Memory probes

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Memory Probes: *Exploring Retrospective User Experience Through Traces of Use on Cherished Objects*

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Our daily interactions with objects can not only leave traces of use on the objects but also leave memories in our minds. These human traces on objects are potential cues that can trigger our autobiographical memories and connect us to social networks. The first aim of this paper is to demonstrate what might be a suitable method of inquiry into the way materials can enrich dialogues about remembered experiences derived from human traces left on cherished possessions. The second aim is to investigate how the accumulation of human traces on objects influences people's remembering and usage. The design of our research artifacts, *Memory Probes*, was situated in relation to three spectra of paired values: (1) the *familiarity* and *strangeness* of tool use, (2) the *definiteness* and *ambiguity* of data capture, and (3) the *objective* and *subjective* reality of interpretation. Our field study revealed a transactive nature between traces of interaction with possessions and memories in the owners' minds. It also informed us of how gradual and curiosity-driven understanding could become a methodological nuance when we are empathetically engaged in a collaborative way of knowing with other participants. To conclude, several implications for designing products that can participate in our everyday reminiscing and meaning-making are proposed.

Keywords – Cherished Objects, Design Probe, Participatory Inquiry Paradigm, Remembering Experiences, Retrospective User Experience, Traces of Use.

Relevance to Design Practice – We propose a dialogical inquiry approach with a set of research artifacts that can inform the design of value-sensitive tools for understanding retrospective user experience. The implications of the field study can enrich design by expanding our understanding of the multi-faceted relationship between designed products and ourselves.

Introduction

Material objects participate in our daily lives and perform as *actors* in our social networks if we adopt a flat world view (Latour, 2005). In these dynamic and transient networks, our relations to objects exist in a context characterized by the constant making and re-making of the meanings, values, and norms associated with the objects. From an *intersubjective* point of view, humans and technologies entangle and shape each other in dialogical interaction (McCarthy & Wright, 2004) and are in a constant dialectic of change in both material and symbolic ways during a process of *domestication* (Silverstone, 2006). This person-object interaction can not only leave material traces of use on our cherished objects but also memories in our minds.

Human traces on objects, such as wear, usage marks, and personal adaptations or hacks, explicitly change the state of an object as a result of human activity. These traces differ from those that simply reflect the passage of time as they are embodiments of interactions between persons and objects that also act as material clues about the way an object has been used (Rosner, 2012). The traces on these objects are potential memory cues that have the capability of triggering our autobiographical memories and connecting us socially. Cherished objects that are anchored in our memories and live with us throughout an extended period become appropriated and incorporated into our personal and social identification (Karapanos, Zimmerman, Forlizzi, & Martens, 2009). There has been a growing interest in understanding how people keep and manage both physical and digital objects which are cherished (Golsteijn, Hoven, Frohlich, & Sellen, 2012; Kirk & Sellen, 2010; Petrelli & Whittaker, 2010) as well as how to design objects which will capture personal memories and project external memory cues (Hoven & Eggen, 2014; Hoven, Sas, & Whittaker, 2012). In line with this growing area of inquiry we are interested in examining how human traces left on cherished objects resulting from daily person-object interaction produce remembered experiences.

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When we examine the relationship between personal cherished objects, the human traces left on those objects, and related remembering experiences, this relationship should be seen as one which is constantly changing. By accumulating traces, cherished objects constantly change in response to changes in surrounding people and environments, and vice versa. This type of retrospective user experience is reflective (Norman, 2005), dynamic, and situated (Hassenzahl, 2010). Therefore, this inquiry attempts to answer both of the following questions at the same time: What approaches and materials might be suitable to enrich people's dialogues about remembered experiences related to cherished objects with human traces? How do human traces on cherished objects influence people's remembering experiences and person-object interaction with these objects? To answer these questions, we adopted a constructive design research approach (Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2011) with an adapted design probe method (Mattelmäki, 2006; Wallace, Wright et al., 2013).

