmental information specifically and current practices in general for purchasing consumer electronics. In the following, we summarize the findings that were derived from the affinity diagram. Based on these findings, we propose a set of design implications to help designers address these issues, overcome existing barriers, and provide consumers with more helpful means to inform their purchase decisions. The design implications are targeted towards systems that provide consumers with environmental information prior to their purchases and offer data about the environmental sustainability of consumer electronics products.

3.2.1.1 Sources of Environmental Information

We were interested in how our participants inform themselves in order to make sustainable purchasing choices. As it turns out, our participants were not able to do this effectively when it comes to consumer electronics, for reasons we will explore in the following sections. However, they did discuss their strategies in other product domains.

One area where all interview participants stated that they make environmentally-informed purchasing choices is food. Examples are eggs (P3: *"For eggs I buy generally not from cage systems or so, free range is the very least"*) or fruit and vegetables (P11: *"So in any case I buy only what's offered seasonally at the moment, and I always go to this organic stand, and I always buy my fruit and*

vegetables there"). These examples highlight two of the main factors for how to make this informed purchase: for eggs, consumers look at the labels, whereas in the second example the source itself ensures that P11 buys only sustainable products.

However, for many products much of the information gathering takes place before the actual purchase, and here various media play an important role in delivering more in-depth information:

> *"I also watch a lot of documentary movies about this topic [sustainability in general] and then when you go to the TV station's website about this movie, then there were indeed listed some websites."* (P6)

> *"You read about [sustainability] in a journal, then you look it up on the internet, and then of course there is more information as more links are listed, where [sustainability] strategies of other companies are explained, or you can click on the website for the certifications."* (P9)

Participants conducted most of their active research online. They get to these websites in different ways; in the examples above they were pointed there by a documentary and a journal, while other participants check certain websites frequently (P2: *"I just visit the H&M website frequently [to get information about organic cotton]"*). Some people even specifically search for environmental information on the internet:

> *"Yes, I gather [environmental] information on the internet for sure, or from leaflets [...], sometimes it's interesting to browse through them."* (P4)

Design Implication: Offer Information in Multiple Locations

Our interviews indicate that the process of making consumer electronics purchasing choices plays out in ways similar to how they make sustainable choices in other domains, albeit based on other factors than sustainability. Again we find two basic patterns. First, spontaneous purchases, where participants would just go to a store and base their decision on information from store signs, the shop dealer, or labels on the product itself. Second, the majority of our interview participants spent a large amount of time on product research on the internet.

Based on these patterns, environmental information should be available at multiple points in the product research process and accessible in many ways, such as from an online information resource, but also at the store in front of the product. Not only can this offer background information for environmentally concerned consumers, it may also attract the attention of people who have not previously been concerned about these issues, or who were not even aware that such information exists.

3.2.1.2 Lack of Usable Environmental Information for Electronics

One of the most prominent results, supported by data from all participants, is that they felt that there is almost no information about the environmental impact of consumer electronics available, such as information on the production process or recyclability and disposal of devices. Although all participants are interested in environmental information and take this into account for purchase

decisions for many other products, they did not have such data for electronic appliances. Some participants complained that even extensive research did not yield any environmental information, such as P7:

> *"Zero! There is absolutely no information about it. I've searched for that before, but there is zero [information about the production of electronic devices], as if it's unimportant".*

In some rare cases, participants reported having at least some anecdotal knowledge about the manufacturing of consumer electronics, e.g., P1:

> *"I know, for example, that a lot of the electronic materials come from… ehm… what was it… Democratic Republic of Congo, from the mine they have, and I know that the conditions and the circumstances under which those materials are being mined are just outrageous."*

At the same time, he acknowledged that this information did not help him in any of his purchase decisions, because as an end-consumer he was unable to connect this knowledge and information to a specific product:

> *"But those materials are gonna be bought from… I don't know… international companies… and those international companies move those materials to locations that are far away, I don't know where they are, I assume they are somewhere in Asia […] it gets pretty much impossible to track it down."*

Helpless to make an informed choice, he dismissed sustainability issues from consideration, instead taking the view that it probably didn't make any difference what he chose:

> *"I assume… most of the parts they use are being produced in the same factories anyways. So I don't assume that this phone is any better than the other phone."*

Information that the participants had access to, as in P1's example above, was often vague and of uncertain relevance, and thus did not affect their purchasing practices. The general finding also agrees with our preliminary survey results; many participants would like this information to make purchasing choices, but they were unable to find it.

The only kind of information about electronics that the interview participants had reliable knowledge of was energy consumption. And even this was reported by many as a vague figure, without any connection to a concrete idea of what it really means, especially in terms of the environmental impact:

> *"With the TV, I checked for energy consumption just because I know they use a lot of energy. If you would ask me in absolute numbers, I would have no clue. […] Energy consumption as a whole to me is very abstract."* (P1)

But participants were also aware that sustainability entailed more than just energy consumption. Many participants specifically expressed a desire for information about the manufacturing process: where is a device produced (P8), what are the circumstances for the workers (P1, P4, P6, P10), which materials are being used (P4, P5, P8), where do they come from (P1), how is the environment at the production site influenced and are plants, animals, or humans being harmed (P3, P11)? Similar concerns were raised about disposal of a device – who

is responsible for recycling (p3, p4), what happens to the materials (P7, P9, P11), and will the device even be recycled at all (P6, P11)?

However, there is an important distinction to be made here: when participants feel that information is not available, this does not necessarily mean that it does not exist. It rather implies that our participants, who were generally environmentally informed, were not able to find and identify the types of information that they sought. In some cases, they spent a considerable amount of time searching for environmental data, but were unable to find it through their usual information seeking channels, thus rendering it essentially unavailable from their perspective.

Design Implication: Offer Information about all Stages of the Product Cycle

Although the scarcity of usable, available information cannot be addressed entirely through design, it is indeed possible to make at least some environmental data available to partially address consumers' need for information. One participant mentioned an example where his cell phone manual provided him with useful advice about how to use the device in a more sustainable way and where to dispose of it once it is no longer being used. While the best solution would be to offer information about all stages of a product life, an information system to provide environmental purchasing decision help should at least show information about the expected environmental impact while using the product and on disposal. In general, environmental information of any kind is rarely offered for consumer electronics upon purchase, and future systems or applications should aim to close this gap.

3.2.1.3 Demand for Trustworthy and Reliable Information

Across all different domains we observed issues of trust. Participants expressed doubt in information provided by certain companies, labels, and even official certifications for organic products:

> *"You pay just for the label 'organic', and I think that's a little annoying."* (P4)

> *"Well, everybody's advertising that they are kind of 'green' because they don't use much packaging and don't produce much CO_2. To what extent they really do this – you don't know. […] everybody wants to be green."* (P8)

There were several instances where participants mentioned that they did not trust the information presented to them. However, in most cases they did not have any alternative information sources, which forced them to make trade-offs, in the end often acting on the basis of the unreliable information.

But apart from these issues of mistrust and unreliable information, there were also patterns of trust from participants into certain brands, labels, or products. For example, trust was established by having a personal connection:

> *"I support the Nokia brand. Because my father worked for them for a long time. […] Besides, I like the way they work, so I bought a Nokia again, there was no question about that."* (P9)

Once this trust is established, it can become an important factor in purchasing decisions. One participant went so far to say he would stick with it forever:

> *"If I liked the brand, then it will always be this brand. I'm not going to go there and think 'now you should try something else'."* (P10)

Similarly, participants tended to stick with one brand they considered sustainable. For example, P7 mentioned that she only buys cleaning products from a company that had a long history of sustainability, rather than companies that *"do this because they realized 'now there is a market for that and there is a demand'"*.

Participants were equally likely to form negative opinions about a company. In several cases their distrust was based on particular incidents or reports that made a strong and lasting impression:

> *"There was this list once [in the newspaper], which stores are like that [poor working conditions]. And that actually fit my preconceptions a bit, so it just confirmed it, and since then I make sure to avoid those stores."* (P6)

> *"There was a list from one institution, a German institute published a list, and measured the radiation of mobile phones. That was eight years ago. [...] It was a Sony Ericsson back then [that emitted the least radiation]. I bought that one, and I still have this device as of today."* (P10)

Design Implication: Prioritize Trust in the Data

Sustainability information faces a major trust issue. The proliferation of labels and certifications in many other domains has made consumers skeptical of superficially flattering environmental claims, which they perceive as greenwashing. They are not well placed to evaluate the trustworthiness of different sources, so their judgments are based on subjective factors and anecdotal information. As reported by many participants, single pieces of information can either build up or destroy consumers' trust in a label for years.

An information system must therefore be careful to ensure not just the integrity of its data, but that its trustworthiness is communicated effectively to consumers. Systems should aim to support transparency of data by providing evidence of sustainability claims, or indicating the use of trustworthy scientific or official sources, to help increase the level of acceptance and credibility for this environmental information.

3.2.1.4 Ease of Information Accessibility

Although environmentally concerned consumers may put a lot of work into researching the information, they are not necessarily experts, and sometimes find it impossible to get the data:

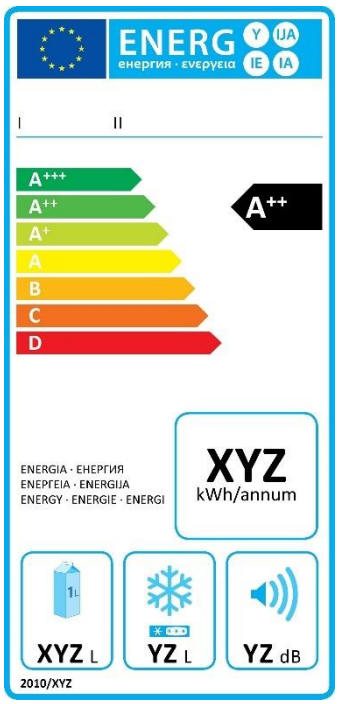

Figure 3.2: European Union energy label [CECED].

"For laptops, I have absolutely no idea [about environmental information]. You probably need to be a researcher to figure this out." (P5)

To overcome this issue and make a well-informed decision despite their lack of knowledge, there are two patterns that occur more frequently than others in our data. Firstly, consumers strive to become experts by reading up on the necessary information, mainly on the internet; secondly, they look for simple data that is easy to digest and allows for quick comparison.

For the first approach, which was almost the same among all interview participants when asked about their consumer electronics purchases, they would enter their product of choice in search engines and look for results. While some search for expert information, such as online websites of magazines or professional review sites, most interviewees relied on the knowledge of the masses, such as customer reviews at online stores or user forums. The usual approach of product research went like this:

> *"Google review, for example 'Top 10 LCD TV', then look at the results, then maybe enter model number with 'review' together, and then you get feedback, too."* (P8)

Many participants mentioned the drawbacks of this approach – there is an overwhelming amount of information that takes a lot of time to read. What some participants preferred instead were simple visualizations, as described by P11 when purchasing a laptop:

> *"There are always these bars or pictures or asterisks, I can't remember anymore, but with green colors. That's something I've always looked out for, like, what basically has the higher points, visually."*

Likewise, P4 claims that these labels enable quick comparison without the need to understand the whole matter:

> *"And then there's also... for the light bulbs, there are these descriptions, this bar chart, what category this is. This is also good if you don't know what these categories mean, like A, B, or C, but that one with the green bar is ok, you don't need to understand that."*

Many participants pointed out how useful these labels are, such as these two quotes show:

> *"The only thing that I as a dumb consumer can do is, I look at those labels, energy efficiency labels, and I want a TV that is in the 'A' label."* (P1)

> *"[For] the freezer, [...] there is this beautiful energy efficiency rating, from green to dark red."* (P7)

While they allow for quick comparison and evaluation of the products, participants were aware that this is just a visual guidance to make a more well-informed choice, and still requires thinking and consideration. When explaining the decision-making process upon purchasing a new fridge, P11 referred to the European Union energy label [CECED] (see Figure 3.2) and its meaning as follows:

> *"What do I know, watts per... no idea. And it also depends on the capacity in any case, and whether it comes with an additional cool box, etc. But, A++ isn't always equally good, if I have a giant refrigerator, it may also be that one with an A+ is better, if I have a small refrigerator."*

Design Implication: Provide Simple and Easily Accessible Information

Not all consumers are experts, and most consumers who search for information are not interested in becoming experts, either. Unless the consumer explicitly asks for it, all information should be as easy to digest as possible. However, to meet the consumers' demands for more background information as mentioned in other sections of this paper, these consumer information systems should provide environmental information about more than just one aspect of sustainability. To solve this conflict of offering a huge amount of information but still be easy to access, offer multiple views depending on what is appropriate and flexibility in the amount of detail should be offered to the consumer.

Design Implication: Make it Easy to Compare

Having one rating for one product without any scale is only helpful if the decision is to buy or not to buy a product. As the examples from the findings indicate, some consumers like to have simple labels such as the energy efficiency label, where they can simply compare different products and make their choice based on environmental information without the need to understand all the data behind it.

3.2.1.5 The Influence of Personal Experiences and Connections

An important factor in participants' purchasing-decision-making process was the shared experience from other customers with similar products and similar circumstances. For example, P7 lives in an area in the mountains where the satellite television reception is poor on most devices, and therefore she searched for consumers who experienced the same issue:

> *"Customer reviews from people who live in a similar area as we do, because that's causing a lot of trouble."*

In a similar way, participants found certain aspects of sustainability to be more relevant to them. Also in this case, personal experience was an important factor in creating interest. Experiences that made participants relate issues to their personal life did not just influence their attitudes slightly, but sometimes changed their thinking completely:

> *"Like for example child labor, it was not a big thing for me before I had a child on my own. That's where it starts... like, if it concerns your own life, then you start to think about it."* (P5)

Likewise, personal experience and seeing things happen with their own eyes also changed purchasing behavior, such as for P8:

> *"Of course there are already certain things that you should pay attention to, such as that not everything is 'Made in China.' I myself was in China for 6 weeks, and it's not nice how they work in the factories over there."*

We observed this connection with environmental information not only by participants who experienced something personally. Having an emotional connection caused similar effects and shaped their view on certain issues:

> *"Everything that contains palm oil is unsustainable; which is to say virtually all foods, almost. And in this candy bar it's definitely in there, and these palm oil plantations are… I think it's planted in Borneo, and there the rain forest is cut down and orangutans die because of that."* (P11)

In the decision-making process of purchasing consumer electronics, personal experience came into play in a different way. Whereas many participants consulted customer reviews, the final decision to buy a product was often heavily influenced by a friend, who was considered a trustworthy source with expert knowledge. These personal contacts oftentimes provided the decisive opinions, such as in these two examples:

> *"I have informed myself a bit before, but I find it incredibly difficult to inform myself via the internet for consumer electronics or electronics in general […] if I can't really judge the individual differences really well… for that I just called my friend, then."* (P9)

> *"Then I search for my stuff with my criteria, and then my husband looks at all the devices that I chose, and decides what is technically acceptable. That's how it goes, usually."* (P2)

In ideal circumstances, then, well-informed friends and family members (often with first-hand experience) provided highly trusted advice by, and in a way that our participants could readily understand and apply.

Design Implication: Allow for Sharing Experience

Sustainability information systems should allow people to share their experiences and establish connections with others who have similar concerns. Opinions from other consumers with shared experiences or personal connections to participants were generally influential in purchasing decisions. Participants aimed to identify others with similar backgrounds, or relied upon known, trusted information sources. When searching for environmental information, the integration of personal experiences and, connections, may positively influence the perception of provided sustainability information.

3.3 Discussion

Our initial goal was to investigate environmentally-informed processes for purchasing consumer electronics. However, as our survey and the interviews revealed, there is an apparent lack of accessible environmental information for consumer electronics. Therefore, we refocused our study with two goals: first, we aimed to understand how environmental information was used in purchasing

in general; second, we aimed to understand the barriers to challenges to incorporating environmental information into electronics purchasing. Our data surrounding the former demonstrated that participants bought a variety of non-electronic products taking environmental information into account. This indicates that these people were not merely claiming to be environmentally concerned, but took interest in such matters and sometimes had extensive knowledge about sustainability in general.

Regarding our second goal, our interviews revealed that little environmental information about consumer electronics was available to them, confirming our survey results held even with a user population of environmentally-concerned participants. Many participants stated that they searched for information, but could not find what they sought, such as information about the manufacturing process of consumer electronics. But is this information really unavailable?

Although participants claimed that they did not find the detailed environmental information they were looking for, this does not necessarily imply that this data is entirely unavailable. In fact, useful and reliable sources of information exist, although participants were unable to access it through their familiar information channels. For example, *SourceMap* [Bonanni et al. 2010] provides carbon footprint data about products, including a small number of electronic devices; likewise, the *Eco-Benchmark* [Nissinen et al. 2006] offers labels to inform consumers about a variety of environmental data, though it was never made publicly available. The underlying data in both cases comes from a *Life Cycle Assessment* (LCA) [European Commission: LCA n.d.] database that contains much of the information requested by participants. Unfortunately, this data is not accessible to consumers, and due to its comprehensiveness and complexity is not readily comprehensible to individuals without specialized knowledge of LCA. *GoodGuide* [GoodGuide, Inc. n.d.] also uses LCA data as a source for environmental information when available and fills remaining gaps with information from various other sources, mainly scientific data. We believe that identifying new information sources and making them accessible to consumers to satisfy their need for environmental information is a key longer-term research goal.

3.3.1 Barriers to Making Environmentally-Informed Purchases

The lack of environmental information that consumers perceive is a symptom of a more complex underlying situation, as much of the desired information may exist though it is not easily available. We believe that the four other findings we

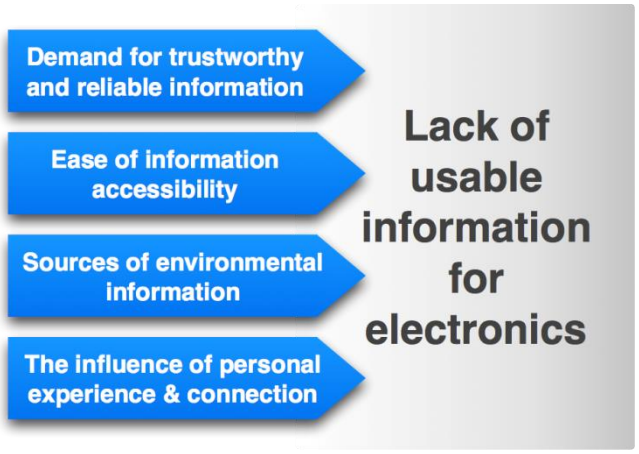

Figure 3.3: Four factors contributing to the lack of information. (Image courtesy: Daniel Greenblatt).

identify in this paper contribute to the perceived lack of environmental information, and present barriers that research needs to overcome (Figure 3.3):

Participants reported issues of *trust* in given environmental information, which then resulted in decisions made based on other factors, deprioritizing environmental information. People only accept information that they perceive to be trustworthy and reliable; otherwise they disregard it and refrain from including it in their consumer electronics purchasing process. Establishing trust in information is a difficult design challenge, but a critical one for achieving user acceptance.

Another barrier we discovered was a lack of *accessibility* of environmental information. While there are consumers who spend significant time on product research and also environmental information retrieval, not every participant had the time or patience to put in extensive effort. If the information is hard to access, consumers may overlook it and interpret this as a lack of environmental information. Fortunately, the skills of HCI designers are well suited for creating usable, simple, and accessible systems that allow for quick comparison.

The *sources* of information that customers use to search for environmental information do not contain the data they seek. Although we observed several different approaches to information research for other products, such as on-product information for food items, occasional information from newspapers or documentaries, and information from websites, our participants were not able to make informed choices regarding electronics. Adapting existing or creating new information sources for consumers at multiple locations can help address this issue.

Furthermore, we identified *personal experiences* as one of the main drivers in the decision-making process, both in purchasing consumer electronics in general and in accepting environmental information. Taking advantage of existing experiences and fostering the identification personal connections can contribute to increased acceptance and help overcome the lack of environmental information.

3.4 The Lifecycle of a Product

Our study discovered that even environmentally-minded consumers are rarely influenced by factors pertaining to sustainability when purchasing consumer electronics. The reasons for this are manifold as elaborated earlier, but two of the main issues can be summarized as environmental information being too complex to understand or not trustworthy enough [Remy and Huang 2012]. As we learned from our excursion to marketing research, deliver information to consumers in meaningful ways in order to affect their purchasing behavior is neither a new issue nor a simple and straightforward task. Despite there being many different points in the purchasing decision process that can be targeted to convey a message about the product [Remy and Huang 2012], the successful delivery and reception of such information does not guarantee a change in action regarding environmental behavior [Jackson 2005]. This aligns with more recent observations in SHCI that discuss the effectiveness of persuasive technology in general and call for a rethinking thereof [Brynjarsdottir et al. 2012; Knowles et al. 2014].

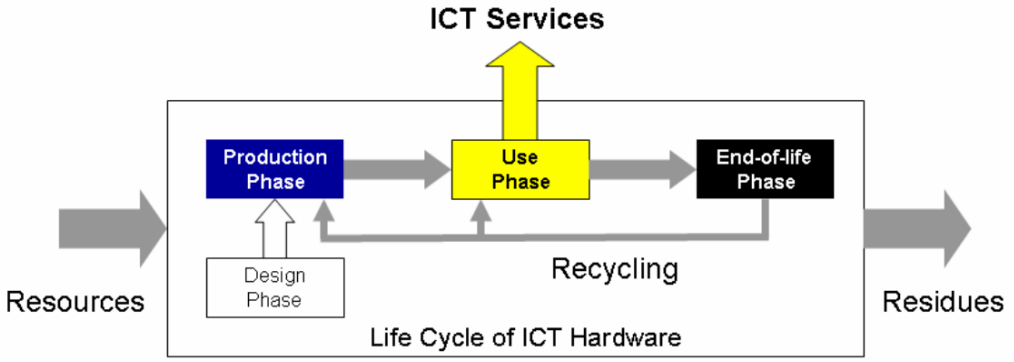

Figure 3.4: The life cycle of ICT hardware. (Courtesy of Hilty et al. [2008], © iEMSs 2008).

Considering those issues, it is time to take a step back and reflect on our initial research question: "What are the opportunities for Sustainable HCI to make an impact for sustainability on consumer electronics?" We emphasize that providing information to consumers is only one potential approach of many. Despite the multitude of different ways to tackle obsolescence through persuasive technology, such as providing information to customers, their impact mostly concerns the same phase in the lifecycle of products; the "use phase" (Figure 3.4) [Hilty et al. 2008; Hilty 2008]. However, it is a rather indirect approach that hopes to achieve change through the combined consumers' actions, and its effectiveness has been questioned by SHCI researchers [e.g., Dourish 2010; Khan 2011; Mankoff 2012]. Besides the meager chances of success for individuals' collective behavior creating an effect on the market, Dourish notes that this approach obscures *"important areas for engagement by placing the emphasis upon the actions of consumers rather than states and corporations*". Therefore, we consider the entire lifecycle of a product (Figure 3.4), for which

Hilty et al. name five approaches how technology can address sustainability [2011]:

1. Optimizing the design of other products;
2. Optimizing the production of other products;
3. Optimizing the use of other products;
4. Optimizing the end-of-life treatment of other products;
5. Modifying the demand for another product, either by
    a. Substitution (decreasing demand) or by
    b. Induction (increasing demand).

Going back to the initial claim of Blevis in his seminal paper [2007], sustainability should not just be one of many aspects applied to a design in later stages, but instead it should be one of the main driving aspects from the ideation of the very first design of a product. If the design of a product inherently leads to more sustainable behavior, it is much more powerful and successful than applying sustainability concerns to existing designs or even just encouraging consumers to use or dispose of their products more sustainable. Khan [2011] calls this *Upstream Design: "moving the focus of HCI efforts upstream to product design could have a multiplicative effect, as the production of goods and services is closer to the source of non-renewable consumption choices*". Therefore, we will focus our efforts on the first of the five approaches listed by Hilty et al. [2011] – addressing the design of products.

In Section 2.2 we highlighted the rich body of literature in SHCI on the issue of obsolescence, including many of them focusing on design-oriented solutions. Despite all those concepts and the increased pressure for more sustainable products – both by regulations [e.g., European Commission: LCA; Basel Convention 1992] as well as fostering a public image of being a green company – there is almost no evidence for any of those concepts from SHCI making their way into practice. This is not a new phenomenon but well-known in the general field of HCI as the theory-practice gap [e.g., Rogers 2004]. In the next chapter we elaborate on this gap, its history in HCI, and its particular significance for SHCI. Furthermore, we present a preliminary study that investigates into bridging this gap by bringing SHCI knowledge to practitioners.

4 ADDRESSING THE THEORY-PRACTICE GAP[4]

In this chapter, we explore how SHCI can be better applied to practice. First, we elaborate on the mismatch between SHCI research and its representation in sustainable design practice – the theory-practice gap – and its history in HCI. To investigate potential issues in bridging the theory-practice gap, we then report on a study that takes one instance of SHCI research, the Attachment Framework [Odom et al. 2009], and ask product designers to apply it to their design process. We discuss the results of this design experiment and highlight lessons learned for addressing the theory-practice gap.

4.1 BACKGROUND

The lack of theoretical contributions being applied to design practice, commonly referred to as the "theory – practice gap", was discussed in the last decade [e.g., Sutcliffe 2000; Rogers 2004] and is still an ongoing topic [e.g., Stolterman 2008; Roedl and Stolterman 2013] in the CHI community. This point has also been raised in SHCI, and some seminal works have argued for application of SHCI research to design practice [e.g., Blevis 2007] or criticized the lack thereof [e.g., DiSalvo et al. 2010]. Previous work in SHCI has looked at successful examples of sustainable interaction design, in particular in the domain of eco-feedback technology, which has been one of the most active fields within SHCI. For example, Pierce and Roedl [2008] as well as Strengers [2011] looked at existing eco-feedback technology in the home, highlighting sustainable design in the wild as success stories and drawing valuable lessons for the field. Furthermore, several researchers have built prototypes for the sake of field studies in various domains, such as citizen science [e.g., Aoki et al. 2009; Kuznetsov et al. 2011b; Kuznetsov et al. 2011a] or water conservation [e.g., Arroyo et al. 2005; Kuznetsov and Paulos 2010] that highlight examples of SHCI design in practice, as a proof of concept and often applied by SHCI practitioners themselves.

While these efforts demonstrate that SHCI is addressing the concerns raised about HCI design principles in general (i.e., that those principles are not even applied by the researchers in the respective field itself [e.g., Rogers 2004]), there is still a gap between available frameworks and their application to real-world practice. The goal of sustainable interaction design is to make environmental sustainability a central focus in design practice [Blevis 2007]. A variety of theoretical contributions offers opportunities for such high-impact design, e.g., design principles for sustainable mobile phones [Huang and Truong 2008], more ecological use of time and travel [Reed et al. 2005], or resource consumption in the home [Chetty et al. 2009], to just name a few. This design knowledge is frequently used to fuel other ideas in SHCI and these works have yielded fruitful discussion within the community – however, there is little evidence that it is being transferred to practice and little knowledge of how well it could support design. There are case studies about students [Hauser et al. 2013], do-it-yourself

[4] Contents of this chapter have been published in a conference paper [Remy et al. 2015] and a workshop paper [Remy and Huang 2014].

practitioners [Kuznetsov et al. 2011b], and professional product designers [Grosse-Hering et al. 2013] that investigated the use of sustainability principles being put to design practice.

In this chapter, we want to extend on this previous research and stake it one step further by investigating how SHCI frameworks can be applied to practice. Our research is guided by the following research question:

> RQ2: How can existing sustainable design frameworks be leveraged to provide assistance in the design process of consumer electronics?

In the following, we report on a comparative study including an expert analysis to yield qualitative insights about the value of one SHCI theoretical framework – the Attachment Framework [Odom et al. 2009].

4.1.1 The Attachment Framework

The Attachment Framework is an established framework in SHCI research, being initially introduced by Odom et al. [2009] comprising four criteria. It is based on the Personal Inventories method [Odom 2008] and has been adapted and reused since its inception, including an extension by Gegenbauer and Huang [2012a] reaffirming the original four criteria and adding three additional ones, with a particular focus on technology. We believe that this framework lends itself particularly well to a case study of exploring SHCI design practice for two main reasons. First, it is a well-established, empirical framework and initial attempts of applying it to practice have suggested its usefulness [Gegenbauer and Huang 2012a]. Second, the strength of the Attachment Framework is that it appeals to consumers on an emotional level rather than due to technical features. Not only are those features especially short-lived in the realm of consumer electronics, but emotional appeal has shown to be a powerful factor in establishing long-term relationships between owner and their objects [e.g., Norman 2004].

In their initial study, Odom et al. [2009] surveyed people about objects that they felt attached to, such as heirloom items, collected stories about the shared history between the object and the owner, and identified common themes for the attachment's reason. The resulting Attachment Framework offers design principles, accompanied with examples, which can be applied to new designs to achieve a similar effect. The Attachment Framework was extended by a follow-up study which in particular aimed to identify design principles for fostering attachment in the domain of consumer electronics [Gegenbauer and Huang 2012a], resulting in seven principles:

- **Histories**: Preserve memories connected to the device
- **Augmentation**: Re-use beyond its intended purpose
- **Engagement**: Promote physical engagement in use
- **Perceived Durability**: Long-lasting in terms of function or longevity or both
- **Earned Functionality**: Device is continued to be used because of the effort put into becoming familiar with it
- **Perceived Worth**: High perceived value of the device
- **Sufficiency**: Capable of serving its intended purpose

4.2 Study Design

In order to understand the impact of theoretical frameworks from SHCI applied to design, we choose tablet computers for the design activity. We gave the extended version of the Attachment Framework [Gegenbauer and Huang 2012a] that is specifically directed towards electronic devices to designers and assessed the outcome in terms of quality of overall design as well as the understanding and interpretation of the attachment values as a means of evaluation. Using an extended version of the Attachment Framework that is directed towards electronic devices allowed us to use picturesque examples "as is", thus reducing potential bias in our study design. The benefits of using examples to foster the creation process have been studied in HCI before [Hauser et al. 2013]. In the following, we will elaborate on the study design (step 1), the evaluation of design quality (step 2), and our analysis of the results (step 3).

4.2.1 Step 1: Data Collection

We asked designers to create 2-4 preliminary design sketches of a tablet computer that fosters a strong bond between the device and its owner. We explained the basic concept of attachment as a way to promote environmental sustainability in a brief statement without giving away any details of the framework's design principles. Participants were then divided into two groups, with one of these groups receiving supplementary material explaining the Attachment Framework in detail, and the other group acting as control group that was not given any further advice. This ensured that both groups were on the same track with regard to their design goal, and the only difference was the framework whose value we wanted to assess. The supplementary material included a four-page document with the Attachment Framework principles (engagement, earned functionality, augmentation, histories, perceived durability, perceived worth, sufficiency [cf. Gegenbauer and Huang 2012a]). Each of the principles was illustrated by 2-4 non-technical examples by using unaltered participant quotes from the original study [Gegenbauer 2011]. The design task was created in collaboration with a design expert and piloted with three designers to ensure that it did not deviate from the designers' typical process.

Fourteen participants were recruited using convenience sampling and split into two groups, having equal size of the framework group and control group (7 participants). Participants averaged 3.8 years of experience (st. dev. 1.6 years) and were compensated with a $100 US Amazon voucher. Participants' expertise was in product design, except for one participant who was an interaction designer. Their secondary expertise was in industrial design (four participants) and architectural design (two participants). Gender distribution was equal (seven female, seven male). The majority of participants were between 20 and 29 years old, and one was in his thirties. All designers were recruited in major central European cities and the study was carried out in the participants' native tongue. Based on their background information and previous experience, both groups of designers had similar experience in practice.

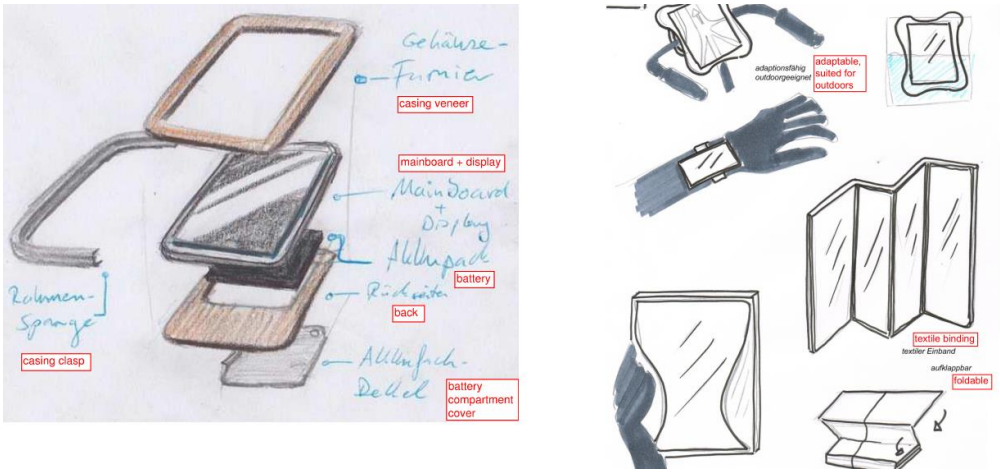

Figure 4.1: Two excerpts from example designs from the design exercise.

The designers received their task via email and sent us scanned copies of their design sketches. We asked them to include explanatory details, such as annotations, descriptions, or storyboards with the design sketches. Altogether, the participants generated 40 design sketches (21 from the group with framework, 19 from the control group), from 1 to 5 per designer. After completing the design task, all participants answered survey questions about their design background, previous experience in "green design", their typical design process, their approach for this particular task, and their thoughts about the activity (e.g., satisfaction with their sketches and difficulty of task). Two of the designs can be seen in Figure 4.1.

4.2.2 Step 2: Evaluation by Design Experts

To assess the value of the Attachment Framework and see what effects it had on the designs, we recruited ten design experts to analyze the sketches according to six different criteria. Besides the "attachment" criterion, which encompasses the basic idea of the Attachment Framework itself, it is important to consider other aspects of design as well, since attachment alone does not suffice for a design to be successful or of good quality. The criteria were developed from surveying product design literature [e.g., Demirbilek and Park 2001; Morris 2009], product design award criteria [e.g., IDSA; iF Design Award; Red Dot Award], and basic industrial design principles [e.g., Ueki-Polet and Klemp 2009]. They were refined through pilots of the evaluation with design experts, and the final criteria were:

- **Attachment** (does the design encourage longer use and foster attachment between the device and its owner)
- **Creativity and novelty** (is the design idea original)
- **Presentation** (is the design clearly communicated and well-presented)
- **Aesthetics** (how aesthetically pleasing is the design)
- **Usefulness** (would a product based upon this design be useful and effective)
- **Feasibility and credibility** (is the design idea feasible, credible, and applicable to a real-world product)

The design experts (two female, eight male) had an average of 4 years of training (st. dev. 1.6 years) and 7.5 years of working experience (st. dev. 4.6 years). Participants had a diverse, often multidisciplinary background and identified their specialization as product design (7), interaction design (7), industrial

design (4), and graphics design (2). While we told the evaluators that the task was to create tablet computer design sketches that fostered attachment, we did not give them the Attachment Framework itself nor tell them that this was a comparative study in which one of the group had received such a framework. Since pilots revealed that the evaluation took a significant amount of time, we decided to split the designs into two groups of 20 designs each, resulting in two interchangeable sets. All annotations and descriptions on the design sketches were translated into English and were visually distinct (delineated by a red text box) to distinguish the added translations from the original design sketch. We encouraged the experts to be critical since we did not pass the feedback to the designers.

We asked designers to select up to three designs that they felt best met each criterion and provide a justification for their choices. Pilot participants expressed concerns about exhaustion towards later criteria that might result in shorter answers, which is why we alternated the order of questions using a Counterbalanced Latin Square distribution. Participants had a choice to complete the task digitally at their computer or hand-written on paper, as the evaluation sheets were printable PDF forms. The activity was accompanied by a short eight-question survey about their background, design process approach, and experiences with regard to sustainable design. Participants received an Amazon voucher worth $50 US or 40€, as preferred.

4.2.3 Step 3: Analysis and Attachment Evaluation

For the analysis of the evaluation results we were mainly interested in qualitative data from the design experts' justification for their selected designs. We analyzed the data using open coding to search for common themes across the comments for each of the criteria on the quality of the design sketches, in particular themes that would only occur for either the framework or non-framework condition. Our approach was to find patterns and themes in the evaluation responses, according to the six different criteria.

The criterion "attachment" was arguably one of the most important ones to us, as it aimed to assess the core aspect of the framework and how designers interpreted it. However, most design experts indicated in their survey background questions that they had no in-depth knowledge of or experience with sustainable designs, and none of the experts had any knowledge about the Attachment Framework as such. Therefore, we added an additional evaluation step by asking three Attachment Framework experts to go through all 40 designs and, for each of the seven Attachment Framework criteria, decide whether or not they think the design exhibits this particular criterion.

We will refer to the designs as FD1 to FD21 for the designs from the framework group and CD1 to CD19 for the designs from the control group. E1 to E10 refers to comments from the evaluators. For example, E7-FD13 would be the justification provided by evaluator 7 about why she picked design number 13 (which happened to be from the framework group) for a specific criterion.

4.2.4 Limitations

Despite the relatively high incentive, all participants recruited for the first study were relatively young and had only a few years of working experience. One of the reasons may have been the rather substantial work load of the study (pilots indicated an estimate of four hours of work time). Another limitation was the fact that both studies were conducted remotely; however, especially for recruiting evaluators a remote study allowed us to get a diverse set of experts from all over the world. Furthermore, we only look at one specific family of devices with tablet computers, and we acknowledge that the results might not be representative findings regarding attachment for other technical devices.

4.3 RESULTS

In the following, we report on the insights from our data analysis in detail, grouped by the six design criteria that were used in the expert evaluation. While the framework seemed to have no effect on the *attachment* values communicated in the designs, there was a noticeable effect on *novelty and creativity* of the designs. However, this advantage came at the price of seemingly losing out in two other criteria, *aesthetics and presentation*, and a tie in the *usefulness* and *feasibility* criteria. Overall, the non-framework designs were mentioned slightly more often than design concepts by the framework group (85 vs. 72, not significant with $p=0.102$ for χ^2), and the qualitative results did not clearly favor one of the groups either.

4.3.1 Attachment

Since the task was to create a tablet computer that fostered attachment and this study was about evaluating the impact of the attachment on design, this was arguably the most important design criterion for us. Therefore, the results of this part of the evaluation were the most surprising for us: we found no evidence that the group of designers that had been given the Attachment Framework produced any better results in that regard compared to the control group. Our design experts selected eleven designs from both groups respectively that stood out as showcasing a particular idea of encouraging a stronger bond between a device and its owner. Likewise, the derived themes from the design experts' responses spanned across both groups of designs.

One design concept that was frequently mentioned was the material and its ability to develop patina or a worn-out effect over time, as was mentioned by these two evaluators: *"the use of tin as material is unconventional and nice. tin tells a story. it is used by products that proved to be able to survive under all circumstances. using materials that collect patina is essential I think.it makes a product a personal belonging" (E6-CD1)* and *"The feeling of attachment comes when something looks more aesthetic and apealing. The unique patina background will help the user with that sense of attachment. An analogy to the above is my jeans. The older it turns the more attached and more comfortable I am to that jeans" (E10-CD15).*

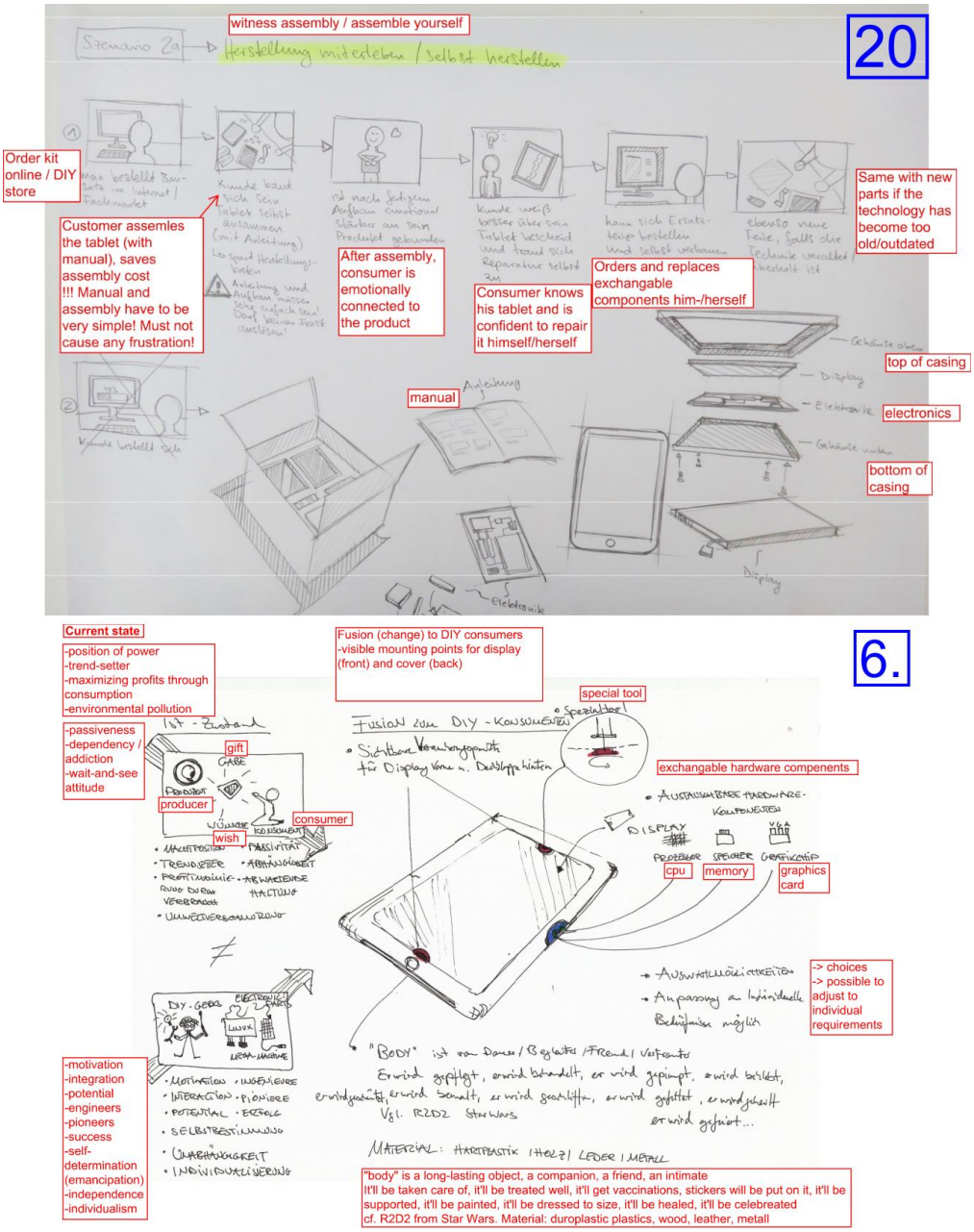

Figure 4.2: (a) top - design CD19; (b) bottom - design FD11.

Similar remarks were made by other design experts (e.g., E1-CD15, E3-CD5, E4-FD12, E4-FD18, E5-CD15). Another example for a design approach that participants thought of as fostering attachment was that of being able to replace parts (FD11 and CD19, see Figure 4.2): *"Exchanging parts will keep the device up-to-date through more than just software updates. It is less likely to become obsolete."* (E1-FD11) and *"the possibility to exchange parts as they break or because of changing preferences helps the product to survive over a longer period of time"* (E4-CD19). Other themes that we found in our analysis were personalization of the device's hardware (E3-FD6, E5-FD11, and E8-CD10) and software (E3-CD16, E8-CD16, E9-FD5, and E10-FD21).

4.3.2 Evaluation by Attachment Experts

One might argue that this result is not surprising or has little validity as the design experts were not experts in sustainable design or had no knowledge of the Attachment Framework besides the short introduction provided by us. However, the evaluation of attachment criteria by the Attachment Framework experts yielded similar results: counting every single instance of attachment identified in all of the designs, the evaluators found 103 in the framework group and 77 in the non-framework group (not significant with $p=0.246$ for χ^2). This becomes even more apparent if we look at instances for which two or all three evaluators agreed on one criterion for a specific design: for eleven (framework) and eight (non-framework) designs all experts identified the same criterion; for fourteen (framework) and twelve (non-framework) designs at least two experts agreed on the same attachment value. An interesting observation was that there was less agreement on the attachment criteria than one might expect, especially given that all three evaluators had the same background.

4.3.3 Novelty

In terms of novelty of the design ideas, this was the only of the six design criteria where the framework-supported designs achieved clearly better results in the evaluation. The design experts deemed ten such designs as more creative and novel (17 comments), and only five of the control group (seven comments). We found three themes that were present in both groups: unusual choice of material (E7-CD1 and E10-FD6), development of patina (E6-FD18 and E10-CD15), and an adaptive user interface:

> *"This design concept focused on an interface that adapts to the user and gets to know her, in turn building loyality. It anticipates my needs - a big trend as we move to smarter devices and software." (E1-CD16)*

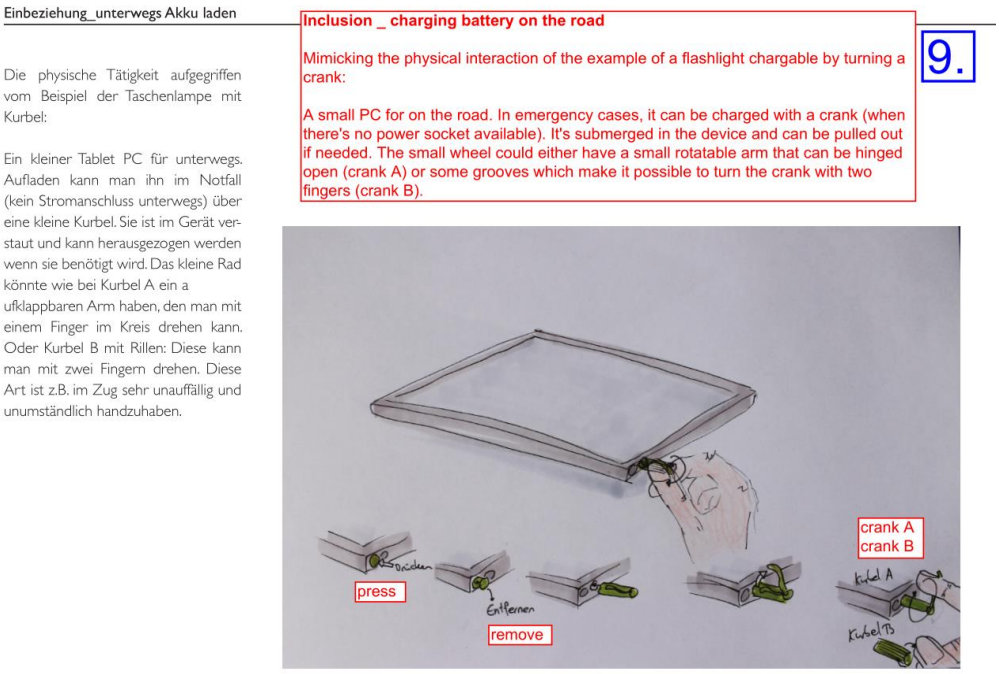

Figure 4.3: Design FD17.

"I think the thought about the computer interface that adapts to the user is quite novel and is definitely a step forward from todays UI paradigms" (E4-FD5)

A similar notion was observed by the same design expert in E4-FD21. Furthermore, two design concepts were mentioned for the non-framework group only: a foldable display (E2-CD4, E4-CD4, E5-CD5) and a design sketch that showcased multi-purpose use in context (E5-CD9), which was praised for its flexibility. Interestingly, a sketching tablet received critical acclaim for the opposite concept – a single-purpose device focusing on one task only (E6-FD9).

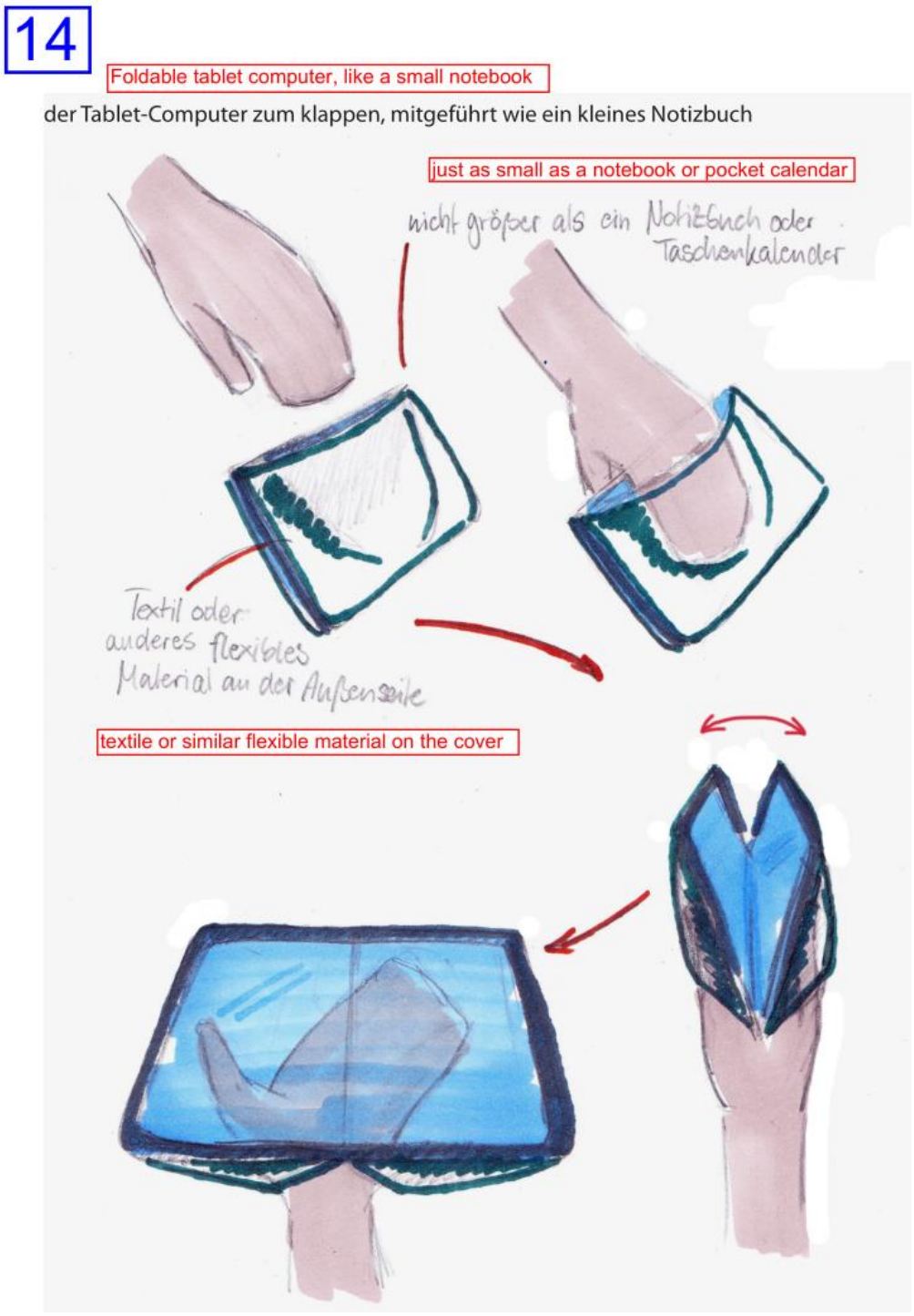

Figure 4.4: Design CD5.

All other themes of novel concepts (e.g., exchangeable parts, personalization, visual feedback through changing color) occurred in the framework group only. However, there was no overlap between ideas within that group either – rather, one idea per design was seen as the core novel aspect or creative design concept. Three of these novel concepts were mentioned by multiple evaluators: a tablet computer that could be re-used to serve a new purpose (FD7, mentioned by E1 and E3); a display frame that would change its color according to battery charge left (FD21, mentioned by E2, E6, and E7); and a small lever that allows for a quick emergency battery recharge by winding up (FD17, see Figure 4.3, mentioned by E3 and E8).

4.3.4 Connection between Novelty and Attachment

Upon identifying those themes, many of them were features that can be attributed to sustainable design, which led us to ask the question if there is a connection between the novelty aspects as identified by the evaluators and the attachment values as provided by the framework. We therefore added an additional layer of analysis: all of the evaluators' comments for the novelty aspects were analyzed with regard to values of the Attachment Framework. Three Attachment Framework experts individually decided for each comment about novelty if it resembled one (or multiple) of the attachment criteria.

Similar to the attachment evaluation, there was a strong subjectivity noticeable in the results. Only for three designs did all evaluators agree on one attachment criterion; for most of them (seven) two evaluators identified the same attachment criterion. For two designs the attachment criteria were different, and for the remaining three designs only one evaluator found that the novelty aspect was connected to attachment. Overall, 40 instances of attachment were identified in the novelty comments and only eight times was no criterion found to be present in the novelty justification, whereas at least one attachment expert saw attachment criteria present in any of the designs. Two examples for the novelty-attachment relationship can be found in Figure 4.2 (b) and Figure 4.4: E5 praises CD5 (Figure 4.4) as *"the designer re-considers the form factor"* in the novel foldable design, while E3 points out that the *"similarity to a pocket diary/wallet would make it more likely for users to foster an attachment"*. Similarly, E1 considers FD11 (Figure 4.2 (b)) to be novel as *"this design went the opposite direction [to the throw-away paradigm], emphasizing exchangeable parts"* which contribute to attachment as they *"will keep the device up-to-date"* and *"less likely to become obsolete"* (E1), and even allow for *"strong personalization"* (E5).

4.3.5 Presentation

The criterion of presentation quality yielded the most clear-cut result: only seven times was a design sketch from the framework group among the top three, compared to 20 from the control group. As mentioned earlier, we notified participants that we were to blame for the text clutter since we provided red-colored translations to the original designers' comments. However, the designs produced by the framework group already had a significantly higher amount of text and our added translation multiplied this clutter effect. The designs that were selected for best presentation, on the other hand, were those that came

with less text and more polished graphical concepts, with two exceptions: *"Concise text. Simple reference points. Easy to understand instantly." (E6-FD9)* and *"Very well explained on how the complete flowchart would look like. Different ways to personalize your tablet is presented with good description and clearly communicated" (E10-FD6).*

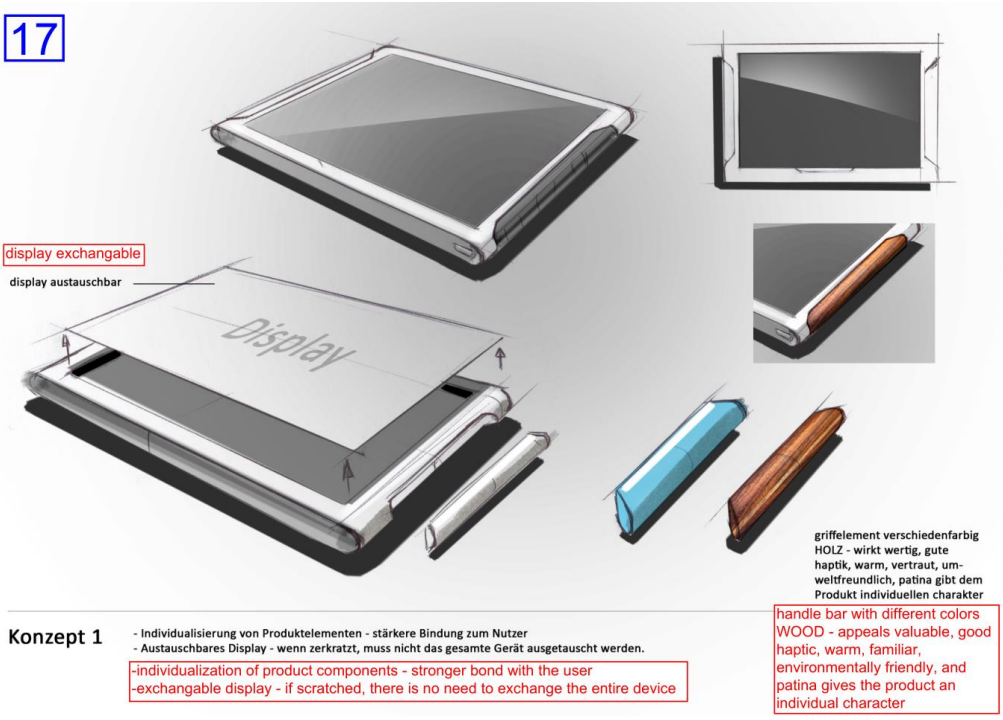

Figure 4.5: Design CD12.