In conjunction with another paper describing the details of the design and usage of our research artifacts, i.e., the Memory Probes (Tsai, Orth, & Hoven, 2017), we present two iterations of our inquiry into people's remembering experiences when stimulated by their cherished objects with human traces. In the first iteration, we focused on the creation of Memory Probes through an exploratory study in collaboration with experienced interaction design researchers. In the second iteration, we constructed our understanding about the relationship between human traces and participants in a field study focused on deploying the probes in the real world. This paper documents our approach to this inquiry: an inquiry that explores ways of communicating through probes as a way to form a dialogue between participants and researchers from fragments of created imagery. Several implications for designing value-sensitive tools that can be used for understanding ever-changing user experiences are proposed based on our findings from the field study. The insights derived from this inquiry can also contribute to our understanding of how to design products that can participate in, and extend, our everyday reminiscing and meaning-making.

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Background and Related Work

We benefited from existing knowledge in a range of disciplines to form and shape our design rationale, including social psychology, ethnographic research on material traces, and object memory studies using probe methods.

Definition of Cherished Objects

It is hard to give a precise definition of *cherished* objects because it is often used as an umbrella term to cover the meanings derived from several prompt words, all of which have nuanced differences, such as *special*, *significant*, *meaningful*, *highly valued*, and *useful* (Csikszentmihalyi & Rochberg-Halton, 1981). In a study by Kamptner, different possessions were elicited when different prompt words were given (Kamptner, 1989). People in different age groups also tended to choose objects from different categories. For example, younger people preferred objects requiring physical manipulation because they enabled a sense of control, but older people found more value in contemplation for conscious reflection (Csikszentmihalyi & Rochberg-Halton, 1981). In our study, we were interested in objects with *possession attachment* where positive memories were the strongest contributors to this person-object relationship (Sherman, 1991; Schifferstein & Zwartkruis-Pelgrim, 2008). Therefore, the working definition of cherished objects in our study is the key question we put to our participants: "Is there one personal possession with human traces that can bring back your valuable memories?" We used the less precise prompt cherished objects in our study and were open to participants' personal interpretations of what constitutes the meaning of a cherished object as well as their preference of the types of objects they chose and the traces they perceived on them.

Traces on Objects and Memory

Rosner (2012) defined three types of material traces in his work on book restoration—traces of *use*, *time*, and *skill*. The first type of trace shows how an object has been used as a result of human activities. The second type of trace is not associated with human activity but explicitly reveals the passage of time and the influences of the elements. The third type of change reflects technicians' and experts' decisions in their restoration processes. Our daily interactions with and appropriation of personal belongings leads to an accumulation of the first and third types of traces on the objects, whether noticed or not. Those accumulated traces reshape not only the objects but also the way we look and treat the objects. For example, breakage of a mother's cherished seashell by her children may lead to repair and relocation to a more sheltered place (Kirk & Sellen, 2010). Through constant or habitual use, these objects with traces of use can create strong *attachments* in their owners, which makes them become irreplaceable (Belk, 1991; Kleine & Baker, 2004).

When we trace the timeline of the development of material traces on an object, there might be cues to different memory events or, sometimes, lifetime periods of other people. It is an

opportunity for us to learn and be informed. For example, the activity traces left in a house by predecessors can become manuals and diaries that connect existing residents with the past evocatively, as well as passing on this appreciation into the future (Dong, Ackerman, & Newman, 2014). In addition to this, the perceptual quality of *maturation* and *inspiration* that traces on objects bring can become resources in design practice (Lee, Son, & Nam, 2016; Giaccardi, Karana, Robbins, & D'Olivo, 2014; Ikemiya & Rosner, 2013). Traces on cherished objects can not only serve as a connection to the past but can also serve as an opportunity for designing meaningful interaction in the future.

Compared with their physical counterparts, *digital objects*, e.g., digital documents and photos, have greater potential for discussion than physical objects themselves. There are examples of layering a *history-of-use* on digital objects as a result of social use (Schütte, 1998). Digital collections can also develop an expressive legacy with new meanings as a result of visual effects relating to weather and time (Gulotta, Odom, Forlizzi, & Faste, 2013). In fact, the lives and accessibility of digital objects that live with us mainly depend on their physical containers. Digital objects cannot exist by themselves. For example, the bits of information which make up a digital photo that are stored in a hard disk drive will no longer be accessible if the track of that hard disk is physically damaged. Therefore, in this paper, we consider physical objects, e.g., the hard disk, with digital components, or the bits information of a digital photo, as *hybrid* entities (Kirk & Sellen, 2010). From this perspective, the digital components of a hybrid object can similarly be viewed for its accumulated traces in our discussion.