The majority of comments, however, expressed a preference for sketches that were understandable without requiring the reading of large amounts of text (E7-CD1: *"I don't need to read anything and I get it immediately"*) or praised good drawing skills. One evaluator even presumed that the concept was created by someone *"who knows how to render 3D objects with light + shadow"* (E1-CD13). CD12 (see Figure 4.5) stood out as it was praised by four different design experts for its *"good rendering"* (E2), *"detailed product design sketches"* (E4), being *"easy to understand within seconds"* (E7), and ready for *"showing [it to] a client"* (E9).

4.3.6 Aesthetics

Designs from the control group were more often mentioned as being particularly aesthetic (18 times) than framework designs (ten comments). Interestingly, if we were to look at the number of designs those comments were attributed to, it is evenly split among both groups (nine each) since three designs in the control group were mentioned repetitively by at least three evaluators. Four design experts (E1, E3, E6, and E8) mentioned patina as an aspect that would lead to increased aesthetics of the device. This was especially surprising as the two sketches that the evaluators referred to were produced by the control group (CD1, CD15) only. Surprising because patina was identified as a theme for the novelty and attachment criteria as well – but in those cases, stretching across both groups.

Besides other single mentions that we cannot really classify as themes (e.g., *"'easy-to-carry' style"*, E3-CD5; foldable display, E2-CD4), there were three main aspects that the design experts highlighted as particularly aesthetically pleasing. First, showcasing context of use (E5-FD7, E6-FD7, and E6-CD14), which might not appear as an aesthetic property as such, but E5 justifies it as follows: *"The idea has [s]ome poetic value, as the designer con[s]iders the device part of an environment"*. Second, exchangeable parts contributed to the aesthetics of two designs (E2-CD12, E3-FD6, and E7-CD12). Third, the most frequent pattern across all sketches that the design experts found to be aesthetically pleasing was the choice of material (e.g., E1-CD9, E4-FD16, E8-CD2, and six more). This differs from the patina theme as the evaluators' point was not about gaining a visually pleasing effect over time, but that the design came with a *"classy and high quality metal"* (E7-FD18) or *"ruggedness"* (E1-CD2) by default.

4.3.7 Usefulness

In raw numbers, the non-framework group was slightly ahead, with fourteen comments on this criterion, compared to twelve comments by the framework group. However, in terms of themes that emerged from our qualitative results, there was no clear winner. Several of the features that were attributed to usefulness did not fit onto overarching patterns and therefore stood out as single concepts depicted in one design, such as a sturdy and break-proof design (E1-CD9) or a wind-up crank for quick battery recharge (FD17, see Figure 4.3). The latter received positive comments from three evaluators: E3 liked *"the combination of such an old-fashioned mechanism with a high-tech gadget"*, especially if it were to be coupled with a *"cute charging UI"*, E5 envisions *"the user [to be] more mobile and less dependent from infrastructure"*, and E10 notes that the mechanism *"is the need of the hour [...] and can help one for longer use"*.

One theme we identified in three designs was adaptability (E1-CD16, E3-CD16, E5-FD5, and E10-FD4). E1 pointed out: *"A device that learns my needs and behavior, leading it to adapt is incredibly valuable in streamlining my life"*. While this pattern of usefulness mainly referred to software and user interface features, the most frequent themes were flexibility (six designs) and the ability to transform (five designs), originating from either group. A quote for the justification of E5-CD9, summarized the evaluators' opinion about design concepts quite well: *"A tablet that can be mounted in many different ways and places is very useful, and I liked the mention of future technology-screens that are foldable, durable and not so precious"*.

4.3.8 Feasibility

As with usefulness, feasibility and credibility of the design sketches was almost evenly split between the two groups (thirteen comments on eleven designs with framework, twelve comments on nine designs without). Two dominant themes emerged in our analysis: many evaluators picked designs that were about a specific material (eight designs) and pointed out that *"it could be produced today"* (E1-FD1). By relating the proposed design concept to already existing products, the design experts highlighted that some of these ideas are *"totally feasible"*, such as E7-CD1: *"it's essentially an iPad with a leather skin."*

The other theme that had almost as many occurrences as material was software (seven designs). The design experts mentioned existing software products or concepts that would solve the main problems in bringing the design sketch to reality, such as *"Google Now"* (E1-CD16) or *"TimeHop with a diary twist"* (E6-CD14).

4.3.9 Summarization of the Results

We conclude that the framework had a positive effect on the novelty criterion and mixed effects on the other five criteria (attachment, presentation, aesthetics, usefulness, and feasibility). Especially surprising was that the control group had almost as many attachment criteria present in their designs as the framework group. One possible explanation might be that many of the designers expressed in their background survey having had experience in sustainable design ("green design" was a frequently mentioned term) during their studies or a personal interest in those fields, and thus possessed an already existing knowledge repository. However, the framework group's designs displayed a significantly higher quality with regard to novelty and creativity, which in turn can be linked to attachment criteria. The results indicate that the Attachment Framework might hold value for designing products that exhibit both sustainable as well as novel design.

Despite the success of our design activity in this particular aspect, the limitations of using this framework in SHCI design lies in the fact that in other five criteria – attachment, presentation, aesthetics, usefulness, and feasibility and credibility – the Attachment Framework did not perform better. Similarly, the ambiguity in evaluating the attachment criteria highlights that the framework can be interpreted in many different ways. In the following, we discuss how the insights from this study can inform future research by presenting a set of challenges that need to be addressed when applying theoretical frameworks from SHCI or similar fields to design practice.

4.4 Bridging the Gap: Challenges in Applying SHCI Theory to Design Practice

Based on the insights from our study we identify and discuss a set of four challenges that aim to bridge the gap between SHCI theory and design practice, which can be separated into two different categories:

Category 1: The first three challenges address issues in the earlier stages of SHCI design knowledge transfer, in particular, identifying 1) the suitable target audience, 2) the appropriate stage in the process, and 3) the most effective medium of communication. Each challenge is organized as follows: first, we elaborate on how we identified the challenge based on the study insights. Second, we discuss the challenge by drawing lessons from design research literature, including fields such as product, industrial, and architectural design. Our goal is to provoke discussion and reflection on how to address these challenges.

Category 2: The fourth challenge addresses an important question in a later stage of the design process: once we have examples of SHCI research applied to

design practice, how do we evaluate those instances of design in light of the given framework? We discuss this challenge based on previous SHCI research insights and the experience from our own evaluation in our study.

4.4.1 Challenge 1: Addressing the Right Target Audience

The potential differences in target audience became apparent when comparing the background surveys of the two different group of designers we recruited – the fourteen designers for the design activity and the ten design experts for the evaluation. While the designers had less experience in design overall in terms of years of expertise in teaching and practice, all of them expressed interest in or even experience with the design of sustainable products. The design experts, on the other hand, expressed only borderline knowledge or interest in sustainable design, but a significantly longer amount of working expertise in design practice. This sparked our interest to see if there are other differences with regard to the target audience that impact the knowledge transfer between disciplines.

4.4.1.1 Insights from Design Research

In a survey of design expertise studies, Cross [2004] points out that expert designers tend to spend less time on the problem definition and more on actually developing the solution (solution-focused versus problem-focused). A survey of 103 novice designers and 52 expert designers by Gonçalves et al. [2011] confirms these insights with empirical data of actual design practice. An implication would be to tailor frameworks or design guidelines to the respective stage these designers deem to be most important and spend more time on; e.g., in the case of expert designers this would be the solution generation process, while for novice designers one might focus on supporting the problem elicitation stage.

Cross concludes his survey with a warning that seems to be counter-intuitive to some HCI researchers: *"Generating a very wide range of alternatives may not be a good thing"* [Cross 2004]. This is based on the fact that expert designers tend to focus on a single design quite early in the idea generation phase. Combined with his advice to be *"wary about importing behaviour from other fields"*, one should be careful to not cause any changes to the designers' practices when offering tools to support the design process – unless the designers agree to (or even ask for) the change and the benefits are clearly communicated. Otherwise, such a tool might not make its way into designer's practice and the design knowledge transfer will not be successful.

4.4.2 Challenge 2: Finding the Appropriate Stage in the Design Process

Another insight from the background survey of our participants was that their typical approach to design tasks differed from designer to designer. Some designers mentioned they would usually spend more time on background research – which was limited due to the time constraints in this experiment – while others did not put as much emphasis on this part of the process, mainly because the already had a repository of background from a previous, similar design task. There were also differences in their approach to brainstorming designs: most of our designers liked to sketch many different ideas and pursue one (or a few selected ones) more in-depth, while some designers mentioned they would sometimes just take the first idea that comes to their mind, sketch it

in detail, and then go back and think about other ideas and repeat the process. We therefore looked into design research literature to see if there is a typical design process, if so, what it looks like, and how this changes the way we try to apply our SHCI knowledge to this process.

4.4.2.1 Insights from Design Research

The basic concept of many design disciplines looks similar to HCI's iterative design cycle [e.g., Nielsen 1994]. For example, for product design and engineering, Cross [2008] provides a simplified four-stage model. The four different steps are exploration, generation, evaluation, and communication; the cyclic resemblance of iterative design is depicted by a repetition of generation and evaluation. For another discipline, architecture design, Lawson's model [2006] is more generalized with a three-stage "analysis – synthesis – evaluation" circular process, almost identical to the HCI iterative cycle. Both authors, however, point out that as one looks closer at either of these models, the individual steps differ from discipline to discipline, product to product, and even designer to designer.

When SHCI researchers propose theoretical frameworks to be used by other disciplines, these frameworks need to fit into the target audience's work process. For example, in our study the target audience would be industrial and product designers. Looking at one more detailed model of that discipline – Kruger and Cross's expertise model of product design [2006] – we highlight how complex the process, and therefore identifying the most suitable stage, is. Kruger and Cross's model is accompanied with a breakdown of eight tasks and activities: 1) Gather data, 2) Assess value and validity of data, 3) Identify constraints and requirements, 4) Model behavior and environment, 5) Define problems and possibilities, 6) Generate partial solutions, 7) Evaluate solutions, and 8) Assemble a coherent solution.

As these stages highlight, there exist different opportunities to transfer knowledge, depending on which stage is to be addressed. For example, in a design process mimicking Kruger and Cross's model, SHCI design knowledge can be fed into the first step as part of the designer's background research. This might be a stage where designers are likely to be more open towards traditional HCI design principles, as their background research process is relatively widespread at this point. But in the later steps (e.g., step six), concrete tools and applications that support the ideation process might be more helpful. Traditional guidelines are likely to be neglected at this stage in the process; however, they might be helpful if tailored to the specific stage and embedded into the tools used during the solution generation process. We therefore believe that HCI researchers have to be aware of the complex stages of the design process, consider at which stage(s) their findings may be most beneficial, and tailor their frameworks and guidelines for the appropriate stage(s) of the design process. This may significantly increase the chance of SHCI design knowledge to be applied to real-world practice.

4.4.3 Challenge 3: Transferring and Transforming SHCI Design Knowledge

It is important to keep in mind that the designers did not implement the Attachment Framework's principles, but their *interpretations* of those principles

in the ideation phase. This matters because interpretations can be both beneficial and unfavorable: interpretation allows for less restricted thinking and enables designers to explore many different ways to apply design knowledge to their activities; but it can also lead to misinterpretation and therefore mean that it has no or even an adverse effect on design. While we do not want to limit the benefits of a framework that is open to interpretation, we need to make sure the essence of the framework communicates the same values. One approach to how this challenge can be addressed is to explore ways in which frameworks and guidelines can be presented in the designers' ideation process.

4.4.3.1 Insights from Design Research

HCI research literature often ends with implications for design, guidelines, design principles, or a framework – as in the example of the Attachment Framework that we applied in our experiment. But if such work aims to inform future design, the theoretical, text-based form of conveying the findings and insights might not be enough to reach its goal. Textual guidelines are by themselves not applicable to all stages of the design process and are not what all target audiences might prefer. There is an ongoing debate over the different impact that visual and textual stimuli have in the design process [e.g., Eckert and Stacey 2000; Goldschmidt and Sever 2011; Goldschmidt and Smolkov 2006; Muller 1989]. A balanced approach of textual and visual stimuli might present a good middle way, noting that one should rely more on visual stimuli with expert designers, as they tend to be less susceptible to be biased by these examples and make less use of text [Gonçalves et al. 2011].

Therefore, we propose that SHCI should search for ways to not only transfer its knowledge into other domains, but also present and communicate the knowledge using representations that take the needs and practices of the target audience into account. One way to go about this is by using examples to fuel the ideation process [Herring et al. 2009a]. Based on the target audience's preferences, mixing verbal examples and pictures can be useful, but if possible also including real-world objects such as end-products or prototypes; this can be especially useful for expert designers [Gonçalves et al. 2011].

There is a variety of different ideation techniques used by designers: Smith identified 172 different techniques [1998], Gonçalves et al. reported on the frequency in actual use of 14 of those [2011], and Herring et al. provides an in-depth analysis of 19 [2009b]. If one aims to support the ideation process, SHCI design knowledge could also be integrated into tools and applications supporting these techniques instead of simply providing examples that are being used during the ideation process. While brainstorming seems to be the most frequently used and most preferred method by designers [Gonçalves et al. 2011], there are many different ways to approach brainstorming and therefore different ways to support this process by developing tools for it. SHCI principles could be embedded into applications that facilitate the creation of checklists [Gonçalves et al. 2011] or attribute lists [Herring et al. 2009b], or serve as basis for new axes of classifications in either of these.

One has to keep in mind that the ideation process is a concrete step in only one specific stage of the design process (step 6 in the expertise model [Kruger and

Cross 2006]). Since ideas can emerge indirectly anywhere in the cyclic design process, there might be other ways to embed design knowledge into designers' practices beyond this phase. If formulated as rules that blend into the constraints and requirements being identified in step 3 [Kruger and Cross 2006], abstract design implications can be turned into concrete guidance for designers. This ensures that the design process is not altered, yet the SHCI principles are considered in the design process – with equal importance to other design rules.

4.4.4 Challenge 4: Evaluating Applications of SHCI Design

The last challenge we encountered (as also articulated in [Silberman and Tomlinson 2010]) is one that poses a more general question: *How do we evaluate the impact of our contributions in SHCI once they have been applied to practice?* To answer this question, we contrast our evaluation approach with that of Grosse-Hering et al. [2013], which is to date the only evaluation of this kind.

Grosse-Hering et al. [2013] performed a case study of the application of slow design principles to design. They evaluated their design by asking six participants to imagine the use of a mock-up device and report on their experience. This works because for slow design the interaction is meant to actively engage and change people's practices and thinking immediately; some of the Attachment Framework principles, however, are subtler and require a ready-made product (sufficiency, earned functionality) or a long timeframe to be applicable (histories, perceived worth). Therefore, building prototypes and mock-ups is not a suitable strategy for evaluating attachment. Some of the designs in our study resembled storyboards or use-case scenarios (e.g., CD19, see Figure 4.2 (a)), but this approach does not work for all designs. This hints that a "one size fits all" solution it is unlikely to be found, but rather that every application of SHCI research requires its own evaluation, depending on its goal – which is a notion expressed by the SHCI community itself recently [Silberman et al. 2014].

In our own case we used the Attachment Framework itself as an evaluation tool. This raises an additional question: *Can we use a framework that is intended to inform the design of objects for the purpose of evaluation?* The attachment experts who have had extensive experience with the framework itself did not agree on all the criteria for all the designs; in fact, there was more difference in assessing the attachment values than agreement. Despite the differences in assessing *which criterion was expressed in a certain design*, there was a general agreement on particular designs *that a design displayed some notion of attachment*. Silberman and Tomlinson [2010] provided a categorization of evaluation tools, in which the Attachment Framework falls into the category of "principles" for which a certain amount of ambiguity is expected and needs to be dealt with.

The fact that both the design experts, who had no previous experience with attachment, and the attachment experts came to roughly the same results in assessing the attachment values in the designs – no clear evidence that the framework group did significantly better than the control group – might imply that the Attachment Framework holds some value to serve as a means of evaluating attachment in designs. However, the definition of the attachment principles should be phrased much more unambiguously to allow for more

agreement among the evaluators. Contrary to the purpose of applying frameworks to design practice, when room for interpretation can be desirable, we argue that such frameworks should be more constrained and have as little ambiguity as possible when being used as a tool for evaluation.

We included general design criteria in our evaluation since attachment alone does not suffice as the only criterion for successful design if a product were to appeal to a broader audience. However, maybe one of the obstacles in bridging the theory-practice gap is that traditional design and evaluation criteria are not compatible to sustainable design and the emphasis for evaluating success should only be on sustainability.

4.5 Next Step: Embedding Tools into the Product Design Process

In the work reported on in this chapter, we investigated the application of a theoretical framework from SHCI to design practice by studying its effect on the design process and outcome. This study was guided by the following research question: "How can existing sustainable design frameworks be leveraged to provide assistance in the design process of consumer electronics?"

Our evaluation results indicated a positive effect on novelty, where a subsequent evaluation suggested a clear link between novelty and attachment. However, we saw mixed effects of the Attachment Framework on the other five criteria. We identified a set of challenges that researchers might face when frameworks are being applied to practice, which we believe help to address future efforts to bridge the theory-practice gap. In the following, we report on two example projects that aim to build on the lessons learned from our study results.

5 INCORPORATING ATTACHMENT INTO DESIGN PRACTICE

Based on the insights of our preliminary design study, we sought to investigate further how to bring the attachment framework to design practice and create a higher impact. Our approach starts by addressing the four challenges identified in Chapter 3 and brainstorm potential solutions for the theory-practice gap. We ended up with two potential approaches, tackling the issue in different stages of the design process: First, *StickyDesignSpace*, a web application that allows for sorting of design-relevant information and targets the background research stage of the design process; second, *InspiredDesign*, a tablet application that offers inspirational advice and thought-provoking questions during the brainstorming process. In this chapter we report on the process of how we arrived at those two applications, the evaluation thereof, and discuss the insights gained from both approaches for our research. The overarching research question that guided our research at this stage was as follows:

> RQ3: How can an existing sustainability framework be integrated into tools for designing consumer electronics, and what effects does this have on the design process and design outcomes?

While the research question assumes to solve the problem for SHCI research in general, we continue using the attachment framework as the example for a sustainable framework. This is for a variety of reasons: First and foremost, the same arguments we mentioned earlier apply to this step of our research as well, namely the attachment framework building on a powerful connection between owner and device due to its emotional component, as well as being a well-established framework in SHCI research. Second, utilizing the same framework

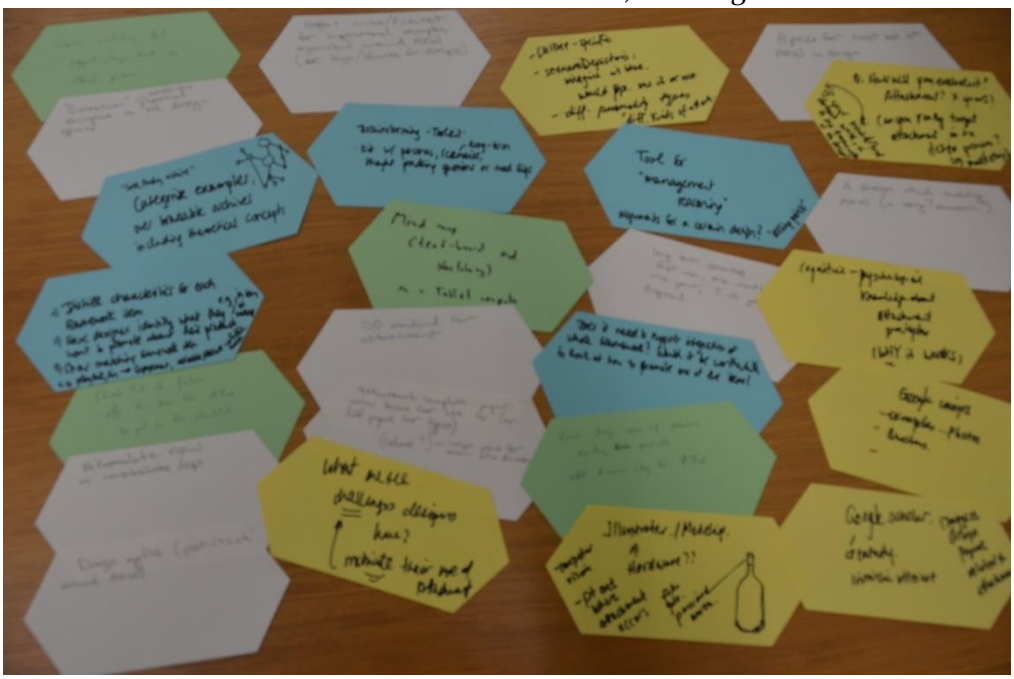

Figure 5.1: Brainwriting cards from the brainstorming of potential tools for bringing the attachment framework to designers.

allows us to avoid potential pitfalls and issues we might encounter when using a different framework that we are less familiar with. Third, continuing the research with the same framework and extending the previous work by employing new methods to facilitate the knowledge transfer between research and practice allows us to compare our results to our previous insights.

To gather inspiration for potential approaches, a group of HCI researchers brainstormed ways for bringing the attachment framework to design practice. We started with a brainwriting session, a technique in which brainstorming participants individually note down ideas on flash cards before exchanging those ideas in the actual group brainstorming activity [Rohrbach 1969]. The resulting concepts that evolved from this brainstorming were then discussed in light of the challenges identified in our previous research to identify which solutions are most promising and feasible. Here, we focused on the second and third challenge – choosing a stage in the design process and translating the SHCI knowledge. For the first challenge, we decided to stick to our previously selected target audience of product designers; however, we sought to avoid designers who had too much training in interaction design as we anticipated blurred results for our main goal of knowledge transfer if the participants had too much in-depth knowledge of the discipline of origin for the design knowledge. The fourth challenge of evaluating designs is discussed later on in the next chapter and was only tentatively a criterion in our discussion of tool ideas. Out of all ideas considered, we selected the two ideas that were later developed and evaluated – StickyDesignSpace (section 5.1) and InspiredDesign (section 5.2). After presenting both designs and its separate evaluation in detail, we discuss the lessons learned for bridging the theory-practice gap and transferring SHCI design knowledge in chapter 6.

5.1 StickyDesignSpace

The first selected idea marries the concepts of the background research stage in the design process [Kruger and Cross 2006] with the design space methodology from HCI [Card et al. 1990]. It seemed particularly promising to us since the background research process is usually the first action the designer undertakes after receiving the design brief; it is similar to the related work search of an HCI researcher after they identified a problem. There are two main differences between a related work search and the background research stage:

First, a related work search oftentimes focuses on scientific research or, in case the research project is about developing a tool, finding products that resemble the anticipated prototypes to be developed. In contrast, the background research of a designer has almost no constraints and includes virtually every available resource. Examples of background research resources based on our interview results (cf. study in Chapter 3) include internet search, skimming magazines and books, revisiting previous design exercises, and browsing cabinets of filed design samples – a practice especially common among designers who learned their craft before the days of internet search.

Second, the goal of a related work search differs compared to that of background research: the main purpose of this activity in research is to find unexplored

solutions to the problem in question, whereas design does not necessarily have to be novel (though it is usually desirable) but can also be a combination, alteration, or extension of a previous design.

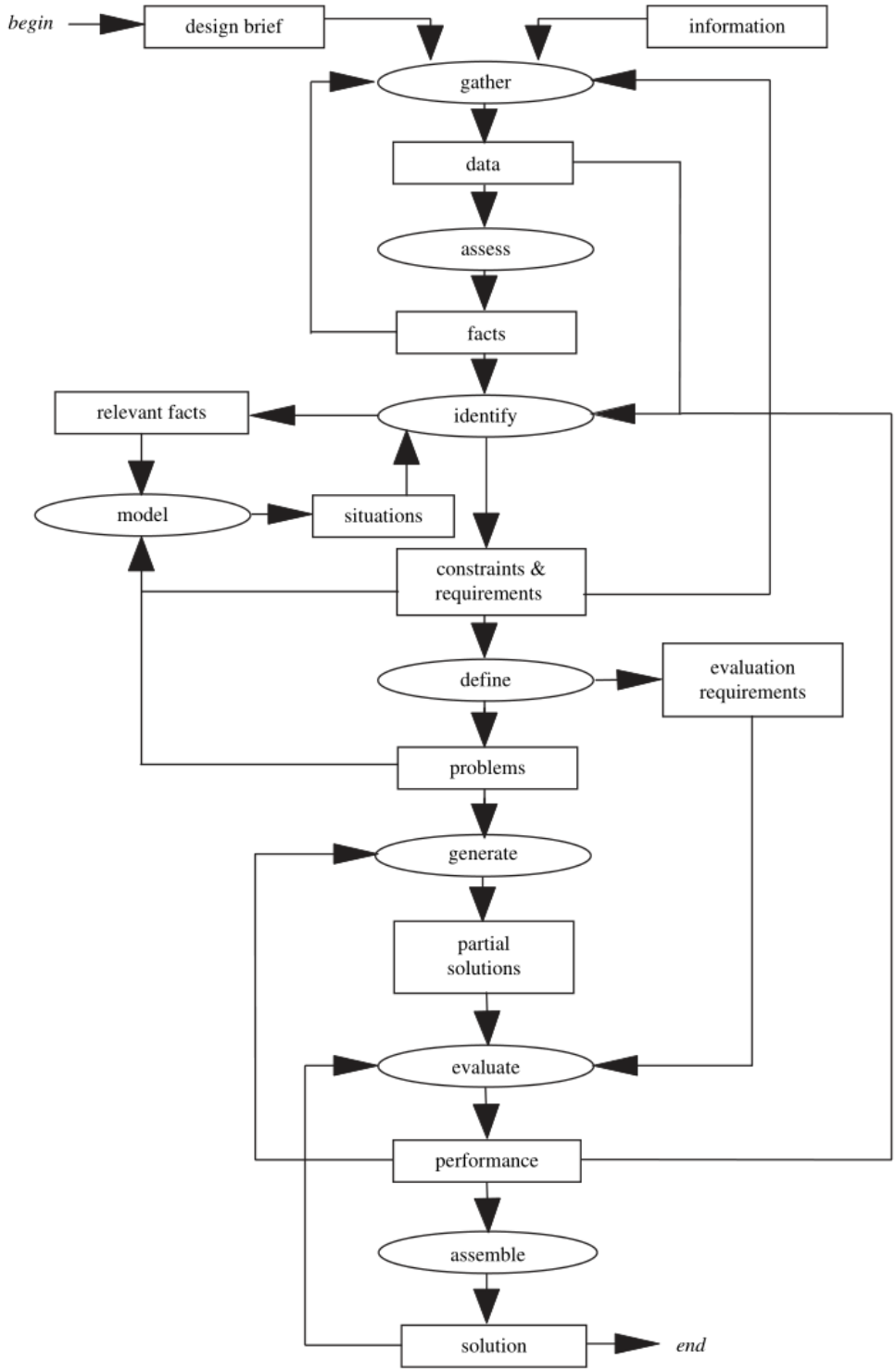

Figure 5.2: Expertise model of product design. (Courtesy of Kruger and Cross [2006], © Elsevier 2006.)

Kruger and Cross [2006] suggest that a design activity starts by *gathering data*, following by *assessing its value and validity*. In their model, the outcome of this stage leads to constraints and requirements (see Figure 5.2). This resembles

other models in design research (cf. surveys by Lawson [2006] and Cross [2008]) which follow a pattern of organizing or even evaluating the data collected in the background research process. While the specific activity differed from designer to designer, we identified this process in every interview conducted in our studies. Therefore, targeting this stage seemed particularly apt for creating a tool supporting this process.

5.1.1 Background and Related Work

The concept of a design space originates in research by Card et al. [1990; 1991], who used their methodology to categorize input devices of a computer based on their input modalities. A design space is a two-dimensional chart, with physical properties along the vertical axis (e.g., movement and position) and dimensions of movement along the horizontal axis (e.g., linear or rotary). Creating such a taxonomy for input devices was not a novel idea; Foley et al. [1984] listed properties for a variety of metrics for available input devices, and even one year earlier Buxton [1983] presented a two-dimensional chart for input devices. However, the final design space of Card et al. adds several visual cues to distinguish input devices even further, such as numbers within the circle of an entry to denote the number of buttons, its position within the cell, or the connection of circles to highlight input devices with combined input modalities. An example of such a design space can be seen in Figure 5.3.

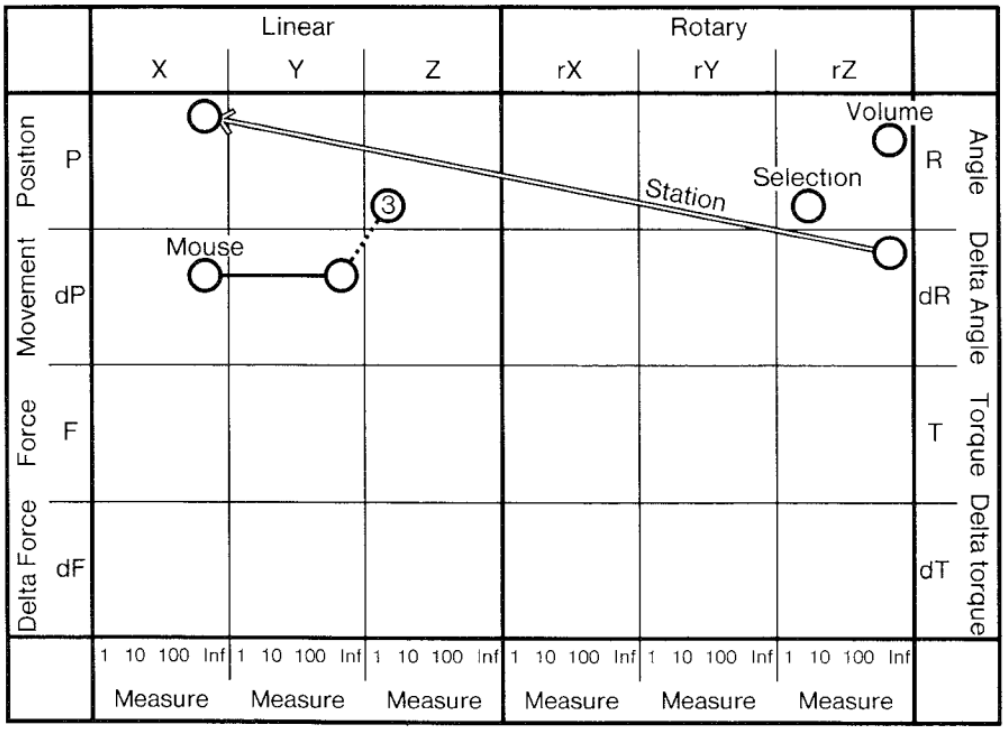

Figure 5.3: Design space of input devices. (Courtesy of Card et al. [1991], © ACM 1991.)

We sought to implement a web-based design space application that allows for designers to easily drag and drop artifacts from their background research process into such a design space. Our application was intentionally kept more simple and did not have as many different modalities as the original concept. However, we still believe for the main advantages of a design space to be intact: it provides a quick overview of the data gathered in the background research

process, and it does so by categorizing those results. This allows for getting a feel of common themes among the background research data as well as identifying blank spots of underused design features or attachment criteria. This also distinguishes StickyDesignSpace from similar implementations that are oftentimes used by designers; for example, many designers in our preliminary interviews stated that they used Pinterest [Pinterest] or simple card drawers for storing and managing inspirational design data. Thus, we sought to keep our implementation close to the functionality of platforms such as Pinterest, though our main focus was on incorporating the attachment framework and not on creating a novel application.

5.1.2 Paper Prototype

As we had learned from our preliminary design study, it is important to consider both the sustainable impact as well as traditional design values for the product design process. Therefore, we decided to devote one axis of the design space to the attachment framework, and the other for features subject to the designer's choice. We named our application "StickyDesignSpace", in reference to sticky notes one would put on a whiteboard similar to the design space. To gather first feedback and impressions from designers, we conducted a pilot study using paper prototyping [Snyder 2003]. Paper prototyping is an especially useful method to explore core interaction principles without paying attention to design details such as color and graphics, as the look of sketched drawing on paper makes it clear to the evaluators that they are looking at a prototype and not the final design.

For the axis labeling, we created sticky notes with the description of the attachment categories as well as traditional design properties (e.g., "materials", "form", "surface"). We provided additional sticky notes for custom labels and a range of other tools for participants to choose from, such as differently colored sticky notes, scrap paper, a variety of pens and pencils, and clay for putting "marks" on the design space similar to the original concept. The main component was a white sheet of paper with a two-dimensional design space and 16 cells provided by us as a template (Figure 5.4).

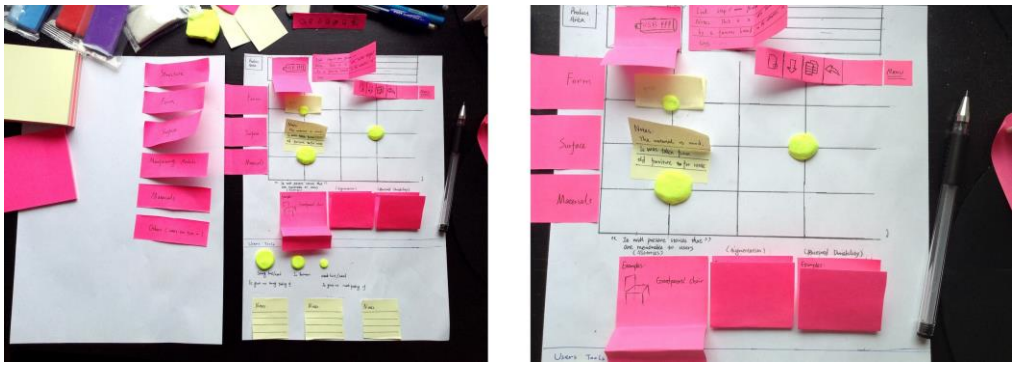

Figure 5.4: Paper prototypes for the initial concept evaluation of StickyDesignSpace.

The two participants of this preliminary evaluation were design students with working experience as designers. Neither of them had previous experience with the attachment framework. At the start, the concept of the design space was explained to the participants, as well as the goal of our study and the background

of the attachment framework. During the activity, notes were taken based on students' activity as well as on questions to clarify the participant's understanding of the prototype and its idea. The interview was recorded and partially transcribed for analysis. Based on the results of this preliminary paper prototype, the following four insights emerged:

Need for a tutorial. Both participants struggled to grasp the concept of the design space at first, asking *"what do I do with it?"* when presented the paper prototype in the beginning. Following a brief explanation, they were still hesitant where to start – only a short demo of the researcher adding an example entry to the design space cleared the confusion. Therefore, we decided that our final prototype needs to have a thorough tutorial not only explaining what StickyDesignSpace is, but also provide a guiding example.

Show commonly used design criteria on the vertical axis. We mixed some predefined categories with blank sticky notes for the vertical axis in the paper prototype because we wanted give participants an idea about potential design criteria they might use to sort their data while at the same time allowing them to choose their own. This was based on insights from the previous interviews and aligned with the thinking of designers in our prototype test, such as P2: *"I would identify other things that stands out in other products, but if they are not relevant to my needs, I will just ignore them. For example, the aesthetic perspective, I don't need them to be shiny or look luxurious"*. In our final prototype we implemented default criteria, but also allowed removal of those as well as adding new, custom criteria on the vertical axis.

Emphasize distinguishing features of the attachment principles. To scale down the paper prototype's complexity, we chose only three criteria from the attachment framework to start with: histories, engagement, and augmentation. However, one participant asked for those to be more distinct as he found the description of the attachment framework's principles to be too similar to each other: *"At first glance, it is hard to tell the difference between the first [histories] and third [engagement] category, because they are kind of similar to a certain extent. Maybe you can illustrate something broken in the first category, something that is not usable anymore, without function value, only with sentimental value"*. Note that due to the nature of paper prototypes we only sketched some examples along with a short explanation on the sticky notes for the horizontal axis; in the final prototype we added images to the attachment criteria that were shown when hovering over the descriptions (see Figure 5.5). We also redefined each of the seven descriptions to make sure they were distinguishable while maintaining the original attachment criteria idea.

Organizing data versus design space as inspiration. After the concept of the design space was explained and the researcher walked the participant through a design space example, P2 realized *"aha, it is not about my own product"*. In part this was due to the artificial setting of a lab study which makes it difficult to put participants into the real mindset of the respective stage in the design process and separate the background research activity from brainstorming. In fact, the input from the horizontal axis immediately brought ideas to the P2's mind: *"What if I don't see them [the attachment principles] on other products, but I have*

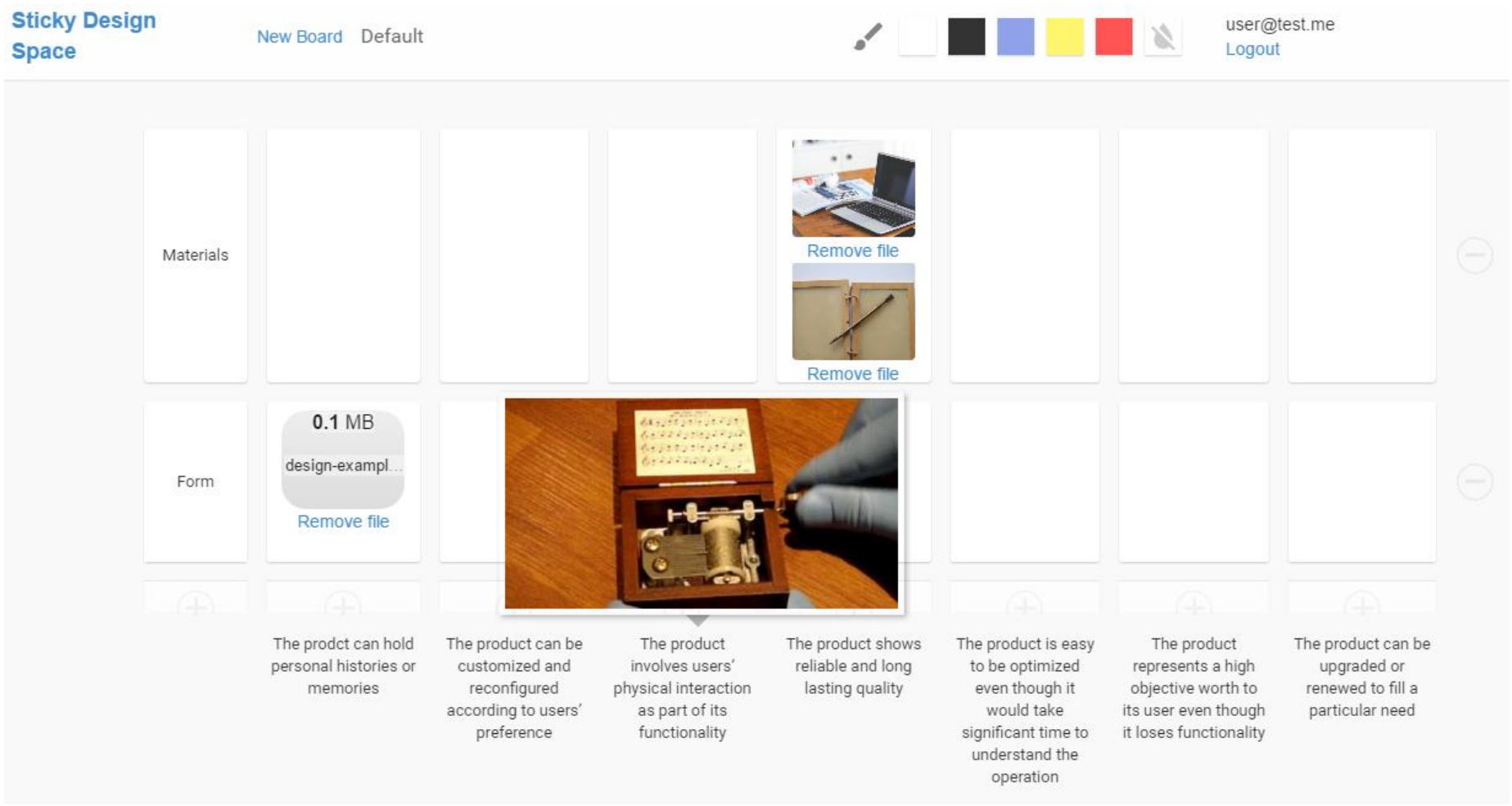

Figure 5.5: Final layout of StickyDesignSpace. The mouse is hovering over the third attachment criterion and showing the respective image.

an idea on my own, can I still put the mark here? I think I have everything in my mind already". This was a challenging finding from our paper prototype – while we do not want to restrict the designer's creativity, it also blurs the lines between the design processes. This is no new insight as design research has discussed at length that the stages of a design process [Kruger and Cross 2006] are not to be seen in isolation but can often blur as designers leap forward or go back within those models [Lawson 2006]. Therefore, our final prototype offers the option to highlight certain cells, for example with color markers that can be drawn from the top onto any cell (see Figure 5.5), but want to clarify the task in the introductory video to make sure the designers in our final evaluation are in the right mindset.

5.1.3 Interactive Prototype and Evaluation

Our final prototype was developed as a web-based application, using HTML5, JavaScript, and CSS3 for the front-end and a MySQL database for the backend. To accommodate for the finding that an introduction is necessary, we set up a front page with a login form and a brief video explaining the tool and its usage. The video showed the same scenario as used in the evaluation (see Appendix C.2), which allowed us to maintain consistency in our description of the tool to the participants. After creating an account or logging in, a button labeled "Start the tool" appears which opens the StickyDesignSpace site as shown in Figure 5.5.

As mentioned in the result section of the paper prototype evaluation, criteria on the vertical axis can be added, changed, and removed easily: by clicking on any of the criteria, a dropdown menu opens at the mouse cursor. Clicking on any of the "plus" signs in the bottom row adds a new row, clicking on the "minus" signs on the right removes a row. The color selectors at the top can be dragged onto any cell, and we also allowed for every user to store multiple design spaces, clicking on the "New board" button at the top. The main functionality, however, is to be found in the design space cells: images can be dragged into them and will automatically be uploaded onto the server and be displayed in there. One can also click into the cell which opens a file browser window to select data, and a cell has no restriction on file type or number of elements – though only image files can be displayed (such as the bottom left cell in Figure 5.5, which contains a PDF file).

For the evaluation, we recruited designers using convenience sampling. They were given background information about a fictional design task for a mobile phone, and we asked them to gather inspirational material and sort it into the StickyDesignSpace web application. The introductory video on the frontpage of our website would then guide them through the process by giving a walkthrough of using StickyDesignSpace. Participants were free to search online for any background information to be added into the design space, but in addition we also prepared a folder containing images of several design artifacts. The evaluation comprised three phases: In phase one, participants were asked to read and use the website for approximately ten minutes using the "think aloud" method [Rogers et al. 2011]. This is a process in which participants use a prototype without any assistance from the researcher and explain all their thoughts verbally, which helps to identify usability issues such as confusing

interaction design or misinterpretation of interface elements. In phase two, participants interacted with the prototype for organizing their background research data, and it lasted about 10 to 20 minutes. They searched for inspiration online, looked through the design artifacts we provided them, and added elements to the design space. The evaluation was concluded with a semi-structured interview in phase three in which we asked participants about their experience using the tool, their opinion on its usefulness in their personal design process, and general feedback (see Appendix C.3 for interview protocol). The interview lasted for approximately 25 to 35 minutes.

A total of four designers were recruited for the evaluation, all of them having working experience as a designer ranging from one to four years, either as a self-employed designer (P3) or employed in a company (P1, P2, and P4). Their design background included fields such as product design, jewelry design, web application design, and interaction design. None of the designers in this evaluation had participated in the earlier paper prototype evaluation, to avoid potential bias. In addition to taking notes, the evaluation was recorded and the interview was fully transcribed afterwards. Both the notes from the observation and the interview transcripts served as data for an affinity analysis [Beyer and Holtzblatt 1998] in which we identified themes emerging from the evaluation.

5.1.3.1 Designers' Background Research Processes

Since our evaluation heavily relied on the designers' understanding and typical approach to the background research process, one important aspect was to ask them about how they approached this in their daily work processes. This helps us later in the analysis to better understand their interaction with our prototype, but also how the prototype would be used in their design work.

While participants P1 and P2 consider background research more as an investigation into previous designs to ensure that they have a baseline comparison for the designs created later in the process, P3 and P4 regard the background research process as a first creative step in their design activity and expect to have a set of first rough ideas once their background research process is finished. In terms of methodology there were no significant differences – all designers reported web search engines as their main source of background research data. This observation aligns with insights from our previous interviews which revealed that the use of physical material for inspiration, such as browsing magazines, was more common among older designers. Design research reported on the differences in background research practice before [Kruger and Cross 2006; Herring et al. 2009b; Gonçalves et al. 2011], however, in our evaluation it was beneficial to have only designers who prefer to search for inspiration online as the application required a digital artifact to be dragged onto the design space. An overview of our participants' typical background research process can be found in Table 5.1 [Chu 2015].

ID	Goal	Data collection method	Data collected	Expected outcome
P1	1. Find research data to backup solutions or design ideas that are already formed. 2. Develop understanding and knowledge about trend in design filed, for example, competitors' work.	Web search engine	Trustful resources such as articles, reports, famous blog, online magazine.	Synthesize the collected data as a summary of report.
P2	Find the gap between existing products and potential design for future products	Web search engine phone camera	Images of related products in market or daily life.	Separate the collected data into different categories and then synthesize the data into a report.
P3	1. Make the design outcome more accurate and unique. 2. Non-physical material to guide the use of physical material.	Web search engine Pinterest.com	1. Images that generate feelings that the design work can present. 2. Images of related products that provide insights for current design work. 3. Light articles which have a broad topic about design.	Use the collected data as references to make prototype.
P4	1. Find out functions based on users' requirements. 2. Build an image of what the product looks like in mind.	Web search engine	Mostly images of design style and inspirations.	Collect relevant data in order to go smoothly into prototype design phase.

Table 5.1: Typical background research process of the participants in our evaluation (reprinted from Chu [2015]).

5.1.4 Findings

In the following, we present the insights that emerged from our affinity analysis of the data gathered during the evaluation and the debriefing interviews. We cluster those findings into five main themes, highlighting how the tool is used in the design process and to what extent SHCI design knowledge transfer was observed.

5.1.4.1 StickyDesignSpace as Tool for Organization and Inspiration

Analyzing the observation for participants' understanding of StickyDesignSpace as a tool to support the background research process, it showed significant improvements over the results of the paper prototypes. Due to the differences in each designer's background research process, the exact usage and interpretation

of the tool differed slightly from participant to participant; however, all of them understood the tool as a tool *"to help designers to organize design inspirations, like design resources"* (P4).

This combination of inspiration by organizing data became apparent in multiple of our observations during the evaluation. For example, after reading the axes' descriptions and using the interface for a while, P1 went to an Internet search for "lego phone", downloaded the image, and uploaded it onto StickyDesignSpace. She explained her motivation as follows:

> *"With the awareness of these two lines, I upload this picture [of a Lego phone] into "materials" [row] and "preferences" [second column]. If I can make my own phone with different types of materials, such as bricks or woods, then it can fill my satisfaction of using or my preferences, so I uploaded this picture." (P1)*

Another example of similar thinking was found in P3's search for "old shoes", which he concluded by uploading a picture into StickyDesignSpace's quadrant matching "materials" and "personal histories and memory". He elaborated his choice as follows:

> *"Material can be related to what it does and to its function… in the end, my shoe always looks like my feet. That can be influenced by how I use it and being mine." (P3)*

Those instances do not only highlight that participants used the design space as we anticipated and instructed, but also that they saw value in doing their own search and organizing the results into the tool. Their actions also confirmed what P4 mentioned in the debriefing interview – that StickyDesignSpace is not only a tool for organizing data, but also for inspiration. While we imagined that organizing existing data might lead to inspiration after completing the background research process, we were surprised to see to what extent the design space and its axes' labels itself served as inspiration or designers to lead their background research into new directions.

5.1.4.2 Conveying Notions of Attachment

One important aspect in our evaluation was to analyze how participants would perceive the attachment framework that we had translated into the cues presented on the horizontal axis. The participants regarded those as principles for design leading to longer-lasting products, as those interview quotes highlight:

> *"They [descriptions on horizontal axis] act like guidelines, you [designers] need to find something that is useable for the users, the design resource should be durable and reliable. They are trying to guide you build a good design project." (P4)*

> *"It is to create products that user will use for many years, product that user will not easily throw away." (P2)*

Those quotes, along with the observations and reasoning for participants' interaction with the tool when adding specific items into the design space, makes us confident that our translations of the attachment framework were understood and designers could successfully incorporate them into this stage of

the design process. Nevertheless, further improvements can be made; we received multiple suggestions for improvement in presenting and phrasing the attachment criteria, such as shortening them. For example, one participant mentioned that “the product can hold personal histories and memories” can be shortened to “histories and memories”. However, it is speculative whether this leads to the same level of understanding that we achieved in our evaluation, as we deliberately decided to add full-stop sentences for the attachment criteria on the horizontal axis after the paper prototype (which had such shorter descriptions) revealed confusion and misunderstanding. The drawback of long descriptions though is that it seemed too long to be able to understood at one glance.

Only one of the four designers (P3) had previous experience with designing longer-lasting products, as her field of expertise is jewelry design. Prompted by the input provided by StickyDesignSpace, she brought up an example of one of the challenges she encountered when designing durable jewelry that put her at unease:

> *"I really had a great challenge with the surface, I had to make it shiny and also look good, and I had to plate it by myself. In order to plate, I have to use the plating liquid, which is toxic. If I keep using it maybe I have to throw the residue away. [...] I feel good as a craftsman... it is a kind of conscience that I don't feel good if I make waste in the [design] process and things that are difficult to maintain, I don't feel good to sell it as a designer." (P3)*

This weighed heavily on her conscience as she had to make both ends meet: Offering an aesthetically pleasing, long-lasting artifact that would satisfy the customer while maintaining a manufacturing process that was sustainable enough for her own standards. Using StickyDesignSpace gave her new inspirations for solving those conflicts in the future, as she said she might consider using real silver or gold instead of a gold plating in the future in such a scenario: *"I really gained the knowledge that I have to use lasting material"*.

5.1.4.3 StickyDesignSpace in the Design Process

When asking the participants if they could envision using StickyDesignSpace in their design process and how they would incorporate it into their daily routines, we received a range of varying answers. P2, who expressed most interest in the organizing aspect of our tool to structure the background research data, was the one whose vision came closest to how we anticipated it being used in the design process. She went one step further and asked for a feature to use one design space with multiple designers, sharing ideas and inspirations:

> *"I think it would be helpful if I am working in a team. Because I can upload pictures to the tool and other teammates could also upload pictures to the tool, and finish the background research together." (P2)*

The other designer who said she could see herself using the tool in her design process was P3, who interpreted StickyDesignSpace as a tool to show her the big picture emerging from the background research data:

> *"It is like a concept map, so I can locate different things within these axes, and there is also the third dimension which is the photo itself. It is like you can*

distance the project a little bit by the map, when you are in a certain place you don't have the distance; but when you see the map, you see everything from [...] high above, so now you see how to [orient yourself] within the process." (P3)

The interpretation of a third dimension based on data in a cell of the design space bears similarity to the original design space of Card et al. [1990] which had further distinguishing features within a cell, such as position and shape of an artifact. We see potential here to extend the design space to accommodate for thoughts such as P3's, although it might create an overload of functionality and detract too much from the original design task in this stage – the background research. It might be an option for an advanced mode or a customization by the designer to change the design space application to their needs, which was expressed by P3 as well, further elaborating on the "big picture" aspect mentioned earlier:

"It is good to map, if I can customize everything, I would really like to use this kind of tool, I can have some bullet points of things that I consider, and then have some images, materials or thoughts and everything, and it is really easy, it really helps me to see the big picture in one glance." (P3)

Not every participant shared this enthusiasm though. Although she said she was happy to learn about the principles for longer-lasting design on the horizontal axis, P4 feared using this tool in the design process would slow her down too much: "*it takes a lot of time to figure out the puzzle"* [referring to the design space], and might even threaten to limit her design ideas:

"I have to spend a lot of time to think about how to match the pictures into categories so I think it is a limitation to my creativity." (P4)

To understand the differences between P3 and P4, it is important to consider their approach to StickyDesignSpace in context with their typical design process. While P3 does not strictly follow a top-down design process but just starts designing a prototype from intuition and conducts background research later, P4 starts eliciting the user's needs for her design task. What was missing from our application to make the tool useful for her design process would probably be a way to enter those user requirements into the design space. Arguably, the tool then would not target the background research stage anymore but rather the "requirements and needs elicitation" stage [Kruger and Cross 2006]. There were other suggestions brought forward by the designers for turning StickyDesignSpace into a tool that could be applied to other stages in the design process as well; one of them is to turn it into a tool for evaluation that offers to check off sustainable design goals that need to be hit: *"I think it can be used for evaluation process to see if I make my design sustainable"* (P3). Another idea was to use it during brainstorming assistance tool, such as suggested by P1: "*Maybe during brainstorming session we can use this software."* Incidentally, the second tool we were investigating at the same time targeted exactly the brainstorming stage.

5.2 InspiredDesign

Looking at the different stages in the design process [Kruger and Cross 2006], the stage in which the actual ideas are conceived and articulated for the very first time is the brainstorming stage. It is also considered a very central stage to every design process that, despite being executed differently by different practitioners, is present in every design activity and oftentimes regarded to as the most creative stage. For example, a survey by Smith [1998] identifies no less than 172 ideation techniques; however, by far the most popular method is brainstorming [e.g., Gonçalves et al. 2011]. Therefore, many of the ideas we came up with during our initial brainstorming process for tools were targeting this stage, and we were eager to implement at least one of those. We believe that the universality of the brainstorming technique offers a particularly well-suited opportunity to incorporate SHCI design knowledge into the design process without causing unnecessary changes. Furthermore, the early stage of this design process provides a great potential for SHCI principles to become interwoven with the very fundamental aspects of the resulting design concept.

Despite brainstorming being a widely-used technique, there are variations depending on the preference and experience of the designer. A variety of different techniques can be found in practice, from writing down a loose collection of words, to coherent sentences and ideas, or even drawing fully fledged design ideas. The original concept of brainstorming [Osborn 1957] names four principles to guide brainstorming: 1) quantity – produce as many ideas as possible; 2) defer judgment – do not criticize ideas; 3) creativity – welcome especially wild and unusual ideas; and 4) combine – improve and expand on existing ideas. With these in mind, we decided to keep our application as simple as possible so minimize the introduction of potentially unwelcome constraints into the process through additional interaction with our tool. We also revisited relevant material, transcripts, and survey responses from our previous studies with designers in order to gain a deeper understanding of the product design brainstorming process; this allowed us to anticipate our target audience's experience with and practices in brainstorming sessions.

Based on insights from previous discussions about bridging the theory–practice gap [e.g., Rogers 2004] we decided to restrict the number of features to a minimum, only showing brainstorming "flash cards". We envisioned InspiredDesign to be a brainstorming companion, supporting the designers' process by providing input through the flash cards. This is similar to the input of an additional brainstorming participant, though different in that our flash cards do not provide context to the specific discussion. A question of particular interest in design research is how design ideation techniques can be supported by technology, and even more fundamentally, how different stimuli influence the idea-generation process – in particular textual versus visual stimuli [e.g., Eckert and Stacey 2000; Goldschmidt and Sever 2011; Goldschmidt and Smolkov 2006; Gonçalves et al. 2011]. Since this ongoing debate highlights both advantages and disadvantages for either choice, we went for the middle way and combined short textual statements with example pictures.

5.2.1 Related Work

Insights from these studies, especially the repeated reports on underestimating the complexity of design practice, also had an impact on the development of InspiredDesign. Tools to support the ideation process already exist: a search for "brainstorming" in Google's Play Store lists thousands of apps, and a search for "brainstorming app" on Google yields 13,300 results. The simplicity of InspiredDesign could easily be simulated with one of those existing applications. However, we needed to be in full control of the content for the purpose of the study and minimize the functionality to a bare minimum to not distract the design process in any way. Furthermore, creating our own application allowed us to embed the recording function for the user tests.