Traces of use on objects are the embodiment of interactions between the object, the user, and memory. Interactions with an object will change the associations a person has with it and also change the memories that the object is attached to. These objects and memories are not static but fluid as expressed in the belief manifested in the Buddhist worldview: "all things are impermanent and constantly changing" (Shields, 2013). With this worldview, we argue that used objects and memory both have properties characterized as the aesthetic perception known as *Wabi-sabi* (Koren, 1994) and *Kintsugi* (Keulemans, 2016). It is an aesthetic perception which is *imperfect*, *impermanent*, and *incomplete*.

- *Imperfection:* an object is imperfect when traces of use are left; our memory is imperfect when we cannot retrieve something we want.
- *Impermanence:* an object is constantly changing with time and use; our memory is constantly changing with time and each time we recall.
- *Incompleteness:* an object is always modified and adapted into the user's daily life; our memories are selected in order to fit our working self.

To investigate a phenomenon occurring in interactions between two inconstant subjects that are entangled with personal significance, we need an inquiry method and need to find ways to foster dialogue through creative means about objects, memories, and their interactions (Tsai et al., 2017).

Probing and Memory

Most of the studies which focus on the relationship between memories and objects were focused on objects as a whole, not their inconstant nature. We needed to adopt a method that can sensitize and shift people's attention from the wholeness of objects to the perceivable changes in them. At the same time, this method also must preserve individuals' personal values in the inquiry process.

Constructive design research into the relationship between autobiographical memory and cherished objects is inevitably value-oriented. In this type of inquiry, participants are often sensitized to become more aware of their everyday routines and more reflective about their preferences. Applying probes is one of the methods adopted by researchers to meet the goals of this kind of inquiry (Mols, Hoven, & Eggen, 2014; Petrelli, Hoven, & Whittaker, 2009). The use of probes has been examined extensively in the human-computer interaction and interaction design communities (Boehner, Vertesi, Sengers, & Dourish, 2007). *Cultural probes* and *design probes* are both used to support designers and users with their processes of interpretation and with their creativity. However, they work in different ways (Gaver, Boucher, Pennington, & Walker, 2004; Mattelmäki, 2006; Wallace, McCarthy, Wright, & Olivier, 2013). Cultural probes are particularly dependent on designers' interpretations; on the other hand, design probes, which we adopt in this paper, rely on a co-constructed understanding between designers and users.

The use of probes itself is a constructive process and resonates with the constructive nature of autobiographical memory (Tsai et al., 2017). During this process users are prompted and sensitized not only by instructions on the probes but also by the probes' implicit properties, e.g., the material properties of the probes, and the involuntary memories which they bring to mind. All of these have an impact on the users' interpretation and choices. As we were interested in understanding autobiographical memories related to personal possessions and traces of use, we provided participants with an opportunity to reflect and reconstruct after they reviewed their cherished objects. Deviating from the original concept of a cultural probe (Gaver et al., 2004), we invited participants into a follow-up interview to interpret and express themselves through captured information (Mattelmäki, 2006). By doing so, we tried to record the diversity of participants' personal values and meanings rather than replace these with our own interpretations. Through narration, fragmented clues were connected through the stories of individuals. In this dialogical approach, the users could actively co-construct meaning rather than merely make reports to us about their belongings. (Leong, Wright, Vetere, & Howard, 2010).

The materials and tools used with the probe method are usually simple, cheap, and disposable (Boucher et al., 2018). On the other hand, carefully crafted objects, fabricated from carefully chosen materials can be used in order to pose thought-provoking questions to participants (Wallace, Wright et al., 2013). There are few studies on how these probes work in interaction with users (Boehner et al., 2007; Graham, Rouncefield, Gibbs, Vetere, & Cheverst, 2007; Wallace, McCarthy et al., 2013). We still know

little about how the perceived form and function of design probes moderate users' responses. In this study we contribute to the knowledge pool by illustrating the details of our iterative probe design and the various ways we observed the probes being used in our study (Tsai et al., 2017). In addition to the lessons learned about probe design and use, this paper documents the ways in which the quality and expressivity of collected information can lead to a designer's understanding of the relationship between memories and ever-changing objects.