From this vast amount of existing applications to support the ideation process, we highlight a few examples in the following which stand out because of various reasons – such as their rich functionality, being close to our implementation, or just being very popular. This is list is by no means exhaustive, but gives an overview of the existing variety of applications and both the offer and demand for such ideation support tools. We roughly categorize related applications into three different themes: 1) Tools for ideation, 2) tools for visualizing ideas, and 3) tools for managing and sharing ideas.

5.2.1.1 Tools for Ideation

Supporting the ideation process via mobile applications has two main aspects: first, offering inspiration to fuel the inspiration process, and second, enabling users to quickly note down the ideas before they vanish. Tools of the first category sometimes conceptually resemble the popular web application Pinterest [Pinterest], offering seemingly random input roughly based around a certain theme, provided by other users. The second family of tools usually allows for structuring the conceived ideas into mind maps. Examples of those applications are compared in Table 5.2 [Hediger 2015].

Name	Main Purpose	Main Target Audience	Target Platform/ Device	URL
Brainsparker	Application to brainstorm and to share ideas	Private persons	iOS	brainsparker.com
Fleck	Share inspiring photos to topics, vote on submissions	Private persons	iOS	getfleck.com
Idea Generator	Tool that use random input creativity technique for inspiring people	Private persons	Android	play.google.com /store/apps/details?id= com.designtop.generator
iThoughts	Mind map tool	Private persons, organizations	iOS	toketaware.com
SimpleMind	Mind map tool	Private persons	iOS and Android	simpleapps.eu /simplemind
SchematicMind Free mind map	Mind map tool	Private persons	Android	qdvsoftworks.wordpress.com /schematicmind

Table 5.2: Mobile applications for ideation (reprinted from Hediger [2015]).

5.2.1.2 Tools for Visualizing Ideas

Mobile applications that support the visualization of ideas are focusing on the specific input modality of smartphones and tablets – direct touch, which allows the user to quickly manipulate the visualization. Therefore, many of those applications resemble "mind map" organization features known from web and desktop applications, but oftentimes with the added feature of sketching and drawing and thus focusing on tablets rather than smartphones. While some applications are more basic in functionality, the most popular ones offer a rich set of features. A list of the surveyed tools is shown in Table 5.3 [Hediger 2015].

Name	Main Purpose	Main Target Audience	Target Platform/ Device	URL
Exobrain	A web-based mind mapping tool for visualizing, organizing and generating ideas.	Private persons	Desktop Computer	exobrain.co
blubbl.us	To easily create colorful mind maps to print or share with others.	Private persons, organizations	Available on several platforms, devices	bubbl.us
Mindjet	Mind Map Software for visualizing ideas	Private persons, organizations	Available on several platforms, devices	mindjet.com
MindMeister	Online-Mindmapping tool that supports collaboration and other features.	Private persons, organizations	Available on several platforms, devices	mindmeister.com
XMind	An open source project for creating mind maps	Private persons, organizations	Desktop Computer	xmind.net
Coggle	Shared workspace to create and work on mind maps together	Private persons, organizations	Desktop Computer	coggle.it

Table 5.3: Mobile applications for visualizing ideas (reprinted from Hediger [2015]).

5.2.1.3 Tools for Managing and Sharing Ideas

The last category of tools goes one step further – once the ideas have been conceived, those applications allows for storing, managing, and sharing them in different ways. We still consider those relevant because those tools allow for refining ideas and therefore are useful for ideation as well. While at first glance, the functionality of StickyDesignSpace would seem to make it a fit for those applications as well, the difference is that these apps self-fuel the ideation process as they collect ideas with the purpose to create even more ideas (see Table 5.4 [Hediger 2015]).

Name	Main Purpose	Main Target Audience	Target Platform/ Device	URL
Barineet	Sharing of ideas with companies (i.e. Nespresso) to improve the everyday used products. Brands receive valuable feedback about their products.	Private persons, brands	Available on several platforms, devices	braineet.com
OpenIDEO	Community members can interact with each other on the open innovation platform to tackle the toughest global issues.	Private persons	Desktop Computer, optimized for mobile usage	openideo.com
IdeaScale	Cloud-based innovation software platform, where the community members can share, review and rate ideas for implementation.	Private persons	Available on several platforms, devices	ideascale.com
Vetter	Employee suggestion box to gather, to edit and to reward ideas form employees	Organizations	Desktop Computer, optimized for mobile usage	getvetter.com
IdeasMine	Collaborative Idea Management System to gather progress ideas form the employees	Organizations	Desktop Computer, optimized for mobile usage	ideasmine.net
Codigital	Enable groups to generate, prioritize and refine ideas	Organizations, interest groups	Desktop Computer, optimized for mobile usage	codigital.com
Crowdicity	Idea management software to gather the thoughts of employees	Organizations	Desktop Computer, optimized for mobile usage	crowdicity.com

Table 5.4: Mobile applications for managing and sharing ideas (reprinted from Hediger [2015]).

In this landscape of existing applications, there are probably examples which we could have taken and adapted to our needs. However, InspiredDesign is not about creating a novel application but about studying the impact of an SHCI design framework in product design practice. Developing a new application provided us with the ability to reduce the number of features to a bare minimum, but also implement background features (such as recording and tracking input) to help evaluating the design activity.

5.2.2 The Design and Development of InspiredDesign

Our prototype was developed using an open-source, platform-independent mobile development framework, Apache Cordova [Apache Software Foundation], in conjunction with AngularJS [Google] and Bootstrap [Bootstrap Core Team] for the layout. This allowed us to test the application on different operating systems. For the user tests, we chose an Android tablet (ASUS Transformer Infinity, without the detachable keyboard).

We chose a tablet computer as target device for our prototype, mimicking the form factor of a magazine, book, or sheet of paper on the table. After a simple start screen and a short introduction (only upon first start of the application), InspiredDesign shows a random flash card with a short statement derived from the attachment framework, and supported by a picture loosely related to the statement. Examples of flash cards as they appeared in the final iteration of the application are shown in Figure 5.6.

Participants were able to flip between flash cards by swiping left/right or pressing the left/right arrows on each screen. Although the order of flash cards was randomized in each user test, swiping back and forth resulted in seeing the same, consistent order (similar to skipping back and forth through a randomized

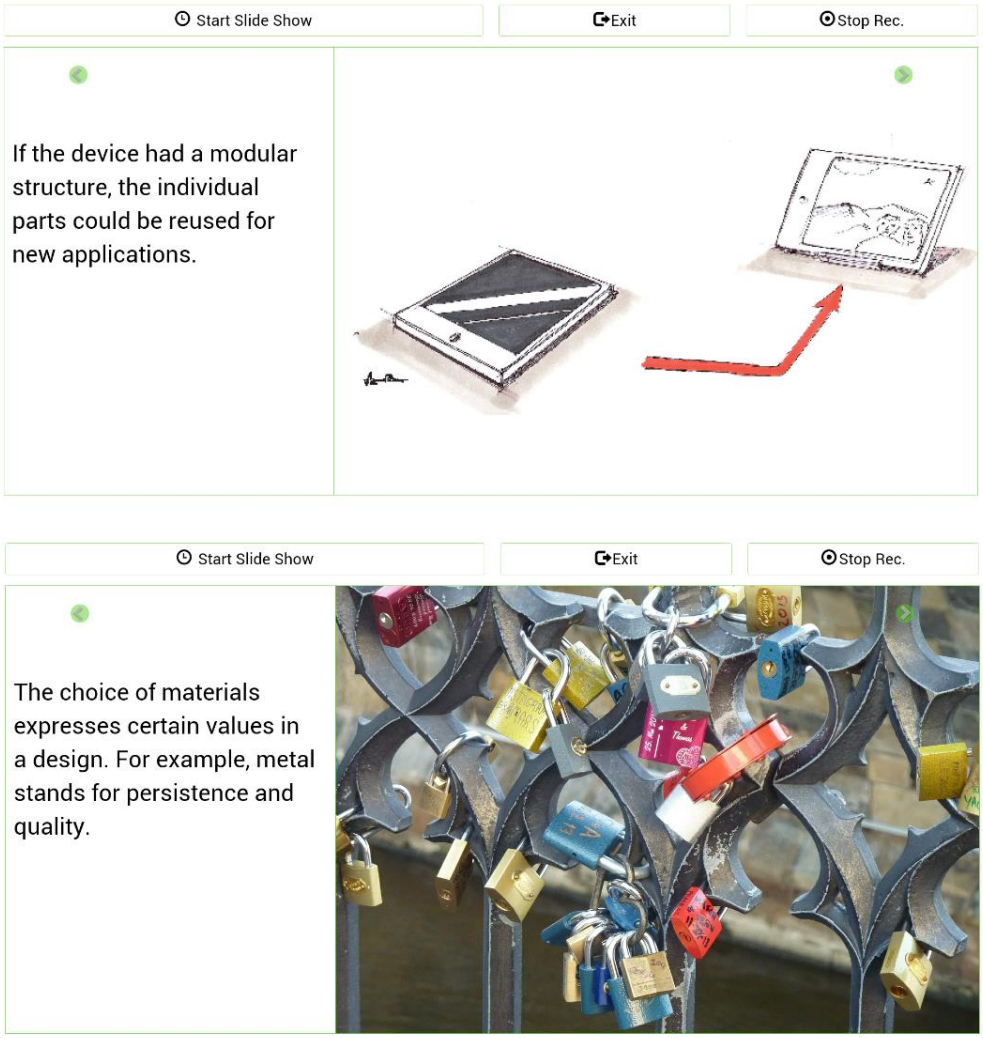

Figure 5.6: Two examples of the brainstorming flash cards as seen in the final prototype.

playlist on a music player). In "study mode", the application recorded the brainstorming session using the tablet's built-in microphone, and took timestamps of the current flash card visible. This allowed us to backtrack the discussion and know which flash card was visible during a specific point in time. Hence the "stop recording" button at the top left, which was meant to allow the participant to interrupt the user test or make a statement off record. We also implemented a slide show option which, based on a time interval selection from a dropdown menu, would automatically skip to the next flash card. However, no participant used either of those functionalities during the course of the study.

To generate the brainstorming flash cards, we created a mind map based on material from previous attachment framework studies, evaluating photos and stories from studies about people's attachment to objects in their home [Odom et al. 2009; Gegenbauer and Huang 2012a] and design sketches and interview transcripts from attachment framework studies with designers [Gegenbauer and Huang 2012a; Remy et al. 2015]. A variety of short statements were written to cover as many different aspects of the attachment framework as possible without being redundant. To avoid monotony, we rephrased some of the statements into a mix of short questions, examples, and requests. An important aspect in formulating those sentences was to make sure that they were easy to understand and did not cause any confusion due to SHCI-related jargon or terminology. The researcher who created the flash cards was not affiliated with the project prior to the development of the application and had no knowledge of the attachment framework before engaging in this research.

The text is accompanied by pictures related to the statement, either based on design sketches from previous studies or royalty-free pictures from Pixabay [Pixabay]. Initially, the picture was in the background of each flash card and the text in the foreground, centered and placed on a semi-transparent banner. However, feedback from design practitioners led us to change the design to a side-by-side view of pictures and text, which also prevents either input from being dominant over the other. Altogether, we ended up with 28 flash cards; examples can be seen in Figure 5.6.

5.2.3 Study Design

To evaluate the application and its impact on the design process, we conducted a qualitative user study with design practitioners. Our study goals and focus were to determine the impact of the application on the design process as well as the designers' perception of how it affected their practice. Thus, we split the sessions into three parts: 1) an initial brainstorming without the application, 2) brainstorming with the application, 3) a semi-structured interview. The design task was to create ideas for a health and fitness monitoring tool; in addition, we also asked the designers to think about how to encourage a strong bond between the owner and the device, reducing the likelihood of premature disposal. We did not aim for a comparative study with the goal to evaluate the design outcome, thus we did not counterbalance the order of the first two study parts; we were more interested in qualitative findings as to how InspiredDesign influenced the designers' brainstorming process and considered part one as a warm-up task.

In the first part of the design task, we provided the designers with pens and small cards and asked them to sketch or scribble their thoughts and ideas for potential designs. This technique of making notes during or prior to a brainstorming session is not particularly different from traditional brainstorming; it resembles an activity commonly referred to as "brainwriting", which is then usually followed by a discussion or a more traditional brainstorming. This is also what we asked participants to do in the second part of our study – use the app and its flash cards as additional input to create new ideas or extend on the existing ideas from the first part. We switched pens during the two brainstorming parts to make sure that we could identify changes in the sketches caused by the interaction with the application. We encouraged participants to "think aloud" in the second part, as some simply browsed through the brainstorming cards, discussing them without making extensive use of the sketching material provided – in which case the recording gave us insights into their thinking.

For the first part, participants had approximately 10 minutes, after which we asked them to finish their current idea. After a brief introduction to the tablet application, participants had approximately 15 minutes for the brainstorming with the app. The final interview lasted for an average of 20 minutes. Interview questions included basic questions about the participants' background, such as their experience in product design especially with regard to design tasks similar to ours. We also asked what their usual approach to idea generation was, whether they could envision such a tool being integrated into their process, or if they in fact already use any technical tools. All materials as well as the schedule and interview questions can be found in Appendix D.

Since we learned from previous interviews with designers that brainstorming is sometimes done in a group, we recruited single designers as well as groups of designers to participate together. Using mailing lists and local online design communities, we were able to recruit 13 designers (five single designers, four groups of two designers for a total of nine trials). The total duration of the study was estimated to be about one hour, and participants were compensated with an equivalent of $30 USD (single) or $40 USD (each in a group). Six of the participants were female, seven male; six were currently working as professional designers, seven studying design in a professional design program; participants had diverse backgrounds from various design disciplines, although the majority (nine) described their main area of specialization as product or industrial design. Other areas represented were graphic design, interaction design, visual communication, and fashion design.

We transcribed the interviews and used affinity analysis [Beyer and Holtzblatt 1998] to interpret them, targeting the analysis toward our initial study's goals: determining the impact and applicability of such a tool on the design process, but also evaluating how the attachment framework's principles were conveyed through the use of the brainstorming flash cards in the app. Furthermore, we informally evaluated the evolution of participants' designs during the first two parts of the study – with and without the application, in conjunction with our own observation of participants' usage of the tool. We did not employ a formal evaluation of the instances of attachment to be found in the resulting designs,

as the brainstorming results did not always converge into concrete ideas that would have made an evaluation of attachment frameworks possible (e.g., as our preliminary study in Chapter 3). Many of the ideas were only roughly sketched and sometimes not even written down, but only verbally expressed; we therefore refer to a mix of observation during the study, results of the affinity analysis, and raw sketches to informally assess instances of attachment. We elaborate on the issues of evaluating SHCI design knowledge in a limitation section in our findings.

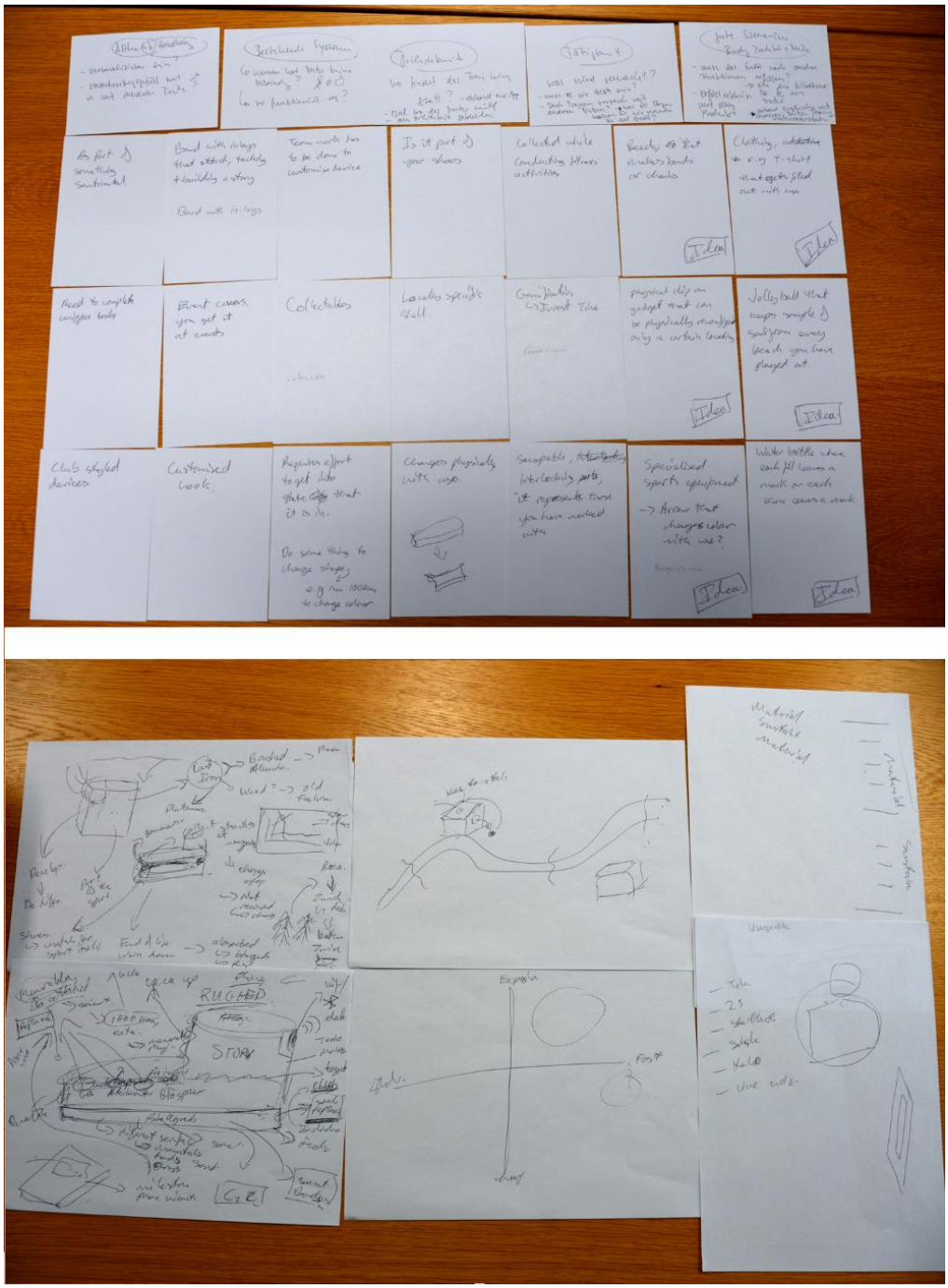

Figure 5.7: Brainwriting and brainstorming sketches from participant P5.

5.2.4 A Case Study of InspiredDesign in Practice

To illustrate how the user study was conducted and how InspiredDesign was used by the participants, we report in detail on one of our user tests. Note that there was a significant variety in how participants used the application, especially in light of their different backgrounds, but also differences in how they approach brainstorming in their daily design practice. We therefore present this example as a case study for a better understanding of our application and our study that should help to put the findings into perspective, but emphasize that certain aspects cannot be generalized.

5.2.4.1 Part 1: Brainwriting

After the usual introduction – welcome to the study, explanation of the study procedure, signing the consent form – Tim[5] (P5), a male student of product design, received the design task. A sheet of paper explained the design objective as well as the basic concept of "brainwriting" in a few sentences, while the instructor summarized the key points: create ideas for a health monitoring tool that encourages a strong bond between owner and device, and make notes/sketches of those ideas on A6 sized cards. Tim did not know the term brainwriting, but understands the concept well enough – and started writing down brief keywords quickly, as well as some more elaborate concepts and ideas.

The entire collection of his brainwriting cards is depicted in Figure 5.7 on the top. Some were short notes, e.g., *"customized look"* or *"teamwork has to be done to customize device"*, some formulated as questions, e.g., *"is it part of your shoes"*, and six of his cards he labeled with *"idea"* as they express more elaborate thoughts, e.g., *"physical clip on gadget that can be physically reconfigured only [at] a certain location"*. After ten minutes, the instructor asked Tim to finish his thought and moved on to the next part of the study.

5.2.4.2 Part 2: Brainstorming

The instructor put the tablet on the table and starts the application. She asked Tim to use InspiredDesign as an additional input channel, similar to the brainwriting cards from the first part, and to continue brainstorming ideas or expand on his previous ones for the same design task. The application showed a brief information screen and informed Tim that he will be recorded for the purpose of the study, and as he pressed "Start", the first flash card appeared. The suggestion reads *"if the device had a modular structure, the individual parts could be reused for new applications"* and showed a sketch of a phone being used as a photo frame (Figure 1, bottom). Tim talked about how modularity can lead to creating a story as one builds a unique device; he further seemed particularly intrigued by the "new application" aspect and made a quick note that for a new sport your device might need to do different things, so the device would become part of the sport. He swiped to the next card which talks about materials (Figure 1, top), to which he responded that *"I didn't really [...] I was playing much more around with the concepts so this is a really good one to pushing me into the*

[5] Participant's name replaced with pseudonym.

material side of things". Tim continued to work on his sports idea and jumps to adding *"brushed aluminum"* to one of his notes, explaining that it expresses *"longevity"*. By the end of the brainstorming, Tim had created a variety of different ideas, one of the more elaborate ones being an interactive sports shoe that combines several of the concepts proposed by the app, such as recyclable material, replaceable parts, but also Bluetooth-connectivity that would enable the shoe to unlock a badge once the wearer has run 1000 km (Figure 5.7, bottom).

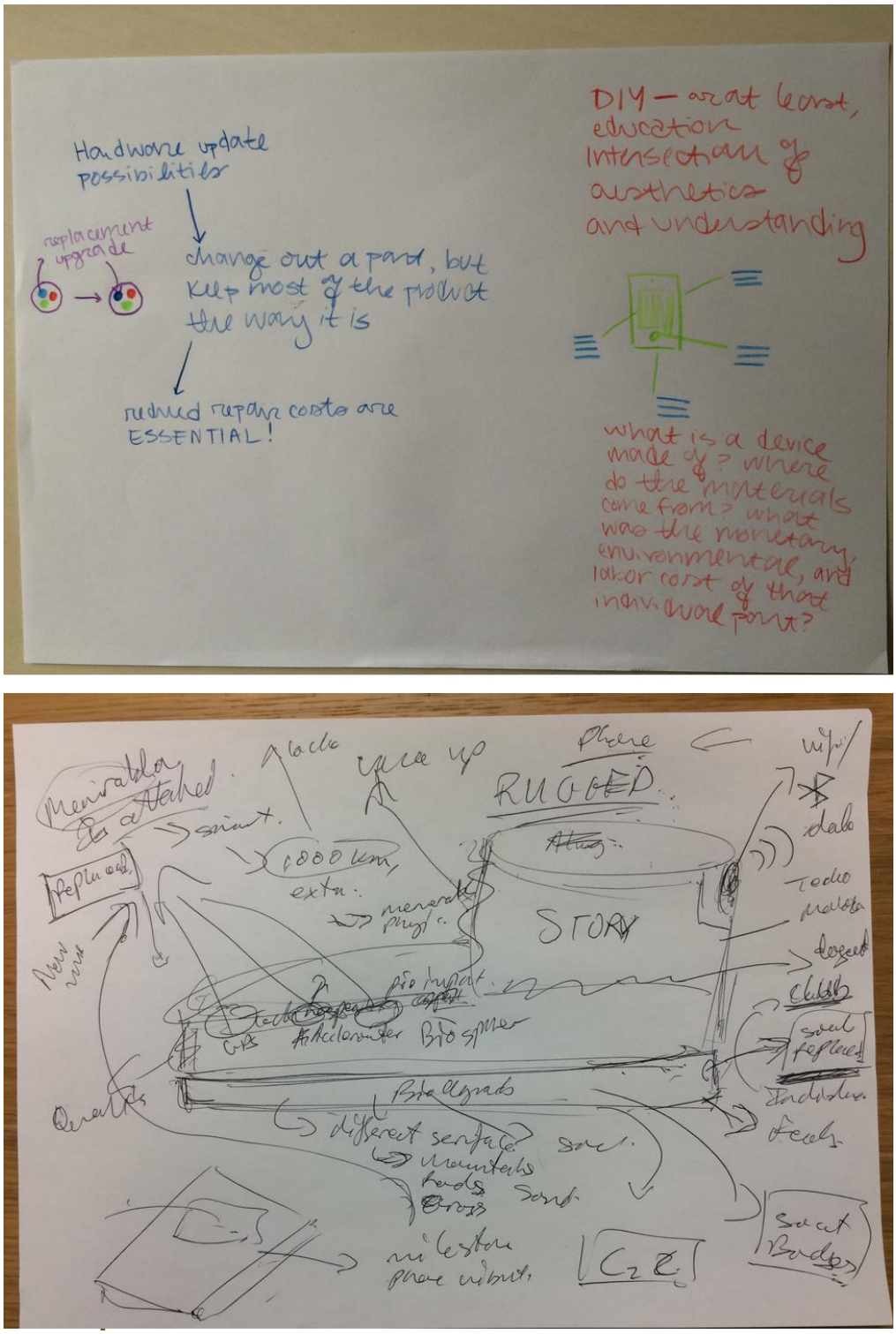

Figure 5.8: Examples of brainwriting/brainstorming scribbles by the study participants.

5.2.4.3 Part 3: Interview

After the brainstorming is concluded, the instructor conducted a semi-structured interview about Tim's design background, his usual approach to design in general and brainstorming technique in particular, as well as any software used for brainstorming. Tim is also asked to explain some of his designs that he thinks stand out as particularly interesting with regard to the design task. Among others he explained the concept of the shoe and some of its features. Asked about the application's usefulness, he opined that it provided valuable input to challenge his thinking, and praised the diversity of the flash cards: *"Whenever I get stuck or I need a new idea, I'll try to find some kind of input to help me go further. It's usually not as good, as different, as diverse as the app."* He concluded that while the application is useful, he would have like to see more features, such as different categories of advice and an integrated sketch app.

5.2.4.4 Summary

In terms of integrating InspiredDesign into his design process, it seemed to be quite natural for Tim – he continued his brainstorming in part two just as in the brainwriting, with the only differences being that he included the external input into his thinking. He was one of the more talkative of the solo participants as he did not need to be encouraged to "think aloud", and also made extensive use of the sketching material we provided. Some of Tim's designs from the brainwriting already exhibited features that could be interpreted as related to the attachment framework; for example, "customizability" as mentioned on one of his flash cards, which he later described as helping to build a story: *"You can add and take away different parts of [the device] and that builds a story or a unique device"*. However, his concepts become much stronger and much more focused on attachment-related features, such as for the example of with the shoe – almost every aspect of the final design bears relevance to one of the attachment criteria. This was a recurring theme: some participants had their own basic intuition for how to encourage a strong bond between the device and its owner, as requested in the design activity. However, while only a few direct links and many far-fetched connections to the attachment framework could be made after part one, the designs at the end of the brainstorming were much more focused on those aspects.

5.2.5 Findings

We discuss the findings from our evaluation, based on the affinity analysis of the interview transcripts, the observation during the study, and the brainstorming results produced as a result of the design task. Note that P1-P5 refers to the single participants, while T1-I to T4-II refers to the four teams, with the first digit denoting the team number and the second Roman numeral distinguishing between team members.

5.2.5.1 Fostering Critical Reflection

During the study we observed frequently that participants used the brainstorming flash cards to critically reflect on their ideas, for example discussing how their ideas from the first part of the study related to the idea presented in the app, extending existing concepts, and creating new ideas based upon previous thoughts in combination with the application's suggestion.

Participants praised this as a particular helpful spin added to their brainstorming:

> *"[The app] challenged my thinking. […] You always initially make a bunch of assumptions to start with. It is important to always try and challenge or break these assumptions. […] Basically, it improved the quality of the design generated." (P5)*

> *"I think it's good to question or to review your own experiences." (P3)*

While at first glance this might border on violating the "defer judgment" principle of the original brainstorming rules, note that the application due to its static nature did not actively discourage or criticize ideas – the participants took it upon themselves to question their own ideas in light of the application's input. This was echoed by the designers' impression in the interviews, who understood the application's input as a means to extend their ideas. One participant compared this to an experience from his design training:

> *"We had a workshop where the teacher told us to start again and again under changing conditions. […] This taught me to not be stubborn. […] To reset myself." (T1-I)*

This highlights another interesting aspect of our findings: the relationship between the application and participants. While we initially envisioned the application to be a brainstorming companion, similar to another person throwing input into the dialogue, participants reacted differently to the flash cards; we can loosely separate their reactions into two patterns. Some participants started off with a critical stance towards the cards, using them as an additional input channel but questioning the application's suggestions, at least in the beginning. This is unusual behavior in a brainstorming session, where it is frowned upon to criticize a participant's input. The other (and more commonly observed) behavior, such as by the team in the aforementioned example, was to consider the application to be almost a higher-level authority whose input was respected and highly valued. Even in cases where the participants did not see an immediate connection between a flash card's suggestion and their design ideas, they still spent a significant amount discussing the card.

Regardless of how the application was perceived, the application often fostered a critical debate that allowed participants to gain a new perspective. This was of course valuable for the single participants, but it was also mentioned as a helpful aspect by the groups, especially in design teams that were looking for external stimuli to foster discussion:

> *"I think [the app] is helpful for people who already know each other very well. Because these groups tend to fall back into the same schema every time. I liked [the app] because it motivated me to talk about different things." (T2-I)*

5.2.5.2 Complementing Design Ideas

Another common observation during the brainstorming session was how participants used the application to complement their design ideas. This was different from the critical reflection we described earlier, as it did not change

their way of thinking or introduce entirely new aspects into a design, but rather worked as a memory aid. A number of participants described the application as a checklist or reminder, e.g.:

> *"[The app] gives you fixed topics that you can discuss. [...] It helps to check that you didn't forget anything." (T3-II)*

The function of a friendly reminder that brings a related topic into the discussion became especially apparent in groups, when one participant brought up an idea related to the flash card, while the other team member pulled up one of the cards from brainwriting and highlighted that they already thought of a similar concept. The team then went on to elaborate on this idea for a while. In brainstorming sessions of single participants, a similar effect occurred when one of the application's suggestions was close to one of the ideas from the brainwriting; for example in this instance from P1 during the brainstorming session, inspired by a slide about jewelry:

> *"That is similar to the idea which I had [pointing to one of her brainwriting cards]. That you could built a chip into your watch, such that no one can see it, and take photos of your food or drinks and recognize what you eat, calculating calories [...]." (P1)*

While reoccurring ideas could be seen as unnecessary redundancy, this was not the view of any of the designers in our study. On the contrary, our participants pointed out that they were reaffirmed by the application complementing their ideas:

> *"For some cards we already had similar ideas but it helps to reformulate the ideas that we already had." (T3-I)*

> *"The app is helpful to get more inspiration and to verify [my own ideas]. It helps to think again about the same topics and to feel approved." (P3)*

> *"Or you have an idea and it is confirmed [by the app]. Thus, the idea gains importance. That's also one of the strengths of the brainstorming, to reaffirm oneself." (T4-I)*

5.2.5.3 Tailoring Advice to a Specific Design Task

Since the extended attachment framework [Gegenbauer and Huang 2012a] was developed with a specific focus on consumer electronics, and most of the study material we used to create the brainstorming flash cards involved advice regarding the design of electronics as well, our application was slanted towards this particular product domain. We chose our design task with respect to this constraint; however, we kept the task intentionally open to avoid constraining the brainstorming results and did not define "health monitoring tool" any further. In our analysis we found this to be an important discussion among participants as well. The majority of participants felt that the app seemed to be tailored to the design task, e.g.:

> *"This app is very specific. The app is designed for this product." (P4)*

> *"The app seems to be tailored for the task we received." (T3-I)*

However, at the same time several participants complained about the task being *"too broad"* (e.g., P4, T4-II). As mentioned in the beginning, we kept the design task intentionally open, which might have influenced the perception of participants that the application was specifically tailored to the task. At the same time, choosing a more focused design task might have narrowed the results more and rendered certain brainstorming flash cards irrelevant. Nevertheless, the chosen scope seemed to be appropriate for the purpose of this study. Interestingly, several participants suggested the same concept, of the app starting with more general advice and narrowing down to specific topics:

> *"In the beginning, [the app] could be more open, because the cards are like inspiration impulses. […] I think the most important thing is that it is open in the beginning and gets more and more specific. This could either be linear […] or you could choose to go a level deeper." (T2-II)*

> *"[…] that you are able to click on a topic and sub-questions arise." (T3-II)*

One participant even mentioned *"different moods"* and categories for various product domains – but also acknowledged that the open-ended nature of brainstorming flash cards *"works well for the ideation phase"* (P5).

5.2.5.4 Structuring Thinking

As previously mentioned, the brainstorming flash cards sparked discussions through critical reflection or affirmation of the designs created in part one of the study. However, said discussion was not veering away from the original design task; rather, the application helped to bring up relevant points for discussion, but oftentimes previously unnoticed by the designers. Several participants noted this in the interview as helpful for the brainstorming session, as it brought structure into the process, e.g.:

> *"You stay focused on the task, the question. Otherwise while brainstorming, it often happens that you go once around the world before you get to a point. […] I think it's important to focus on the result. […] When the app acts like a partner who is relaxed and clever and it makes sure that you come to a point, I would say 'ah, okay'." (T1-I)*

> *"[The app] helps to reduce the essential and to come back to the important questions and to rethink if something is possible. It helps to come down to earth." (P1)*

Our observations confirm this statement: During the second part of the study, the brainstorming with the application, participants created either new designs or elaborated on designs from the brainwriting – but due to the constraints imposed by the brainstorming card, always stayed "on topic". The brainstorming groups of two designers had extensive discussions and sometimes debated for as long as five minutes on a single flash card, bringing up several ideas, making connections between the flash card's suggestion, their design concepts, and stories from previous design experience. Yet those discussions were always related to the overarching task.

Several participants, interestingly especially the teams (T2, T3, T4) asked for an overview of the cards to give the entire brainstorming session more structure,

but also to allow for the creation of clusters similar to mind maps, a step that often follows a brainstorming session:

> *"I think for me it's important to have an overview when you're brainstorming. Thus, you're able to combine ideas (T4-II). Actually, you should have something like a wall, where you could move and combine them (T4-I). Or build clusters (T4-II)."*

5.2.5.5 Reflection without Distraction

As mentioned above, our tablet application had another feature: starting a slide show of flash cards, instead of manually swiping through the suggestions. We initially assumed that this automated slide show would lead to a very time-constrained brainstorming, and were interested in the side effects. However, not a single participant in our study made use of this feature (surprisingly some participants even requested a similar feature during our interviews – note that the "start slide show" button is visible at all times, see Figure 1, and we did not discourage participants in from using it). While we do not have an explanation as to why it was not utilized, the manual slide control by participants caused a side effect we already elaborated on: in-depth reflection and discussion about the application's suggestions. At the same time, the manual control caused the application to be non-interruptive.

Manual control (instead of automatic switching) is important because it combines the best of both worlds: an uninterrupted discussion around the designer's concepts and how they relate to the application's suggestions, which are based on the attachment framework; and for the designers a feeling of being in control, in their usual work environment and process. Note that there was interruption in terms of the direction the design discussion was moving, such as noted by one participant:

> *"Well and then I'm thinking about the material and say 'let's swipe and see if there's more' and then it's a totally different topic…" (P1)*

However, we believe this is similar to episodes in a regular brainstorming session where participants agree that one point has been discussed exhaustively and move on, and not everyone feels that the next topic is part of the natural flow. What the participant expressed in this example was more a feature request beyond typical brainstorming – to get more information and input regarding one particular topic. It can be argued if this is against the original intention of brainstorming, which is supposedly "wild" in the freedom of creativity and ideas. In conclusion, our observations show that the manual control by the participants promoted in-depth reflection and avoided unwarranted interruptions.

6 NEXT STEPS: SHCI, ATTACHMENT, AND A FUTURE OF LIMITS

Our two experiments with StickyDesignSpace and InspiredDesign provided additional insights in our exploration of ways to bridge the theory-practice gap and apply the attachment framework to design practice. In this chapter, we further discuss the lessons learned for SHCI research that seeks its way into design practice, but also takeaways for the broader field of HCI. We also take a step back to look at the big picture of addressing the problem of obsolescence and how our approach fits in today's consumer electronics manufacturer's processes, as well as in future scenarios which might be fundamentally different.

6.1 LESSONS LEARNED FOR SHCI DESIGN KNOWLEDGE TRANSFER

Our findings discussed the impact of the application on the design process and the designers' perception thereof. We now take a step back to relate our findings to our overarching goal: addressing the theory-practice gap by more effectively communicating design knowledge from the SHCI research community to design practitioners. In our analysis, we reflect on our research question that guided the development and evaluation of our tools: "How can an existing sustainability framework be integrated into tools for designing consumer electronics, and what effects does this have on the design process and design outcomes?"

Assessing the effect of this knowledge transfer on the design outcomes, in our case the extent to which the resulting designs actually foster attachment, poses an almost unsurmountable challenge, and we discuss this limitation. Furthermore, we elaborate on how our study findings relate to bridging the theory-practice gap, the takeaways for SHCI researchers, and potentially HCI researchers in general.

6.1.1 Limitation: The Evaluation of SHCI Design

A major issue in our study – and general issue for sustainable interaction design research – is that of how to evaluate design in practice. Researchers have elaborated on the particular difficulties of evaluating SHCI research [e.g., DiSalvo et al. 2010; Silberman and Tomlinson 2010], and no agreed-upon solution or standard for evaluation has yet been established. One approach that has been suggested is to instantiate the design and do a hands-on evaluation of the prototypes [Grosse-Hering et al. 2013]; another is to do a comparative study of designs by design experts [Remy et al. 2015]. Neither technique is applicable in our case, as the outcome of a brainstorming session is far less mature and background research does not even end with designs, but even precedes the ideation process. Even if any of those evaluations were to be attempted, the problem of ambiguity when assessing quality in design remains, which severely hampers the validity and generalizability of any claims made as a result thereof [Silberman and Tomlinson 2010; Remy et al. 2015]. Therefore, we refrain from an in-depth evaluation of the designs.

During the course of our InspiredDesign evaluation, the design ideas were iterated on by our participants, and these design improvements were based on discussions that for the most part revolved around the sustainability issues or attachment-related topics that the application brought up. Furthermore, we

asked participants to explain the concept of their designs, their progression from brainwriting to brainstorming, and their satisfaction with the final result. This inquiry allowed us to get a good grasp of the participants' understanding of the attachment framework as well as an impression of how their design sketches reflected the framework's ideas. In the case study of P5 this progression is reflected, and a similar progression was observed for the other brainstorming sessions; e.g., as P2 reflected on how InspiredDesign influenced his designs:

> *"I get a lot of inspiration from the app and it reminds me of things that I forgot in the brainwriting session, for example customization, durability, some materials, like nature materials". (P2)*

This is one example of many in which participants took their designs from the first part of the study and enriched them with attachment-related features, such as in this instance where P2 changed the material of one of his design concepts to wood with the reasoning of supporting durability – which can be linked to the attachment criterion "perceived durability". We found many of such anecdotal instances of attachment both in the designs and the designer's argumentation for improving their design; our informal inspection of the design ideas suggests that the resulting designs demonstrated attachment-fostering properties rooted in SHCI design knowledge.

These instances give us reason to be cautiously optimistic about the potential of this approach for positive impact on the sustainability of resulting designs. Nevertheless, we cannot definitively assess the quality of the resulting designs in terms of their ability to foster attachment, nor can we conclusively state that attachment-fostering qualities of the designs are a direct result of the use of InspiredDesign. However, such conclusions were not the goals of our research. In the first sentence of his seminal paper, which is widely considered to be one of the foundations of the field, Blevis asserts that *"sustainability can and should be a central focus of interaction design"* [2007]. This objective is what InspiredDesign and our study tried to achieve, and for which we found substantial evidence as highlighted in the findings section: designers incorporated SHCI design knowledge into their processes and often attributed doing so to their use of the application. Evaluating the extent to which the designs exhibit this knowledge would require a complete design process beyond just brainstorming and also depend on other factors we cannot influence, such as the designers' ability to realize their design concepts and convert them into a functional product, and observation of the relationship between devices and owners over a longer period.

6.1.2 How to Translate SHCI Design Knowledge: Language and Level of Abstraction

As highlighted in the third challenge of our first study, translating SHCI design knowledge into a language that the target audience understands is an important step to ensure successful knowledge transfer. Reflecting on the results of both our experiments, especially with respect to the designers' understanding of the attachment framework as derived from our debriefing interviews, StickyDesignSpace and InspiredDesign significantly contributed to achieving our desired goals. Therefore, the question is which particular aspects of our approach were critical in achieving this effect – and how can future research

reproduce these results when bringing SHCI design guidelines to practice. We argue for the two main takeaways of our approach being 1) *speaking the designers' language* and 2) *maintaining a proper level of abstraction*.

In our processes to create both the descriptions on the horizontal axis of StickyDesignSpace as well as the flash cards for the InspiredDesign app, the phrasing was based on quotes from the designers' interpretation of the attachment framework. The researcher responsible for creating the application had no knowledge of the attachment framework prior to this project, further reducing the amount of SHCI-specific jargon. We acknowledge that it is not always feasible nor desirable to conduct an entire study for the purpose of translating SHCI guidelines into the designers' language. A more realistic approach is to look at existing examples that inhibit one particular feature pertaining to the design principles. The purpose of InspiredDesign's flash cards is to inspire the designers and stimulate their creative thinking rather than showing novel and creative concepts; in fact, a flash card that shows an entirely unfamiliar and potentially confusing idea might leave the designer puzzled and disrupt the creative process.

Reviewing existing work is also part of the background research in a typical product design process [Kruger and Cross 2006] and therefore blends into the typical routine of a designer. Annotations, comments, and reviews of those designs retrieved in a background research process can be used to describe design properties in designers' language – rather than adhere to the wording of design principles as commonly used in SHCI literature. In a perfect scenario, the process of searching for, selecting, and refining the translated content would be an iterative process that includes SHCI as well as design experts.

The second insight emerges when we compare the information provided to the designers in our studies: In the preliminary design experiment in Chapter 3, the designers received the very broad and generic description of each of the seven attachment framework criteria, accompanied with two to four textual example stories of attachment. In the evaluation of our design support tools, the both applications provided cues that were shorter and easier to grasp than the original description of the attachment criteria, yet deliberately more concrete. The accompanying background pictures added to this notion by showing a concrete instantiation of design that was loosely connected to the textual hint. This leads us to discuss whether the best guidelines should be concrete or abstract – a debate that is not new to design research and connected to other issues, such as the perception of visual versus textual stimuli or the different preferences of novice versus expert designers [e.g., Cross 2004; Eckert and Stacey 2000; Goldschmidt and Sever 2011; Goldschmidt and Smolkov 2006; Gonçalves et al. 2011]. While there seems to be no unanimous conclusion, the drawbacks of the extremes are beyond doubt: guidelines that are too abstract tend to be absent from the resulting designs, while concrete examples can limit the designers' creativity – especially a concern when targeting novice designers.

Therefore, finding that right level of abstraction is another challenge to consider in the translation of SHCI guidelines. In our example, we iterated over a transformation through multiple levels of abstraction: from generic (the original

framework) too specific (the design sketches from the first study), resulting in a middle ground of short cues.

6.1.3 Takeaways for SHCI Design Knowledge Transfer

As Rogers [2004] pointed out, new ways of knowledge transfer must be found to bridge the theory–practice gap. Our application achieved the goal of transferring the knowledge to its target domain, as the deep level of reflection discussed in our findings shows how InspiredDesign brought the attachment-related themes to the forefront of the brainstorming, and StickyDesignSpace sparked thinking about longer-lasting products as well. Previous studies investigating how to bridge the theory–practice gap [e.g., Grosse-Hering et al. 2013; Remy et al. 2015] took place in artificial settings and had designers deviate from their typical design process. Neglecting the complexities of design practice adds one more reason as to why knowledge transfer often fails [Stolterman 2008]: even if success is observed in the setting of a study, it might not be reproducible in real-world practice.

While our evaluation of InspiredDesign did not involve a real-world task, it differed from previous attempts as it employed one of the most common practices [Gonçalves et al. 2011] of designers, brainstorming, in a way that resembled their usual work practice. We constructed the experiment so as to mimic a typical brainstorming task as described in design literature and in our previous interviews with designers, and our study participants confirmed that the task setting was realistic (with the exception that some of them had not heard the term *brainwriting* before, although they were familiar with the activity itself). The designers created a variety of ideas in various stages of maturity; a small selection of the more visual, less textual scribbles can be seen in Figure 5.6. Our observation as well as the affinity analysis revealed many instances of in-depth design discussions related to the attachment framework's principles, and participants' descriptions of their designs sketches in the interviews highlighted a deep understanding and raised awareness of the concept of attachment after using InspiredDesign. The findings of StickyDesignSpace point to a similar direction; the descriptions of attachment principles on the horizontal axis of the design space were the main discussion point brought up by any participant when asked for feedback about the tool, and the observations from designers using the tool also highlight a focus on longer-lasting products in their background research during the evaluation.

This combination of "teaching attachment" while maintaining the core focus of the target audience on its main task – discussing product designs – echoes one of the core goals we wanted to achieve: supporting reflection without being restrictive [Stolterman 2008], while still communicating the SHCI design knowledge. We therefore believe that our study showed the importance of translating SHCI research into a lingua franca [Rogers 2004; Sutcliffe 2000] and highlights one possible way to do so: by hiding the complexity of SHCI research, abolishing the terminology and genre-specific jargon, and deeply embedding it into existing practices of the target domain while minimizing the alteration of the process. However, generating the content is not an easy task, whether it is creating crisp and nohn-ambiguous descriptions for the horizontal axis of

StickyDesignSpace or prompts for InspiredDesign's flash cards. It is a very important step though, especially considering that the quality of the content is one important factor in realizing the knowledge transfer [cf. Rogers 2004].

6.2 "But Why Would Industry Want This?"

During our research, we were confronted with many challenges when attempting to bring the attachment framework to design practice, but by far the most commonly asked question was: "Why should industry want to implement this? They want to sell more." The underlying message always is that the attachment framework and similar SHCI design principles lead to a decrease in sales, since people hold on to their devices for a longer amount of time, and thus would hurt the manufacturer's revenue stream. At first glance there is almost no incentive for technology companies to implement any of those frameworks; in fact, they might try to avoid establishing any attachment to a device as the customer might skip the next generation and opt out of a purchase.

If one assumes this to be the case and blames companies of being complete unwilling to adapt any such design principles, it would require a fundamentally different line of research: changing companies' way of thinking, potentially changing the entire underlying economic system, and ultimately changing our society at large. There are many examples of such major changes in history, with one of the most prominent being the Industrial Revolution, drastically improving manufacturing processes but in its wake impacting almost every other aspect of human societies. As ubiquitous technology – and with it in particular the Internet – has led to a similar impact on our life in recent decades, popular news and scientific research alike label our current time as the Information Age and observe a Digital Revolution, similar to the Industrial Revolution. Just as the transformation of manufacturing processes in the Industrial Revolution reshaped human society, the Digital Revolution offers challenge and chance at the same time to guide the direction of our future.

This change which is currently happening to our society offers an opportunity for those who seek to steer away from existing societal and economic models towards a more sustainable one. Adversaries for change grew in number, influence, and outreach by moving from activist groups such as Greenpeace in the 1970s towards powerful political branches at the end of the century. As of 2016, there are 85 green parties [Global Greens], 191 countries have signed the Paris Agreement which seeks to reduce greenhouse gas emissions [UN Treaty Collection], and the environmental factors are becoming an increasingly important factor in discussions within governmental jurisdiction, corporate strategies, as well as public opinion. None of those achievements and milestones is without criticism: The green parties might be a powerful force in some countries that can influence decisions and even help steering towards societal change, but they all too often pale in comparison to corporate interest. Scientific authors [e.g., Rogelj et al. 2016] and popular news outlets [e.g., Rubin and Peltier 2015; Harvey 2015] agree that the Paris Agreement is not going far enough. And while many companies have promised to switch to more sustainable practices, customers worriedly argue that those efforts are not only insufficient to save our

planet, but also fear greenwashing [Remy and Huang 2012], i.e., companies pretending to act sustainable for a green image while maintaining bad practices.

From all those examples, we can learn three things: First, change is already happening. Whether this change will ultimately be enough to address issues of climate change and lead to a more sustainable future is unforeseeable – just as the long-term results of the Industrial Revolution were impossible to predict. Second, there is no sign of any of this change slowing down, but rather gaining more and more influence by actors moving from activism into influential governmental and corporate positions of our society, and popular media discussing the issues with regular coverage in the news. Third, it requires large-scale, long-term effort on various levels of our society. Therefore, it is clearly infeasible to develop means for facilitating this societal change in the scope of this thesis. However, depending on what the future might hold, industry's stance on SHCI design principles might change. As we have highlighted in the excursion into marketing practices earlier in this thesis, the methods of HCI and markets are closely related; and in terms of goals, attachment and loyalty is another common aspect – albeit brand loyalty as opposed to device loyalty.

Researchers in SHCI have argued for a change in our society on various levels. DiSalvo et al. [2010] close their survey of SHCI literature with calling for a "radical transformation". Dourish [2010] warns SHCI research about focusing too much on the individual while neglecting opportunities to strive for impact on a larger, societal scale. Håkansson and Sengers [2014] discuss the challenges of societal change for both the individuals as well as HCI designers. Among the outcomes of a CHI 2014 sustainability workshop was the plea to "make changes to larger systems such as institutions, infrastructures, and policies" [Silberman et al. 2014], which was echoed by Nardi and Ebkia [2017] who discuss how SHCI research can gain a political economy perspective to become more influential.

More recently, Thomas [2016] successfully showcased how to transfer SHCI principles to governmental politics by participating in and winning a competition by the Canadian Government. HCI researchers have called for more engagement with policymakers [Lazar 2015; Lazar et al. 2016], and Thomas's policy brief is one example thereof. While Lazar et al. do not limit their call for policy engagement to environmental sustainability, in this field alone there are multiple opportunities offering potential for SHCI research to inform policies and vice versa, such as climate change politics, green ICT procurement, and waste electrical and electronic equipment (WEEE) policies [Thomas et al. 2017].

We argue that more communication is required to engage with those audiences, either through direct contact with policymakers or, if available, mediators on academic level such as policy-experienced research groups. While this effort is time- and resource-consuming, HCI researchers are especially well-equipped for this task due to the interdisciplinary background that is typically prevalent, and

success stories can be used to communicate the lessons learned to other researchers in the field, as in our example [Thomas et al. 2017].[6]

6.3 SHCI IN A FUTURE OF LIMITS[7]

An aspect that we have not emphasized in the previous sections and that falls short entirely in many discussions about environmental actions, such as reducing greenhouse gases and improving energy footprints, is the depletion of natural resources. If we assume that economic growth continues and the rate of consumer electronics devices per household continues to grow, we are facing a future with multiple billions of devices produced, sold, and disposed of – every year. It is unlikely that such a practice can be maintained while combating climate change and moving towards a sustainable future. Concerns about such practices have been brought forward decades ago; most prominently, Meadows [1972] presented Limits to Growth, the results of a computer simulation extrapolating exponential growth of societal factors such as population and consumption, contrasted with finite resources. The results were met with controversy and are subject to debate as of today, but while the numbers might be off, the underlying message is an important one: the resources on our planet are finite.

Notwithstanding the debate about Limits to Growth, the prospect of potentially limited resources has sparked discussions about changing our culture of producing and consuming products. McDonough and Braungart suggest moving from a "cradle to grave" process to "cradle to cradle" [2008], pointing out that the resources used in most products are lost at the end of its life and not properly recycled. Even if there is a recycling plan, it is not sufficient to save the amount and quality of natural resources built into a product, leading to what they label as "downcycling", i.e., material gets lost in the process. Cradle to Cradle describes a production process in which at the end of life of a product the net amount and quality of natural resources is at least as high or even higher ("upcycling") than it was before the manufacturing process. They showcase this in the example of a shoe factory in Switzerland whose waste water coming out of the factory was cleaner than the water going into the manufacturing process. A similar concept is Circular Economy [Pearce and Turner 1989], which has even been adopted into an official EU Action Plan [European Commission: COM 2015], establishing regulation to guide economic developments into a less wasteful and more recycling-centered manufacturing process.

Discussions about resource limits are also omnipresent in computing research. Moore's Law [Moore 1965] states the observation that about every two years the number of transistors doubles, and a similar growth has been attributed to other

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[6] The author of this thesis is not a co-author of the policy brief, which was written by Thomas [2016]; however, he was involved in the effort to distill the takeaways of this policy brief's writing process and the lessons learned for SHCI/HCI research and is a co-author of the subsequent publication [Thomas et al. 2017].

[7] Contents of this chapter have been published in a journal article [Remy and Huang 2015b].

measurable factors in technology development as well. However, on a regular basis it has been argued that Moore's Law would come to an end; not necessarily due to natural resources but due to the limits of engineering, such as the size of integrated circuits being on an atomic level. Although Moore's Law faced many predictions of slowing down, recent engineering discoveries hint that it might continue far longer than expected [Yirka 2013], destroying hope for an engineering-driven slowdown of technological advancement (which might indicate potential for reduced sales).

Those observations, combined with the assumed industry's disinterest of resolving obsolescence, paint a depressing picture for the future of sustainability research. However, the basic assumption for observations such as Moore's Law are that growth is infinite. While early predictions of the end of Moore's Law have been disproven, there is still agreement that it will not continue to go on indefinitely as technological advancement will encounter a limit at some point. Similarly, the increased consumption of resources will hit a ceiling sooner or later, since all natural resources are limited. These limits have only been brought up in the debate in SHCI recently [Tomlinson et al. 2012; Tomlinson et al. 2013; Pargman and Raghavan 2014], and its implications for research have not been discussed in-depth yet in all aspects of the field. Therefore, the question arises: how do those "non-negotiable limits" [Pargman and Raghavan 2014] change and shape future SHCI research? In particular, how does the presence of limits affect the solutions to problems of obsolescence, as well as the discussion itself?

In this chapter, we seek answers to this question by looking at some of the obsolescence-related research from the field of SHCI [Remy and Huang 2015a] in light of the concept of Collapse Informatics [Tomlinson et al. 2012]. In our opinion, Collapse Informatics does not carry the apocalyptic meaning its term might suggest at first glance, but rather presents a new lens for looking at SHCI research: instead of treating the future as a binary entity (a perfectly sustainable society or the end of the world) the more likely future probably lies on a continuum somewhere in between, with neither of those extremes ever becoming reality.

Another important insight from Collapse Informatics is that this future, whatever it may look like, will not arrive in an instant, but our society will slowly transition into it – and probably continue to undergo changes. Tomlinson et al. argue that *"there is a need for research in collapse informatics – the study, design, and development of sociotechnical systems in the abundant present for use in a future of scarcity"* [2012]. Besides the development of systems – which would likely fall into the category of *sustainability through design* [Mankoff et al. 2007] – there is just as much need to look at the design of products in light of *sustainability in design* [Mankoff et al. 2007], especially with regard to the well-established concept of SID [Blevis 2007]. In the following, we will attempt to foreshadow what potential changes to SID are to be expected, how this affects obsolescence-related research in SHCI, and how existing contributions might be reinterpreted.

6.3.1 Example 1: Design for Repair, Re-Use, and Recycling

Many technological devices these days restrict the way users can repair the device or replace parts if hardware breaks or becomes outdated. For example, special tools are needed to open most smartphones, and replacing a battery is not possible without risking warranty for many phones, tablets, and computers. Maestri and Wakkary [2011] argue that technology should be designed such that everyday users can repair them – a vision which seems far-fetched given that most products have gone the other direction in recent years by restricting reparability, but might change entirely in a future of collapse. When resources are scarce, providing replaceable components might become a desirable new opportunity for business, and consumer-reparable devices will hopefully see a comeback.

If repairing is not an option, the device might also be re-used in an entirely new way beyond its intended purpose [Odom et al. 2009] or even recycled entirely to harvest the scarce resources inside them. Kim and Paulos [2011] developed a design vocabulary for re-used, which could be extended or re-envisioned based on the future needs for particular parts in a device, or different purposes of the device. An example for that can be found in a study by Huh et al. [2010], in which participants bought outdated and partially broken PDAs off eBay for the use as music player or cheap GPS navigation. A study in developing countries even suggests the possibility for large-scale re-use of old technology as displayed by TVCs [Lomas et al. 2013], a low-cost game console built from computing parts that were as old as 30 years.