The Memory Probes

Design Rationale

We see research through design probes as a two-way communication with open but limited messages. In one direction, researchers express their interest in probe tasks by giving prompts and imposing constraints on the tools they provide. In the other direction, participants interpret the researchers' interests, sometimes with misunderstandings, and express themselves through the given tasks and materials. In fact, these limitations and misunderstandings within a *multi-layered process* (Gaver et al., 2004) not only create a space for new inspirations for designers but also provide participants with a playground to review, reflect on, and reconstruct related experiences and memories. This is a collaborative form of inquiry that is emphasized in the participatory inquiry paradigm (Heron & Reason, 1997). From a reflexive perspective in this paradigm, we were involved in this constructive design research as *co-subjects* together with the participants. The Memory Probes became cherished objects for our own empathetic engagement in the dialogue with the participants through the traces left on them (Tsai et al., 2017). The information that the participants provided us with about the traces of use on the probes may not have been accurate but this information contained meaningful self-documentation waiting for interpretation (Mattelmäki, 2006). Accompanied by their reconstructed memories, participants' individual preferences and their experiences of using particular probes made each probe unique. The traces on each probe helped us understand their personal values and sense-of-self in a co-constructed way.

The main aim of this research is to identify what materials *might be* suitable for our inquiry and to develop an approach that enriches people's dialogues about remembered experiences related to cherished objects with human traces. We intended to find materials and activities that could not only extract thought-provoking information from participants but also encourage them to express their personal preferences and personhood during meaningful interactions with their cherished objects and with the researchers. Therefore, we proposed the following paired values in our design to make the research tools and activities flexible in their adoption: (1) *familiarity* and *strangeness* of tool use, (2) *definiteness* and *ambiguity* of data capture, and (3) *objective* and *subjective* reality of interpretation (see Figure 1). In Tsai et al. (2017), we described in detail how we conceptualized these values in our probe and activity design as well as the design choices that we made during the exploratory study. These design iterations are illustrated in Figure 2. In the exploratory study, we invited four experts to join an iterative process where each expert participated in a test of one version of the Memory Probes. We improved the probes after every interview. Some of the tools and materials in the package were removed and new materials were added according to experts' feedback and our insights from previous interviews. We used the first study to explore and refine our conceptualized design values and learn from other perspectives. The final version of the Memory Probes was replicated and used in the field study by our seven participants. The second study was used to co-construct our understanding of traces on objects and associated remembering experiences as well as to test our probes in the wild.

Probe Material Design

We wanted participants to start from what are *perceived as traces* and then review the traces through the specific modality addressed by each probe in addition to their dominant visual perception. This was different from the thematic probes of Wallace and McCarthy et al. (2013), which are *designed to relate specifically to a particular question and context.* Instead of giving prescriptive instructions for information collection on our themes, we provided tools and materials for sensitizing users' free association in a more perceptual way while they were revisiting their cherished belongings. In other words, we expected that subjectivity and personal significance as well as individual differences would remain when participants recalled associated memories about traces. We intended to increase participants' awareness of different perceptions by choosing tools and materials with respective purposes, including those being used to capture what they *see*, *hear*, *touch*, and *think*.
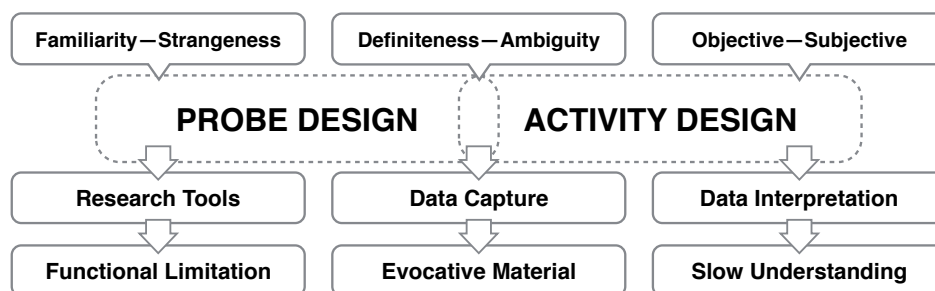

Figure 1. The design rationale of the Memory Probes (Tsai et al., 2017)**.**
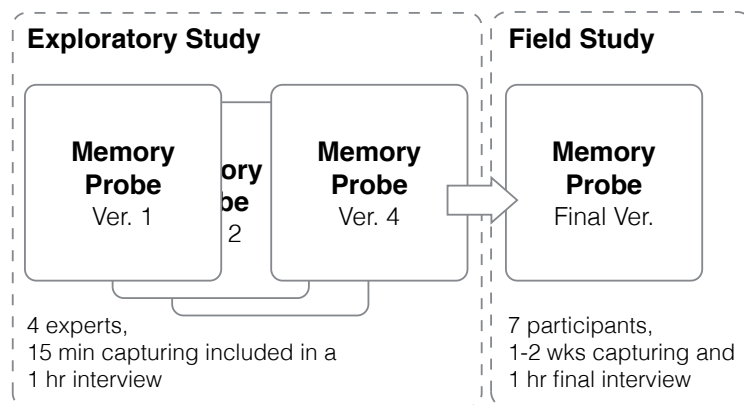
Figure 2. The two studies and probe design iterations in this constructive design research (Tsai et al., 2017).

Previous research shows that limited and altered memory cue information can facilitate meaning-making while remembering (Tsai, Wang, Lee, Liang, & Hsu, 2014). We followed this concept and looked for tools and materials that could capture *low-fidelity information* in each perceptual category. For example, to document what they see, participants could use sheets of paper to record the surface patterns of an object by rubbing its surface or by recording surface patterns by sketching them. Although they also received a disposable camera, participants were told that the photos in the camera would not be developed and printed until after the interview when they would be given as a gift in return for their participation. We were concerned that the printed image of an object might provide too much information for the participants so that their recollection focused too much on the *whole* object that was being recalled, and thus distract the participants from focusing on *traces* in their retrospective interview. However, the act of taking pictures with a disposable camera was an interaction that we would like to keep. While using a disposable camera, users had to use a small viewfinder to see the objects being captured, not a bright and large digital screen as is available on a digital camera. Winding a gear wheel for each shot, which was counted by the counter, slowed down the interaction. This slowed the process of capturing the image and created a space for users to reflect and imagine.

Unlike the other properties of objects that were recorded into materialized forms, audible properties were recorded into a *digital form*. We tried to incorporate low-fidelity quality of sound into a hybrid form at an acceptable cost; therefore, we adopted a recordable chip module that is made for recordable greeting cards and encapsulated it into a metaphorical form, a gift tag (Figure 3). The recordable module can record up to 10 seconds with a low sample rate that produces sounds much like an old radio. The design choice for a 10-second constraint was an insight borrowed from previous *audiophotography* research, which found that 10 seconds is the most popular duration of sound that people recorded for enriching their photos (Frohlich, 2004). *SoundTag* was made of two encapsulated Kraft gift tags and a chip module. Two buttons on the module were marked as P (play button) and R (record button) on one side of the tag.