6.3.2 Example 2: New Luxury and Longevity as a Lifestyle Choice

In our present world of virtually unlimited resources, at least from the consumer's perspective, acquiring the newest piece of technology is often considered a desirable lifestyle choice (e.g., for early adopters [Hanks et al. 2008]). A future of collapse might see a different picture; there are already streams of different behavior present in today's society, as exemplified by the *Slow Movement* [Grosse-Hering et al. 2013; Hallnäs and Redström 2001; Strauss and Fuad-Luke 2008], but also upcoming projects such as the D4R laptop [Beigl et al. 2013], Fairphone [Fairphone], or Phonebloks [Phonebloks]. Although those are small projects that cannot compete with the large-scale industry that produces the majority of electronics, it hints that potentially sustainable options are already being developed. If the prevalent lifestyle choice were to change from early adopter, i.e., users striving to acquire the most recent technological advancement, to one in which it is desirable to own a device for a longer time span, such projects could become major milestones for a new product design paradigm.

Blevis et al. go one step further and discuss the concept of *New Luxury* [2007b], which means that products are associated with a notion of luxury not because they are expensive and exclusive, but because of higher standards of quality while being not too expensive. In a future of scarcity, products that require a large amount of natural resources would automatically be expensive, thus never fall into the category of new luxury. Coincidentally, almost all of the design recommendations of how to realize and achieve new luxury seem to align

perfectly with a future of collapse, e.g., *"promoting services over new physical materials"* or *"promoting concern for secondary markets"* [Blevis et al. 2007b]. To some extent, the development proposed in their paper has already taken place – with the recent trend of cloud storage and digitalization of media distribution. However, many of the steps are still far from realization and contrary to current developments in technology design.

6.3.3 Example 3: Attachment, Ensoulment, and Pleasure Engineering

Another approach to address obsolescence is that of changing the inherent design values of products to foster a deep connection between the device and its owner. Many concepts have been proposed that share one commonality – a product that satisfies the user's needs, addresses their desires, and creates a long-lasting connection to avoid early disposal. The underlying principle can be found in concepts such as *Attachment* [Gegenbauer and Huang 2012a; Odom et al. 2009], *Ensoulment* [Blevis and Stolterman 2007; Nelson and Stolterman 2012], *Pleasure Engineering* [Woolley 2003], or *Emotional Design* [Norman 2004]. Although this list (which is by no means exhaustive) highlights a large number of independent contributions that all hint the same solution to obsolescence, there is no sign of any of those concepts making its way into a successful, large-scale design principle to be found in electronics products. We can only speculate about the reasons, but one major obstacle obviously is that they all are contrary to industry's and marketing's goals, as discussed earlier.

It is safe to assume that in a future of collapse, companies still want to sell products, therefore the question remains: how can all those concepts – that certainly align with the sustainability requirements for a future in which consumers should hold on to their devices longer than it is currently the case – be brought together with industry's goals? We believe that the answer to this question is hinted at in SHCI research as well, such as by Blevis et al. [2007b; Blevis 2008] or Gegenbauer and Huang [2012b]: by promoting services over products. This would present a major shift for many companies, but might be an inevitable change to which there is no alternative, similar to what we have seen for the development of music and movie distribution in the past.

6.3.4 Transitioning into a Future of Limits

As Tomlinson et al. [2012] point out, a future of collapse and limits does not appear in an instance but a society slowly transitions into it. While collapse cannot be measured exactly but rather observed in, a societal system will undergo changes to adapt to this future of limits in which the traditional, wasteful lifestyle cannot be maintained anymore. Some commentators in scientific communities, such as a number of the participants at the LIMITS 2015 workshop [LIMITS 2015], argue that we are already seeing signs of collapse in or society today. At the same time, some of the concepts proposed in this paper that address product design in a future of collapse seem to be hard to realize in the immediate future, especially because they do not align well with industry's interest.

Therefore, we argue that in a phase of transitioning of a future of collapse there is potential for industry to slowly start a shift from products to services, as they rely less on (ultimately limited) material resources. As an example, consider the

first concept proposed in this paper, *design for repair and reuse*: the idea of "everyone being a repairer" [Maestri and Wakkary 2011] might have its limits since not everyone might have the technical knowledge required or the desire to acquire such knowledge and execute it themselves. However, if bringing your device to a local repair shop were to be significantly cheaper than buying a new one and offers other benefits (e.g., minor hardware or software upgrades), it could yield new opportunities for businesses. Maintaining those repair shops, training the repairers, and selling the exchangeable parts could replace the current paradigm of throwaway devices as significant source of revenue for hardware manufacturers.

6.3.5 Conclusion

Limited resources in a future of scarcity and collapse represent a future that is often perceived scary, negative, and difficult – and sometimes even described as almost apocalyptic. While the scenarios in this future certainly come with restrictions and severe changes in our everyday life as well as for industry, these changes also imply that we have to rethink our approach to research, in particular in the field of SHCI. For the particular problem of obsolescence, this future even holds a positive aspect: the motivation to finally implement concepts that have been developed and refined over many years in our still relatively young field. With the potential changes to consumer's perception towards technology acquisition, industry's goals and focus on production, and the inevitable scarcity of resources, old concepts that were deemed to be unrealistic might become viable and new approaches might arise.

In this chapter, we made a first attempt to look at those potential changes and its impact on some of the concepts that can be found in today's SHCI research. However, this can only be the start of a discussion on many levels: How do we approach the transition phase in which all parties – consumers, developers, and researchers – undergo a paradigm change? Which concepts can be applied "as is", which concepts have to be refined, and which concept have to be completely reworked? What are the limits to those concepts – are they all feasible in all possible futures, or depend on a particular state of resource scarcity or societal change? Those and other questions can not only inform the research of today, but even create entirely new fields of research in the future – whatever this future might hold for us.

7 Conclusion and Future Work

In this thesis, we explored the application of sustainable design principles from SHCI research to product design practice. Specifically, we took one of those frameworks – the Attachment Framework [Odom et al. 2009; Gegenbauer and Huang 2012a] and observed its use by product designers in their design process in various different stages and formats. The overarching goal of this research was to contribute to and expand existing solutions to the issue of obsolescence in consumer electronics by facilitating knowledge transfer from SHCI research to product design practice. During the course of this research, insights emerged that led to the following contributions for research – in particular for SHCI research, but potentially even for research in HCI in general and beyond.

7.1 Contributions

A survey of obsolescence-related research in SHCI. Despite its young history of being an established field for less than ten years, SHCI has already seen a staggering number of contributions to problems of environmental sustainability – including but not limited to electronic waste and obsolescence. Assessing the potential of existing frameworks for addressing issues of obsolescence in the realm of consumer electronics was not only important for establishing the foundation of our research and conducting a thorough review of related work; it can also help future researchers to avoid reinventing the wheel and identify blank spots of unexplored research areas. While for our own research, the main insight was that of the existing frameworks the Attachment Framework seemed to be the most promising and powerful one to investigate further, other researchers can quickly assess which directions of sustainable interaction design have already been explored in-depth and which avenues for future research are untouched. (Chapter 2.2, [Remy and Huang 2015a])

Taking a note from marketing research for SHCI. In an excursion to better understand people's purchasing practices as part of our interview study, we expanded into different fields in the spirit of HCI's interdisciplinary nature. There are disciplines of research that have been investigating people's purchasing practices for a longer time than HCI even existed; among those is marketing research. Not only helped the insights of marketing research us to put our interview findings into perspective; it can also guide research targeting behavior change as marketing researchers have decades of experience to understand, manipulate, and successfully alter consumers' purchasing decisions. Our application of the five stage model [Kotler and Keller 2011:166] of consumers' purchasing behavior can guide SHCI research that seeks to create purchasing support tools by leveraging years of experience. Our excursion only sheds light on the tip of the iceberg here, and we envision much more potential in learning from and establishing connections to this one as well as other research areas in general. (Chapter 2.3, [Remy 2012])

The barriers to influencing consumer electronics purchasing behavior. A great deal of research in SHCI has discussed the potential of changing people's behavior through technology [Froehlich et al. 2010], and we conducted a first in-

depth study into general consumer electronics purchasing behavior and the influence of sustainability as a factor of those decisions. The results of our survey and interview study discovered a glaring absence of sustainability as the actual deciding factor in those purchasing decisions – even for environmentally-informed consumers who consider those factors among the most important ones in other aspects of their life. Those barriers, in particular the complexity of information, but also the unavailability and lack of trust in it, are obstacles that future researchers in SHCI and beyond have to consider when designing technology that is to inform consumer electronics purchasing practice. This adds to the rich body of literature in SHCI concerned about the difficulty of changing people's behavior [e.g., Dourish 2010; Brynjarsdottir et al. 2012; Knowles et al. 2014]. (Chapter 3, [Remy and Huang 2012])

Lessons learned for bridging the theory-practice gap in SHCI research. As the vast amount of obsolescence-related research identified in our earlier work highlights, the issue is not one of the research field not proposing enough solutions, but rather its ability to communicate those to practitioners outside the field. While the theory-practice gap is not exclusive to SHCI research, bridging it is of particular interest for the community due to the urgency of solving our environmental problems. Our comparative design study with the Attachment Framework showed the importance of properly understanding the target audience, their work processes, and their language, but also highlighted the difficulty of evaluating SHCI design artifacts. The contributions from this research help to inform future research that attempts to address the theory-practice gap, not limited to SHCI, and we applied those in the research steps to follow. (Chapter 4, [Remy et al. 2015; Remy and Huang 2014])

Tools that showcase successful SHCI design knowledge transfer. We developed two high-maturity prototypes, StickyDesignSpace and InspiredDesigns, and conducted successful evaluations of their applicability to product design practice. The results of those evaluations show that by applying the lessons learned from our preliminary design study, SHCI design knowledge can be incorporated into the product design process. Those tools highlight the importance of translating SHCI design frameworks into the designer's language and incorporating them into their natural design processes. Our applications therefore contribute to SHCI research by providing an example for future research how to bridge the theory-practice gap and achieving knowledge transfer, increasing SHCI's outreach to a much broader audience. (Chapter 5)

SHCI design knowledge and its importance in a future of limited resources. Much of today's research is based on models and assumptions of our society's lifestyle and system that exploits natural resources as if they were infinite. The discussion about limits to growth and finite resources has been started over half a century ago, but has only very recently made its way into SHCI research. While those discussions are often perceived as threatening (due to them challenging the mindset of persistent economic growth resulting in increasing wealth), we believe that those scenarios hold opportunities for future research. We do not know what the future holds for us and which of the scenarios becomes reality; however, SHCI research should not only prepare for

one of those scenarios but consider multiple possible futures. We contribute with a discussion of obsolescence-related research projected onto one of those scenarios: a future of limited resources and changed economical and societal circumstances which affect SHCI research and people's everyday life alike. (Chapter 6, [Remy and Huang 2015b])

7.2 Future Work

Our research has explored one potential way of addressing obsolescence, by investigating one specific framework, and incorporating it into design practice. Within each of those steps, we envision multiple different steps of potential future research.

One would be to address the barriers to environmentally-informed purchasing and investigate into tools that assist in changing people's buying behavior. This would require a major shift of our research as we focused on the sustainability in design branch of SHCI, whereas such persuasive technology would rather fall into the sustainability through design category [Mankoff et al. 2007]. We believe that research in this direction requires an interdisciplinary effort with psychologists and sociologists who have discovered many of the pitfalls of behavior change [e.g., Jackson 2005], with marketing researchers who have invaluable experience in successfully changing people's behavior, but also with environmental experts within other fields of computing to generate and incorporate the necessary background data (e.g., LCA) that is needed to address the lack of information.

Another avenue for future research is to further investigate into communicating SHCI design knowledge. We only explored the applicability of one framework to design practice; however, as we have shown there are many other existing contributions in SHCI research that can address issues of obsolescence. One could even go so far as to test the generalizability of our findings and expand into the general field of HCI to bridge the theory-practice gap in other domains and to other practitioners, not just product design.

Finally, we believe that there is incredible potential in considering SHCI research in different circumstances and scenarios – including, but not limited to, a future of scarce resources. HCI is currently branching out increasingly into developing countries, and what we consider as a future of limits and collapse is the everyday scenario in those regions. Therefore, thinking about SHCI being applied to a future of limited resources can also help expand SHCI research into developing regions, potentially affecting multiple billions of people.

APPENDIX A: ELECTRONICS PURCHASING STUDY

A.1 SURVEY: CONSUMER ELECTRONICS BUYING BEHAVIOR

Thanks for participating and welcome to this survey! Our goal is to get an understanding about the motivations and factors that influence the decision-making process and buying behavior when purchasing consumer electronics. Completing all the questions will take presumably no more than 15 minutes. You can cancel at any time or stop and resume if you decide to take a break.

A note on privacy: This survey is anonymous.

The record of your survey responses does not contain any identifying information about you, unless a specific survey question explicitly asked for it. If you used an identifying token to access this survey, please rest assured that this token will not be stored together with your responses. It is managed in a separate database and will only be updated to indicate whether you did (or did not) complete this survey. There is no way of matching identification tokens with survey responses.

1) Age
   - 25 and younger
   - 26-35
   - 36-45
   - 46-55
   - 56-65
   - 66 and older
2) Gender
   - Female
   - Male
3) Current Country of Residence

_____

4) Occupation

_____

5) What are the three most recent electronic devices you have purchased for yourself?
   1. _____
   2. _____
   3. _____

(For the course of this study, we are looking at consumer electronics such as personal computers, laptops, (mobile) phones, TVs, audio players, tablets, e-book readers, and all similar devices that you would use in everyday activity.)

[The following four questions were repeated for each of the (up to three) devices listed by the survey participant]

6) What factors did you take into account when you chose this device?
   - ☐ Price
   - ☐ Technical features
   - ☐ Aesthetics, design
   - ☐ Physical dimension
   - ☐ Environmental sustainability
   - ☐ Brand
   - ☐ Energy consumption
   - ☐ Promotion/sale
   - ☐ Manufacturing country
   - ☐ Overall product quality
   - ☐ Customer service
   - ☐ Battery life
   - ☐ Recyclability
   - ☐ Other: _____
7) Rank up to five of these factors in order of importance for your decision.

[Same criteria as before in drag and drop ranking interface]

8) Was this device intended to replace another device? If yes, for how long did you own the older device and what did you do with it after acquiring the new one?

_____

9) (Conditional) You marked "environmentally sustainable" as one of the factors that influenced your decision to buy this device. Can you elaborate on the details about this?

_____

10) Do you have any further comments related to this survey, e.g., additional thoughts that came to your mind while filling out the questions, or any feedback in general about the survey or this survey's topic?

_____

11) Would you be willing to answer follow-up questions regarding your answers to this survey? If so, kindly provide a contact email address or phone number at which you can be reached. Your contact information will only be seen by the researchers conducting this study, and will not be shared with any other parties.

_____

Final message on completion: Thank you for completing this questionnaire! Feel free to share this questionnaire with anyone you know, we would appreciate your help in distributing this survey very much and you would contribute significantly to make our research more valuable.

A.2 Consent Form (Interview Study)

Informed Consent for ZPAC Study about Decision-Making Process in Purchasing Consumer Electronics

Dear Participant:

We invite you to participate in our study about the decision-making process in purchasing consumer electronics, which purpose is to gain a deeper understanding about the different factors influencing and their interrelation.

What will we ask you to do?

If you agree to participate in this study, you will be interviewed for approximately 30 to 45 minutes about your experiences when purchasing consumer electronics. We are interested in your stories and which factors were played an important role upon selecting and purchasing specific products, with an eye towards the aspects of environmental sustainability.

What type of personal information will be collected?

The interview will be recorded (audio) and may be partially or fully transcribed. All your data will be anonymized in any stage of further processing it as well as in any written publication or presentation based on this research. If we choose to use some of your comments, they will be attributed to a participant number or a pseudonym.

Are there risks or benefits when participating?

There is no cost to participate in this study and there are no particular risks associated with the study beyond those associated with normal everyday activity.

As a compensation for your participation you will receive an Amazon gift certificate worth 20€.

What happens to the interview data?

Participation in the study is voluntary and confidential. You are free to withdraw your participation at any point during the study, without needing to provide any reasons. Any information you contribute up to the point at which you choose to withdraw will be retained and used in the study, unless you request otherwise. Your data (audio files and/or interview transcripts) will be saved on password-protected devices or in locked university filing cabinets or rooms of the University of Zurich. They will be stored for five years, after which they will be permanently deleted.

Uses of the interview data

The results of this study will potentially appear in both internal and external presentations and publications, as well as academic journals and conference proceedings.

Consent

If the interview is conducted via phone or Skype, we will ask you to give your oral consent during the audio recording.

With your signature on this form you confirm the following statements:

- An investigator explained the study and the listed conditions to me. I had the opportunity to ask questions. I understood the answers and accept them.
- I am at least 18 years old.
- I had enough time to make the decision to participate and I agree to the participation.

In no way does this waive your legal rights or release the investigators or involved institutions from their legal or professional responsibilities. You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information at any time during your participation.

Participant's Name (please print): _____

Participant's Signature: _____

Date: _____

Researcher's Name (please print): _____

Researcher's Signature: _____

Date: _____

[Researcher contact information]

A.3 Interview Protocol

Interview Protocol: Identifying motivating factors in the decision process when purchasing consumer electronics

[Note: Those questions were rarely asked verbatim, but served as a rough guidance and checklist for the semi-structured interviews.]

1. (Warm-up) Can you tell me about your purchases that you made over the last couple of days (either online or in person)?
   a. What?
   b. Where?
   c. Why this specific product?
   d. Purchase process (and preparation, i.e. information gathering)?

   => Try to get the story, probe with subquestions from 2 or 3 when applicable.

2. Tell me about any consumer electronics purchase you made recently that stands out in your mind.
   a. Details: What exactly, when, where?
   b. How often do you usually buy this?

c. Spontaneous buy or informed purchase with long-term preparation?
d. If spontaneous: details
    i. When, where, why, and how did you rate the purchase afterwards)
e. If informed process: Where did you search for information? [Some probes:]
    i. Websites (what kind, online shops, comparison sites, wiki-like or expert sites, …)
    ii. Forums
    iii. Mobile apps
    iv. Signs in local stores
    v. Ads (TV, Newspapers)
    vi. Magazines
    vii. Recommendations (friends, work colleagues, etc)
f. When did you look for these information (in breaks at work, in the morning, before going to bed, designated time spots, …)
g. How much time do you spend on every occasion (a few minutes, an hour, …)?
h. How long until you made a decision (a week, a month, …)?
i. What are the best features of these information sources?
j. What do you not like about them?
k. Have you made any experience in the past where you searched for information, but it wasn't available?
l. How important is the source of the information (in terms of trust)?
m. How do you make sure the data is valid? How does it influence the purchase (decision)?
n. After you got all the information, where did you buy this device? Relation between seller and product information sources?

=> Continue the interview depending on what the participant mentioned previously. Try to get products from at least three different categories out of these:

Food
Clothes
Health & beauty
Small "everyday" products (for the kitchen, office, etc.)
Larger investments, like a bike or even a car (only if within the last 12 months, to avoid having fuzzy memory about the purchasing process)

Ask these questions for three different examples:

3. Can you think of any recent purchases you've made, not necessarily electronics, in which you opted for a more environmental product over a similar but less environmental product? Can you tell me about a specific instance?
    a. What were the reasons, what made it so special for you to buy that device over another?
    b. Was this environmental product more expensive than the alternative(s)? (How much?)
    c. Where did you get the information that this device was more environmental?
    d. How do you know this information is valid/how much do you trust it?

e. What environmental information exactly was important for your purchase?
f. *Depending on how this example experience goes, either probe more for sustainability details or pick some of the probes from question 2.*

4. Can you think of any device that you replaced recently?
   a. What are the main motivations to replace it?
   b. What did you do with the old device?
   c. For how long did you own the old device? (If it's a rather short time span, ask for the previous replacement experience)

5. If you think about the electronic devices in your house, can you name some of them that you haven't replaced for a really long time?
   a. (Pick one, get the story) Can you tell me more about this device:
   b. How old is it?
   c. For how long do you have it?
   d. Any specific reason why you didn't replace it?
   e. What would make them replace it?

6. Have you ever bought a used technical device – if yes, what, when, where etc.?
   a. Why did you acquire this used device rather than a new one?
   b. What were the important information you looked for, and where did you search for it?

7. Think about old devices that you didn't need any longer.
   a. What did you do with these old devices after you didn't use them anymore?
   b. Were or are there devices that you don't use but you don't know how to dispose them properly?
   c. How do these "recycling issues" affect your decision process when actually buying a new device?

APPENDIX B: PRELIMINARY ATTACHMENT DESIGN STUDY

B.1 CONSENT FORM (DESIGN ACTIVITY)

Research Project Consent Form

We invite you to take part in a design activity, being conducted by researchers at the University of Zurich. The purpose of this project is to better understand how to design to foster attachment between people and their personal possessions as a way of promoting environmental sustainability particular in regard to electronic devices.

If you agree to participate in this study you will be given a design activity for which you will have 4 hours to work on. Afterwards, you will receive a questionnaire to give us feedback to your design process.

By participating in the study, you agree to the following:

- We will collect the following personal identifying information: name, gender, age and profession.
- All data collected will be kept secure either on password protected computers or in locked university filing cabinets. Only the researchers involved in this study will have access to the data.
- Participation in this study does not incur any costs.
- There are no particular risks associated with the study above those with normal everyday activity.
- Your design ideas belong to you - the researchers in the study will not claim ownership or authorship of the ideas. In the unlikely case that we would like to pursue one of your ideas further we will ask for your explicit permission.
- You agree to not talk about the study as well as your design ideas to other participants of the study. Especially not to participants, who have not yet finished the design activity.
- You will receive a compensation in the form of a $100 Amazon.com gift certificate for participating in this study.
- The results of this study including your designs and survey responses will potentially be used in both internal and external presentations and publications. They may additionally be published in academic journals or conference proceedings.
- You are at least 18 years of age.
- Participation in this study is completely voluntarily and confidential. You are free to cease participation at any time during the study without providing a reason. Any information you contribute up to the point at which you choose to cease participation will be retained and used in the study unless you request otherwise.

In no way does this waive your legal rights or release the researchers or involved institutions from their legal or professional responsibilities. You should feel free to ask for clarification or new information at any time during your participation.

In the event that we use your sketches in presentations or publications publications, how would you like your designs to be credited?

- □ anonymously.
- □ by name.

Participant's Name (please print): _____

Participant's Signature: _____

Date: _____

Researcher's Name (please print): _____

Researcher's Signature: _____

Date: _____

[Researcher contact information]

B.2 Design Brief (Control Group)

Design Activity Description:

Thank you for agreeing to participate in this study.

As part of a larger research project, we are considering how to increase people's attachment to their personal possessions as a way of promoting environmental sustainability. By fostering a strong bond between owners and objects such as electronic devices, our aim is to promote longer use and ownership of such devices than is currently the case.

In this exercise we ask that you create preliminary designs for a tablet computer. This should be designed in such a way that a stronger bond between owner and object is created, potentially promoting longer use or ownership. We ask that you provide 2-4 designs in total. The designs should be illustrated in the form of sketches with descriptions, or storyboards.

You have 4 hours to work on this exercise and to provide preliminary design drafts. Afterwards, we ask you to scan or photograph your drafts and send them to us. You will then receive a questionnaire to give us feedback to your design process.

You will receive a thank you gift in the form of a $100 Amazon.com gift certification for your participation in this design exercise and survey.

If you have any questions, please feel free to contact us at any point.

B.3 Design Brief (Attachment Framework Group)

Design Activity Description:

Thank you for agreeing to participate in this study.

As part of a larger research project, we are considering how to increase people's attachment to their personal possessions as a way of promoting environmental sustainability. By fostering a strong bond between owners and objects such as electronic devices, our aim is to promote longer use and ownership of such devices than is currently the case.

In this exercise we ask that you create preliminary designs for a tablet computer. This should be designed in such a way that a stronger bond between owner and object is created, potentially promoting longer use or ownership. We ask that you provide 2-4 designs in total. The designs should be illustrated in the form of sketches with descriptions, or storyboards.

We are providing you with descriptions for seven different categories of attachment along with interview quotes to illustrate the attachment. We ask you to read through the attachment types and illustrative quotes, and use them as the basis or inspiration for creating preliminary designs for the tablet computer. You are welcome to use as many of the attachment types as you like in your designs; overall we ask that you use at least 2 of the 7 attachment types. Each design should clearly indicate which attachment types it addresses.

You have 4 hours and 15 minutes to work on this exercise and to provide preliminary design drafts. Afterwards, we ask you to scan or photograph your drafts and send them to us. You will then receive a questionnaire to give us feedback to your design process.

You will receive a thank you gift in the form of a $100 Amazon.com gift certification for your participation in this design exercise and survey.

If you have any questions, please feel free to contact us at any point.

Attachment Types:

Engagement: The extent to which an object invites and promotes physical engagement with its owner during use.

Wind-up Flashlight: "I immediately loved this one; it's one of my favorite things in the house. … The crank makes it easy to produce light and I could go anywhere with it. … I sometimes use it to charge our [her and husband] cell phones. I plug it in [a phone] and start to crank; it starts charging just like that."

Kitchen Utensils: "These are my favorite … I'll probably have them for the rest of my life. … Others [electronic mixers in the kitchen] I have are decent, but have to be fixed and it's harder to find people to do it. I can always count on them [utensils] to work.… I just enjoy cooking with them; it feels more like I'm putting myself into what I'm making. A more real experience. … They feel good in my hand. … I appreciate their craftsmanship and good design."

Earned Functionality: The extent to which an object continues to be used because of the time and effort spent becoming familiar with it.

Wallet: "I have two wallets … I lost one at some point, so I bought a new one, but I got back the other one as well … so I have two. I use the second [new] one to go out partying, when I go out. More like a back up, it's a little smaller. It was more by chance that I own two now. But I'm still attaches to the old one. … I'm used to it, how I organized it, which was the same when I got it back, so I have no reason [to use the new one], the new one might have different pockets, a different layout. So I stayed with the old one."

Blackberry: " I've had my Blackberry for 3 years, and now I know how to handle it. I don't see a reason why I should replace it, now that I know how it works. An newer one would take too much time to understand how to use it."

Remote Control: "A universal remote control for all my equipment. I always thought of it as knickknack, but then there was a good deal … it was a spontaneous purchase, I thought I would try it. And I can't complain. I replaced all other remote controls. now I have only one. And even though I have to recharge it regularly, I got used to that. … I've had that for 4 or 5 months, first in my old apartment. but there we only used it with three devices. Well, there I though it's not so useful. But now that we moved, we have more equipment, now it's 5 devices, so now the purchase has paid off. I wouldn't like to handle 5 remote controls."

Augmentation: The extent to which an object has been reused, renewed, modified, altered or otherwise made to be a part of something augmented beyond its original intended use and as such has become a symbol of the resourcefulness and/or creative expression of its owner.

Alarm Clock: " My digital alarm clock which wakes us in the morning, that I wouldn't give up. … It basically just runs on electricity and you can attach whatever you want to it. Right now, we connected a lamp to it, previously it was connected to the hi-fi system. And it's really easy to use. You can easily choose which time, or when not to wake us up. And it's a nice design and belongs to a stereo/hi-fi system, which I got for my confirmation, just a part of it. … And I think it would be a pity if it were gone."

Bracelet: "The bracelet I got from my best fiends for my confirmation and I'm wearing it every day. And now I have gotten a lot of charms from my parents, friends and so on. So now it's important to me. … I think I've had it for 2 and a half years. … The strawberry came with it. … Yes [she would like to have more charms], but they are pretty expensive. And it should be things I have an association with. For example my 18th birthday. … The 18, which I got for my 18th birthday, which was special. That [a ball?] is from Christmas 2010, very cool. And the elephant was just a gift, no special occasion."

Armchair: "That chair was embroidered by … the godmother of [my husband] for our wedding. For him, well for us. And that's also something that I would never

give up. And that we have also taken everywhere with us. Because it was so much work and it was really nice of her to do that for us. She [her husband's godmother] embroidered it together with a friend of her, an old lady. That's incredible. … When we [got married in] '79. … And a couple of years later they also gave us that table. … But it [the chair] to me is worth so much more, because so much work went into it. … That I would never give up [but also not the table]."

Candleholder: "The candleholder, that you don't use that often. But when I got it, I used it every single night and was really happy about it. And now its more a decorative item. No [she wouldn't give it up], because I bought it at an antique store and then I polished it, since before it wasn't sparkling and now it does. I'm really proud of that."