The final probes adopted in the field study contained the following tools and materials for capturing information about three of a participant's cherished objects with human traces (Figure 4). The *SoundTag*, able to record a 10-second clip of sound, was designed for capturing auditory properties of objects and surrounding environments. The *uppercase alphabet stamps* could be used to strengthen the effect of keyword typing in contrast to writing. A *disposable camera* was kept to play as a visual sensitizer and to take photos of the participants' cherished objects and traces for our data analysis and then become a gift for their participation. We made a *loose-leaf notepad* and provided three different types of sheets for each object; the *Kraft card, tracing paper*, and thin *writing pad paper*. On one page of the Kraft card, there were seven sentence-completion questions that invited participants to stamp in keywords about the past and
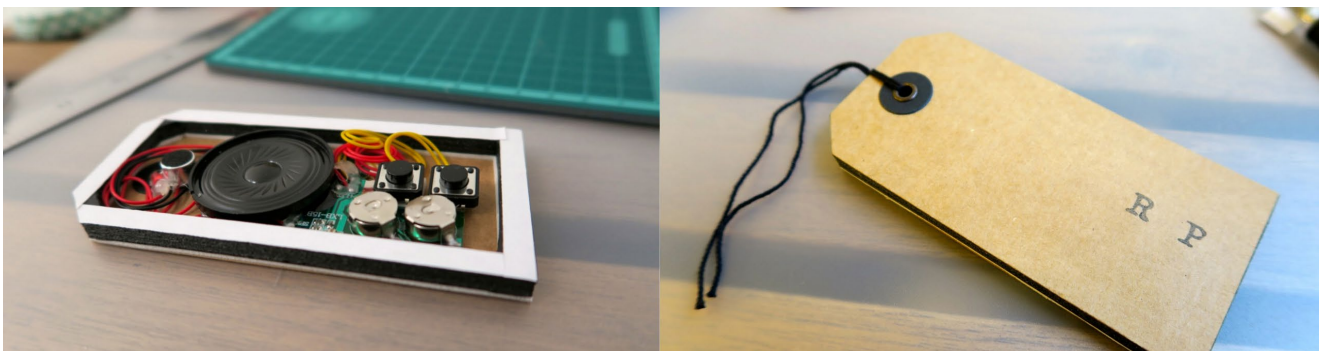

Figure 3. Making of the hybrid form of the SoundTag.

Figure 4. The final probes that were used in the field study,
consisting of a disposable camera, an ink pad, a set of uppercase alphabet stamps, a SoundTag, two chunks of clay, a pencil,
and a loose-leaf notepad (left) containing three types of sheets for capturing each object (right).

future of the objects, the causes and influences of the traces, and their recollected memories and feelings. The tracing paper was the second sheet and the plain writing pad paper was the third so that sketching or rubbing traces on the writing paper could be seen through the tracing paper. Two small chunks of *clay* were provided to capture tactile related properties, such as a crack, by imprinting it or for creating forms of objects by modeling. The clay could stay soft for the whole period of the field study without self-hardening.

In sum, we tried to find a balance between familiarity and strangeness of tool use by providing our Memory Probes with familiar affordance and *functional limitations*. We had tools that were popular in the same era as similar consumer products that reminded participants of an old memory of use, e.g., a disposable camera has similar affordance to a film camera. We provided tools that might have familiar perceptual quality as the recorded properties of objects and traces, e.g., the vintage effect of the SoundTag. We intended to sensitize participants through familiar ways of use, encapsulated in new forms and materials, to provoke reflection in an interaction with aged belongings and old memories. For alternative and enriched interpretation, we also found *evocative materials* with low-fi qualities, such as low-fi sounds, clay, and stamps, to provide the captured information with ambiguity in addition to their defined functions.

Probe Activity Design

We chose to intervene in *revisiting* cherished objects and *sharing* memories of the cherished objects. What we call a revisiting phase is when people are intentionally selecting and reviewing their cherished objects from their collections in their own living spaces, including physically interacting with and reminiscing with those objects. A sharing phase is an interpersonal interaction in which memories of cherished objects are reconstructed and retold. Corresponding to the above phases in a cherished object lifecycle, there were two phases of probe activities in the studies, *capturing* and *introducing*. In the capturing phase, participants had to choose

three of their cherished objects that had human traces. They were provided with a package of our Memory Probes to revisit and capture properties and memories relating to the chosen belongings and traces. Rather than providing a structured instruction to guide participants to easily collect what we were expecting, we were more interested in provoking their personal interpretations of our probes. Instead of clear instructions on *what* we required to be fulfilled, we provided examples of *how* these probes could be used such as demonstrations of imprinting patterns on the clay and taking engraved patterns by rubbing on the papers as shown in Figure 5.