Histories: The extent to which the materials of an object preserve personal histories or other memories, either by explicitly showing physical signs of use or implicitly by virtue of its persistence over time.

Cups: "One thing is really important to me. It's pretty trivial, but it's some plastic cups. When I was in the hospital in America during the births of my sons, they served coffee in it. And it [the cup] wouldn't get too hot to hold and the coffee in it stayed hot for very long. And we were living in a student apartment, since my husband was still a student in Boston. And every time my husband was visiting, he took one of the plastic cups home. Because that way we didn't have to buy any. And for inexplicable reasons, we have really moved a lot, those plastic cups stayed with us. And every day I drink my morning coffee out of those plastic cups. Because it's very close to me somehow. As a reminder of the births of my sons and also of the independent and nice time that we had. … [that was] 30 years [ago]. And they still exist. And I still drink my coffee in the morning out of it. [siehe P11 - 3] … Those plastic cups, well in the beginning, we took them out of usefulness. And now it grow on me, it became something really valuable. Because in the beginning I though, ok let's take them they are useful. And over time I realized they are not just practical, … every time I hold one of those plastic cups in the hand, it became more of a special memory. And the older they get, the more memorable they are. [siehe P11 - 1]"

Chairs: "That chair … that I've used as a child. I took that from my parents' house, and I glued it together again. And the table, this might be even older, because it also belonged to my mother. … [She brought them over from her parents'] About half a year ago. … We used to sit a lot at that table [when they were children], on those chairs doing handicrafts, painting, or even eating, when my parents had company. Then we were sitting at that table, the children were eating at the small table, the adults at the big table. … We also have a second chair, which is broken. But I want to see whether it's possible to repair it."

Bassinet: "I used to play with that. But there wasn't really anything that was worth keeping in our home. That simply didn't exist. In your [her husband] family neither, right? There wasn't anything to inherit, or something that has been in our families for generations, something like that simply doesn't exist. … I played with it [bassinet] as a child. And then my sister didn't want to keep it,

so I took it. And my daughter used to play with it, so I painted it white and put the bug stickers on it. And it used to be in the basement."

Knife: "My husband had a knife, which he always used to use, that he got from his grandmother. I think he had very sentimental attachments to it. And he used it for a long time, until the blade came off the handle. And he would always fix it, but I think at some point it just became too hard to fix. So he stopped using it, but he would use it, if he could. … Ja, he still has it. … It's in the kitchen. … I think [he doesn't get rid of it], because it's from his grandmother and he was quite close to his grandmother. She died, must be 15 years ago, 20 years ago. … It might have a year, if I look at it, I don't know. But it was something she had for a long time so I think, and his grandmother was in her 80s when she died. … I think he got it, when he was a teenager from her. So it must be about 100 years old or something. I don't know, it was probably made around 1910."

Perceived Durability: The extent to which an object's owner regards an object as long lasting either in terms of function or in terms of longevity or both.

Dress: "A polka-dotted dress, like a petticoat, which my sister gave to me. She is a seamstress and worked in a bridal store. And it's really ugly. I never wore it, but I would never dispose of it. Also, a ball gown which belonged to my grandmother. … It was her first ball gown, so she was about 15 years old. … I guess it's probably 75 years old. But the silk is slowly dissolving. But I will still keep it. It's somewhere stored in a box. … It's all hand sewn and my grandmother made it. … Since there were no zippers back then, only buttons, and the buttons are all bordered by hand. … And even though it's just lying around somewhere, and I don't use it, I still know it's there."

Kitchen Table: "The [kitchen] table is the oldest thing. It's from 1952, from my grandparents. Handmade from a carpenter in the Engadin. And I got it, when she [his grandmother] moved into a nursing home. And for me it's pretty important, because it's from her and she and her husband ate from that table for 50 years and it still looks as good as new. It's a very good quality, it's an old Swiss stone pine table [kind of pine tree]. That's the oldest thing I own. … I got it a year ago."

Furniture: „My furniture [sideboard and bar cabinet], which I've had for 23 years. those are probably the oldest things. … The reason for that [not disposing of it] is, because I still like them. I really like them. I liked them, when I bought them and I still do. … In my opinion, even though it used to be an ultramodern sideboard, it's now more of a timeless piece. It used to be modern art. I saw it at the "Art" in Milan and then I found out how to order it, and it was ultramodern. And if I look at it now, after 22 or 23 years, I think it pretty much became a timeless sideboard. I don't see anything modern there anymore, but it's neither antique. I think it's timeless. It would be difficult for me to give it away. Even though it's not that functional. It has very little space. But I love it. I really like it, I really really like it. But I can't tell why that is. It was love at first sight, and I'm still in love. If it were up to my husband, they were long gone."

Kitchen Table: "My parents had the [kitchen table]. … That is such a beautiful piece of furniture. … It's probably a little older than my deceased grandfather, it might be around 150 years old. An I've had it since …99, so that's 12 years."

Perceived Worth: The extent to which an object is perceived as having a high objective worth, thus making it irrational to dispose of.

Bench: "Last weekend, we bought this bench. We don't buy furniture very often, but we have to get some, because the new baby is coming. So we were looking for something for my sons clothes, like a chest of drawers, and then we got this bench, just because we saw it, and we were looking for something like that for a long time. Where you could sit and put on your shoes or take of your shoes. And also to store something inside. It took a long time to find something that fit exactly. But then we just saw it by chance even though we weren't thinking of it. And we bought it."

Dinnerware: "My dinnerware. That we wished for for our wedding. And I still think it's pretty. But it's kind of impractical. I would get something totally different now. … [They've had it for] 3 years. … The plates are somewhat sloped, so when you put the flatware on it, it will slide down and fall down. It might be pretty but it's really not useful in everyday life. … Yes we still do [use it], I wouldn't get rid of it because of that. But if I were to choose something now, I would get something else. … No [she didn't think about replacing it], because it was way too expensive."

Dinner Table: "A new dinner table. But since we have a very clear idea what it should look like and there is no such thing to buy, we will probably have it special made. And a table like that has to appeal to both of us, so [her husband] has to come along. So this can take forever, because we can eat of this table [the one they have right now] as well. … We replaced our chairs and we want a white dinner table and definitely an oval one. A long oval dinner table. So that will probably be the next big purchase. But this can take time, like I said, this [table] is working just fine, and I have some white table cloths which match the chairs."

Clothing: "I've had a piece of clothing repaired, because I had only worn it once when it ripped. And it was way too expensive to just throw away, so I've had it repaired."

Sufficiency: The extent to which an object is continued to be used or kept because it is capable of serving its intended purpose.

Stereo Equipment: "The stereo equipment is [15 years old]. I think it's even a little older. And it keeps working. Actually, I would like a new one, but it's such a sound device, it keeps on working, that's why we still have it. And still serves it's purpose. … We almost always put on music. That's something we use a lot. … It's important to me."

Tennis Racket: "I still have an old tennis racket. It is 4 or 5 years old. … I was planning on buying a new one, but I haven't had time. And now I'm not playing that often. It's still Ok, so I still use it."

Tandem Bicycle: "We have a tandem bicycle downstairs, which we used to use a lot, because in the beginning I wasn't so comfortable biking for longer distances alone. So we would bike together. Then I realized that wasn't so comfortable, because on the tandem you can't choose how you bike, you always have to go with the, the person in front is deciding how fast and when to stop and where to go. And then I decided, … I had to use my own bicycle. … So it's downstairs, and we could use it, but we just haven't. … Probably about two and a half years, two years [haven't they used it]. … [The don't get rid of it] Because it still works and maybe we use it again."

Computer: "Until the computer breaks down, it takes about 5 years, the cell phone takes maybe 2-3 years. … Sometimes I get the feeling that the devices are designed in a way that they don't have a long life guarantee, so they break after 2 years. … When it's really not working anymore [she buys a new cell phone, computer]. … It crashes or doesn't work anymore, or it's beat up or fell down. … Basically because of wear and tear."

B.4 Consent Form (Evaluation of Designs)

Informed Consent for ZPAC Study about Evaluating Sustainable Designs

Dear Participant:

We invite you to participate in an evaluation of design sketches of environmentally sustainable tablet computers. You will be asked to assess these sketches in regard to their design quality and their ability to encourage longer use and promote personal attachment.

What will we ask you to do?

If you agree to participate in this study, you will first be asked to answer some basic demographic questions about yourself and your design background. You will then be asked look at 20 design sketches and assess the designs using the evaluation form provided. The entire study will require approximately two hours.

What type of personal information will be collected?

All your data will be anonymized in any written publication or presentation based on this research. If we use any of your comments, they will be attributed to a participant number or a pseudonym.

Are there risks or benefits when participating?

There is no cost to participate in this study and there are no particular risks associated with the study beyond those associated with normal everyday activity. As compensation for your participation you will receive an Amazon gift certificate worth $50 USD (or the equivalent in another currency, based on your preference).

What happens to the data?

Participation in the study is voluntary and confidential. You are free to withdraw from participation at any point during the study, without providing any reason. Any information you provide up to the point of withdrawal will be retained and may be used in the study, unless you request otherwise. Your data will be saved on password-protected devices or in locked university filing cabinets or rooms of the University of Zurich. They will be stored for five years, after which they will be permanently deleted or destroyed.

Uses of the data

The results of this study will potentially appear in both internal and external presentations and publications, as well as academic journals and conference proceedings.

With your signature on this form you confirm the following statements:

- I understand the conditions of the study and accept them.
- I am at least 18 years old.

In no way does this waive your legal rights or release the investigators or involved institutions from their legal or professional responsibilities. You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information at any time during your participation.

Participant‘s Name (please print): _____

Participant‘s Signature: _____

Date: _____

Researcher‘s Name (please print): _____

Researcher‘s Signature: _____

Date: _____

[Researcher contact information]

B.5 Design Evaluation Sheet

Evaluating Tablet Designs – Evaluation Sheet

Thank you for participating in this exercise.

People often have a favorite pair of old jeans that they’ve had for years, or a pen that they would never part with. As part of a larger research project, we are considering whether the design of *electronic* devices can foster a similar personal attachment. By fostering a bond between owners and electronic devices, our aim is to promote longer retention and ownership of these devices, less frequent disposal or replacement, and subsequently better environmental sustainability.

In this exercise, we provide you with 20 ideas for tablet computers (created by design professionals and design students) that have been designed to encourage

personal attachment. We ask that you evaluate these designs by answering the questions on the following pages. (The designers of the tablets will NOT receive your evaluation.) Sticky notes are provided for your convenience if you would like to make annotations to help in your evaluation process.

When you have completed the evaluation, please return the following to us via email (remy@ifi.uzh.ch):

- Signed consent form (Scanned or clear digital photograph)
- Completed evaluation form (You may fill out the paper form by hand and provide a scan/clear digital photograph OR download a digital copy at *[link to PDF containing 20 designs, link different for every condition]* and complete it electronically.)

Thank you very much for your participation. Upon completion, you will receive a $50 USD Amazon gift certificate (or the equivalent in another currency, based on your preference).

If you have any questions, please feel free to contact us at any point (remy@ifi.uzh.ch).

1) How old are you?

☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ 66 or older

2) What is your area of specialization or primary area of design expertise (as many as apply)?

☐ Industrial design ☐ Product design ☐ Graphics design ☐ Interaction design

☐ Other: _____

3) Do you have any secondary areas of design expertise? If so, please list them:

_____

4) How many years of experience do you have in the field of design?

_____ years professional design experience

_____ years of design training or schooling

5) We would like to learn about your experiences and approach to design. Please provide us with a brief description of your general design process, (e.g., ideation, sketching, exploration, prototyping, etc.):

6) What are the primary tools (conventional or software) you use in your design practice and for what purposes?

7) Have you worked on designs for which environmental sustainability was an important goal or priority? If so, can you please describe the design, the intended audience for the design, and what you did to incorporate sustainability into the design?

8) Have you come across other designs that you think are particularly good examples of sustainable design? If so, what were they and what made them sustainable in your opinion?

For the remaining questions, please review the 20 tablet design sketches to get an overview over the different design ideas. You will be asked to assess the designs based on the following six criteria:

- Creativity and novelty
- Aesthetics
- Communication and presentation
- Usefulness
- Credibility and feasibility
- Foster attachment and encourage longer ownership

Feel free to use the provided sticky notes to take notes or annotate designs. The sticky notes are for your own use and will not be collected.

Please note that the English translations in the callouts on the sketches have been added by us for your convenience. They are not part of the original designs provided by the designers. The designers will NOT receive your evaluations. Any comments used in publications or presentations will be anonymized.

[The following six questions were asked in counterbalanced order for each participant to counter fatigue. Every question was followed by three instances of "Design number: ___" and "Justification:" prompts, with a large textbox of approximately 25% of the page being allotted for justification. We omit those prompts for the sake of brevity in this appendix and only list the questions, in this example for condition 1 out of 6.]

9) Select up to three designs that you think are the best examples of **creativity and novelty**. For each of these, explain what makes them **creative/novel** in your assessment.

10) Select up to three designs that you think are the best examples of **aesthetic design**. For each of these, explain what makes them **aesthetic** in your assessment.

11) Select up to three designs that you think are the best examples of **clear communication and appealing presentation** of design. For each of these, explain why you think they are **well-communicated and well-presented**.

12) Select up to three designs that you think are the best examples of **usefulness of the proposed product**. For each of these, explain what would make the product **useful and effective** in your assessment.

13) Select up to three designs that you think are the best examples of **showing good credibility and feasibility**. For each of these, explain what makes them **credible/feasible** in your assessment.

14) Select up to three designs that you think are most likely to **foster personal attachment** to the tablet or **encourage longer use** (i.e., increased duration of

ownership). For each of these, explain why you think these designs have the potential to **encourage longer use** or foster **attachment**.

15) If you have any additional comments regarding the designs, promoting sustainability through design, or the topic of personal attachment, we would welcome them here.

Thank you very much for your participation!

APPENDIX C: STICKYDESIGNSPACE

C.1 CONSENT FORM

Informed Consent for Study "StickyDesignSpace"

Dear Participant:

We invite you to participate in our study whose purpose is to gain a deeper understanding about the background research process in the design process. This is a joint research project between the Uppsala University, Sweden, and the University of Zurich, Switzerland. In this study, we will present you a website called StickyDesignSpace which is built to support this background research process.

What will we ask you to do?

If you agree to participate in this study, you will be asked to sort data from a background research on a design process you did (or, if not available, use data that we will provide you with) and add them to the StickyDesignSpace website. Following this, we will interview you about your typical design process and ask you a few questions regarding the website and your experience using it.

What type of personal information will be collected?

A researcher will take notes during the study, and the interview at the end of the study will be recorded with an audio recorder. The records will be used for research and may be partially or fully transcribed. All your data will be anonymized in any stage of further processing as well as in any written publication or presentation based on this research. If we choose to use some of your comments, they will be attributed to a participant number or a pseudonym.

Are there risks or benefits when participating?

There is no cost to participate in this study and there are no particular risks associated with the study beyond those associated with normal everyday activity.

What happens to the interview data?

Participation in the study is voluntary and confidential. You are free to withdraw your participation at any point during the study, without needing to provide any reasons. Any information you contribute up to the point at which you choose to withdraw will be retained and used in the study, unless you request otherwise. Your data (audio files and/or interview transcripts as well as the ideas) will be saved on password-protected devices or in locked university filing cabinets or rooms. They will be stored for five years, after which they will be permanently deleted.

Uses of the interview data

The results of this study will potentially appear in both internal and external presentations and publications, as well as academic journals and conference proceedings.

Consent

If the interview is conducted via phone or Skype, we will ask you to give your oral consent during the audio recording.

With your signature on this form you confirm the following statements:

- An investigator explained the study and the conditions to me. I had the opportunity to ask questions. I understood the answers and accept them.
- I am at least 18 years old.
- I had enough time to make the decision to participate and I agree to the participation.

In no way does this waive your legal rights or release the investigators or involved institutions from their legal or professional responsibilities. You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information at any time during your participation.

Participant's Name (please print): _____

Participant's Signature: _____

Date: _____

Researcher's Name (please print): _____

Researcher's Signature: _____

Date: _____

[Researcher contact information]

C.2 Study Schedule and Task

- A folder with background research material prepared
- Introduce participants to the website, let them explore it themselves (register, start the tool). Use it in a "think aloud" process, ask them to "think aloud" about the axes (5 minutes)
- Show the scenario (if they haven't watched it yet because it's on the website) (5 minutes)
- Give participant task to organize background material into design space (their own or ours) (10 minutes)
- Tell participants that if they have an idea for something they want to Google, download, and add they can do this as well!
- Debriefing interview(s) for 25-35 minutes

C.3 INTERVIEW QUESTIONS

Guiding questions:

- Do the participants understand the concept behind StickyDesignSpace?
- Do the participants understand the descriptive categories of the attachment framework?
- Is the tool helpful for designers?
- Does the tool address needs and requirements of designers that just completed the background research phase?
- Do the participants feel that StickyDesignSpace fosters creativity?
- Do the participants feel that StickyDesignSpace imposes constraints on their design process?
- How does StickyDesignSpace influence the design process as well as the outcome?

Interview questions:

Questions about participant's design background

1. Can you tell me a bit about your background:
   a. What's your main field of design?
   b. For how long have you been working in this field and what kind of training or education did you receive?

Do you usually work in team or work individually?

2. Can you tell me about your last design project and the background research that you did for that project?
   a. (If they didn't mention it) Did you also search for "related projects", i.e., designs similar to your design task?

Overview of participant's background research process

3. How do you usually approach the background research process?
   a. What tools do you usually use for your background research process? (Probe [depending on what participant mentioned earlier]: browser, screenshot tool, camera, phone, recorder, whiteboard).
   b. What kind of material do you collect? How? [images, articles, phrases, sketches, websites, etc]
   c. What do you do with the material and data in the end (sorting, organizing, filing, how and with which tools)? Ask for example data if necessary?
   d. What is the outcome of the background research process? What do you want the results to look like in the end?
   e. What's your main purpose and goal when doing background research?
   f. What are the steps to follow after the background research process?
   g. Do you have experience of using a tool similar to StickyDesignSpace in your design process?

How do designers use this tool as a potential way of doing background research process?

4. What do you see as the main purpose for StickyDesignSpace in the design process?
5. Let's take a look at the final design space.

a. Can you walk us through your data you put in?
b. Did the axes descriptions make sense to you or was there anything particularly confusing?
c. What would you do for the next step after having created the design space? (e.g. brainstorming or more background research)
d. Do you think you can get any insights for potential designs out of it (If yes, what exactly? Examples!). For example, the design insights related to design a mobile phone.
e. What do you think about the notion of a two-dimensional design space, does it works for you? Why?
f. Are there any things about the design space that surprise you?
g. Anything that confuses you?
h. What is your general impression of the final design space?

6. Could you see yourself using StickyDesignSpace in your real-life design process?
   a. If no:
      i. why? [do you feel that SDS imposes constrains on your design process?]
   b. If yes:
      ii. How do you think it could be incorporated into your design process?
      iii. Would it replace existing tool(s) or be an additional tool?
      iv. Would you have to alter your design process and do something different - if yes, what?
      v. For what kind of project do you think StickyDesignSpace can be helpful and how?
7. How do you think would SDS influence your design process?
8. How do you think would SDS influence your designs outcome?
9. Do you think the tool could increase creativity or quality of your design process and if yes, how

How does the tool foster attachment-related thinking?

10. Did you get any insights or develop ideas for designing longer-lasting product after using the tool? If yes, what insights did you get and how did you get the insights?

Questions regarding to the usability of the tool

11. Did you have any problems using StickyDesignSpace?
    a. [Asking usability problems observed during testing. (I see that you….why...)]
12. Do you have any suggestions for improvements?

Opinions about sustainable design. Particularly, in regard to and attachment in design

13. Do you have any experience with Sustainable Design? If yes, what was the project about?
14. How do you think designers can influence the attachment that a person feels to a project or object? How do you think designers can create longer-lasting relationship between a user and an object?

Finishing up the interview

15. Any general comments?
16. Is there any kind of material that you want to put into the design space?

APPENDIX D: INSPIREDDESIGN

D.1 CONSENT FORM

Informed Consent for ZPAC Study about Sustainable Interaction Design

Dear Participant:

We invite you to participate in our study about Sustainable Interaction Design, which purpose is to gain a deeper understanding about the ideation process of product designer and to test an app, which is built to support brainstorming.

What will we ask you to do?

If you agree to participate in this study, you will be asked to generate ideas for a specific design task and to write them down. Further, you will be asked to conduct a brainstorming session, with the support of an app, for the same design task. Concluding, we interview you to your everyday ideation process as well as to the usability of the app.

What type of personal information will be collected?

The brainstorming session will be recorded by the app and a voice recorder. The interview will be recorded (audio), too. The records will be used for the research and may be partially or fully transcribed. All your data will be anonymized in any stage of further processing it as well as in any written publication or presentation based on this research. If we choose to use some of your comments, they will be attributed to a participant number or a pseudonym.

Are there risks or benefits when participating?

There is no cost to participate in this study and there are no particular risks associated with the study beyond those associated with normal everyday activity.

As a compensation for your participation you will receive an Amazon gift certificate worth 30 CHF (and an additional bonus of 10 CHF when you participate in a team).

What happens to the interview data?

Participation in the study is voluntary and confidential. You are free to withdraw your participation at any point during the study, without needing to provide any reasons. Any information you contribute up to the point at which you choose to withdraw will be retained and used in the study, unless you request otherwise. Your data (audio files and/or interview transcripts as well as the ideas) will be saved on password-protected devices or in locked university filing cabinets or rooms of the University of Zurich. They will be stored for five years, after which they will be permanently deleted.

Uses of the interview data

The results of this study will potentially appear in both internal and external presentations and publications, as well as academic journals and conference proceedings.

Consent

If the interview is conducted via phone or Skype, we will ask you to give your oral consent during the audio recording.

With your signature on this form you confirm the following statements:

An investigator explained the study and the listed conditions to me. I had the opportunity to ask questions. I understood the answers and accept them.

- I am at least 18 years old.
- I had enough time to make the decision to participate and I agree to the participation.

In no way does this waive your legal rights or release the investigators or involved institutions from their legal or professional responsibilities. You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information at any time during your participation.

Participant's Name (please print): _____

Participant's Signature: _____

Date: _____

Researcher's Name (please print): _____

Researcher's Signature: _____

Date: _____

[Researcher contact information]

D.2 Study Schedule

Lab Study

Research Questions:

- What influence does the app have on the design ideas created in the brainstorming?
- What is the influence of the app on the design process, according to the designers?
- Is the app able to fulfil its purpose as Sustainable Interaction Design brainstorming companion?

Schedule:

1. Preparation: Fill out consent forms (2 paper), fill out incentive receipt

2. Welcome of the participant (meeting point).
3. Ask small talk question to get a better atmosphere (i.e., where did you read about the study?)
4. Inform the participant again about the study (duration, tasks, incentive, …) and give him the consent form to sign.
5. Ask the designer about a design task. In case the designer has no ongoing design task he can use the brainstorming tool for, give him the study design task. Read out study task.
6. Ask the designer about his brainstorming technic. What does he need? *Cards, paper, colored pencils or a whiteboard*? (Prepare everything)
7. Explain brainwriting and purpose of brainwriting, using brainwriting explanation.
8. Ensure everything is clear
9. Participant starts "brainwriting" for 10 minutes about the topic on *flash cards*.
10. Participant starts Brainstorming with app for 15 minutes. (started App with a pre-set participation code) → Repeat that the app should be seen act as a companion
11. End of design task and start of interview for 20 minutes. (voice recorder)
12. End of study, *payment* of the participant.
13. Sign of the incentive receipt.

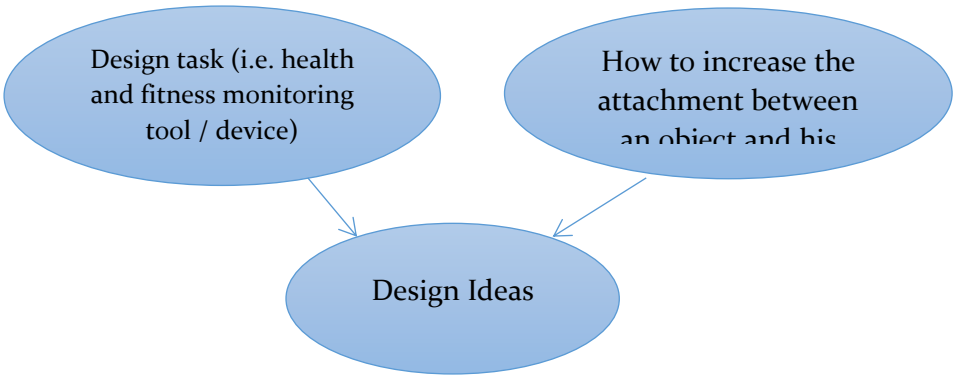
D.3 Brainwriting Task Description

Study Instructions

Design Task

As part of a larger research project, we are considering how to increase people's attachment to their personal possessions as a way of promoting environmental sustainability. By fostering a strong bond between owners and objects such as electronic devices, our aim is to promote longer use and ownership of such devices than is currently the case.

In the following, we ask you to search for ideas how such an object, with a strong bond between the device and his owner, could look like. As a basis you can take a current design task. Otherwise, you can take a health and fitness monitoring tool / device as a basis for your design idea.



Brainwriting

Brainwriting is a creative technique which is similar to brainstorming. During brainwriting the designer should write all his thoughts to a specific topic on flash cards. It is important that the designer produces and combines ideas without limitations/restrictions.

D.4 Interview Questions

Interview Questions

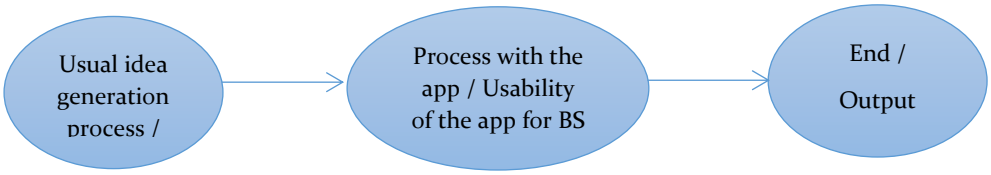
Duration:

20 min

Main focus:

- Influence of app on process
- Usability of the app

Structure of the interview:



Ask for usual approach to find ideas (process without app):

(Questions to get information about the normal idea generation process of the participant)

1. Can you imagine your last idea generation task during work? Please describe it.
2. Is this a frequent task?
3. What is your usual approach when you are confronted with an idea generation task?

(Questions to get specific information about the normal brainstorming process of the participant, if BS was mentioned)

4. You told me, that you use brainstorming for your idea generation process, could you please describe your usual brainstorming approach?
5. *(As an addition to question 4, if not already mentioned by the participant)* How many persons usually participate at your brainstorming session? Do you use any (technical) tools?

(Sustainable design or design of devices for longer lasting use.)

6. Do you have already experiences with Sustainable Design? If yes, please describe them.

Ask how the participant solves the task (process with app and perceived usability):

(Questions to get participant personal process experiences)

7. Did you feel in any way that the app restricted or supported your idea generation process?

(Could you show how you are influenced by the app at the example of one of your ideas)

8. Do you think the app influenced your idea generation process?
9. Did you feel that the flash cards influenced your brainstorming output? (How?)
10. *(May show app with flash cards)* Which flash cards stand out the most? Why? Positively or negatively?
11. Do you have any further comments to the brainstorming flash cards?

(Questions to get participant personal handling experiences / based on UTAUT)

12. Could you envision the app to be included in your typical idea generation process? If yes, how would this influence your ideation process? *(If no, skip next question)*
13. How much effort and time do you think would it need to include the app in your brainstorming process?
    (In which part of the process would you include the app? Would it replace another tool?)
14. Do you think the app could influence the effectiveness of your ideation process? (How?)
15. Would some kind of guidance or instructions be helpful when using the app (for the first time)?
16. What do you like/don't like about the app?
17. Did you have any difficulties using the app?
18. Do you have any suggestions for improvements for the overall interaction with the app?

Concluding questions:

(The participant may want to say sth. positive or critical about the app, the task or the study environment)

19. How content are you with your output and the brainstorming session?
20. What did you perceived as difficult about the task and why?
21. Do you have any other comments regarding the app?

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