In the introducing phase, the participants were told not to bring their objects to individual interviews, but only information captured about them. In the interviews, they introduced and shared their memories relating to the objects and traces, using the information they captured by using the probes (not including photos taken with the disposable cameras, which would not be developed until after the interviews). The results of the exploratory study revealed that the constraint on bringing the actual objects (or images of them) to the interviews encouraged participants to share more in order to make sense of their stories and to help us understand what they chose to let us know and value (Tsai et al., 2017). In other words, they had to *narrate* rather than *describe*. It was a slow revealing process like interacting with slow messaging between senders and receivers, during which we, as co-subjects, were participating and engaging in a *curiosity-driven understanding* process (Tsai, Chen, Hsu, & Liang, 2015). We intended for this *slow understanding* to help us facilitate democratic dialogues in which both objective and subjective reality of interpretation would be encouraged through both parties' external and internal processes of remembering (Hoven & Eggen, 2014).

Field Study

In the field study, we focused on understanding the relationship between human traces on cherished objects and remembering experiences as well as how our Memory Probes mediated interactions between these two.
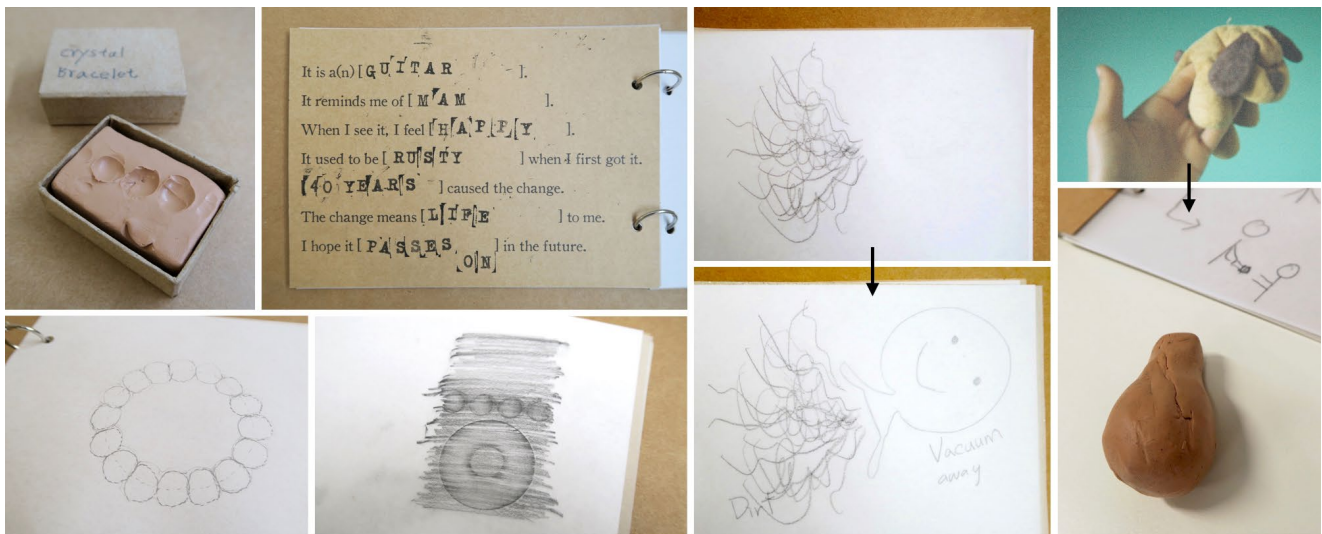
Figure 5. Examples of the use of the Memory Probes.

Participants

We recruited seven participants into a one to two weeks' field study to interact with our Memory Probes followed by a one-hour elicitation interview. Four men and three women who were between 22 to 78 years old and from diverse backgrounds and life experiences participated in our study (Table 1). These volunteers were recruited in Sydney, Australia, through convenience sampling such as networks of friends and recruitment posts on social media. Selection of participants was based on availability. All participants were informed that the photos they took would be sent to them after the study in return for their participation. At the end of the interview, we allowed participants to keep one of the tools or materials they used from their probe kits as a token of our appreciation.

Table 1. Personal profiles of the participants in the field study.

Participant	Gender	Age	Profession or Expertise
N	F	22	Industrial design student
J	M	31	Musician, guitarist
M	M	34	Environmental protection industry, manager
P	F	37	Occupational therapist, stay-at-home mom
T	M	39	Chef, cooking school officer
V	M	49	Vintage film and camera store owner
G	F	78	Volunteer English teacher

Procedure

The first introduction interviews took place at the participants' homes or workplaces, except for M and P. In the interviews, the purpose and procedure of this study were described, and the packages of the probes were also introduced. The probes were introduced according to their capabilities of capturing what people *see*, *hear*, *touch*, and *think*. The functions and properties of each tool and material were demonstrated through another example kit. Participants could try out and feel the probes during the interviews. We emphasized individual differences and encouraged creative uses of these tools and told participants not to be afraid of damaging or breaking anything. Participants were told that they were helping us improve these tools and materials for future participants.

The participants were asked to choose three of their cherished objects that had traces of use which had built up in their everyday environments. We did not guide them to deliberately look into *digital* and *physical* categories of things because we wanted them to freely recall and select objects based on their own life experiences and preferences. The dates of the final elicitation interviews were arranged. The capturing phases for participants varied from one to two weeks, depending on their availability. Participants took the kits home and used the probes to capture properties and memories relating to their cherished objects, including human traces. They were then asked to bring only the probes and the captured information, not the objects, to the final one-on-one interviews.

The final elicitation interviews were conducted at the same locations as each participant's first interview. As the objects and photos taken by participants were not shown in the interviews, they were required to introduce and share their memories relating to the objects and the traces on them using only the information they had captured using the probes. In the one-hour open-ended interviews, each object was introduced over a period of roughly 15 minutes. In the last 15 minutes, the participants were encouraged to share their experiences of using the probes, including how they decided to use or not to use certain tools or materials, how they felt about the quality of captured information, and what they would have liked to do that the kits did not support. All interviews were audio recorded. At the end of the interviews, the participants could choose one item from their packages to keep as a token and were asked to shortly describe why they chose that item.

Data Collection and Ways of Knowing

All narrated stories and descriptions of traces left on probes that were related to us in the interviews were created by the participants as a form of their *presentational knowing*, which can be seen as a metaphorical expression based on their experiences with our probes and their cherished objects (Heron & Reason, 1997). If the captured information brought by the participants was an annotation they used to communicate about their cherished objects and shaped how those objects were appreciated and understood, we tried to preserve these individual perspectives and values in our thematic analysis. After each interview, the notes taken in the interview were immediately reviewed, corrected, and highlighted by the interviewer in alignment with our research questions. These highlighted accounts served as our initial codes for each individual's data.

All information returned in the packages was digitally recorded into high fidelity formats by the interviewer. The visible traces on tools and materials were recorded using digital photography; the sound clips recorded in SoundTags were recorded digitally. The number of pictures that participants took with disposable cameras varied from 3 to 10 out of a maximum of 27. In addition to digitally recording their packages, we used the remaining exposures in each participant's camera to record the traces of use of the kits themselves. These additional pictures were developed, printed, and scanned with participants' pictures and kept by us. The researcher also noted down his own experiences and reflection when he saw those images on the developed photos. We read and immersed ourselves in the account of each participant's individual interview about his or her returned package and personal profile. We tried to stand in each participant's shoes to perceive and value the cherished objects as they would. We looked into the indexed information and the co-constructed understandings which developed in our conversations during the interviews to form our *experiential knowing*, which reflected an empathetic resonance with the participant (Heron & Reason, 1997).

Only after knowledge was gained one by one from each participant did we juxtapose and compare the findings across all participants. The juxtaposed findings from all participants were analyzed into themes. Along with that we, as knowers, participated in a slow understanding process that we put ourselves through. In our process of understanding, we began with becoming sensitized through a face-to-face meeting with our participants. They led us to focus on what they valued and were willing to present. With captured information, they shared recollected memories that led to our group meaning-making with them so that we could make sense of their personal experiences. Until we finally saw the *real* objects on printed photos, we were experiencing a gradual accumulation of fragmented, lo-fi, and value-laden information.

Field Study Findings

Cherished Objects with Human Traces

All participants chose three personal cherished objects and each object turned out to be different from those chosen by others (Table 2). The types of objects ranged from everyday objects (e.g.,

car logbook and portable vacuum), to personal devices (e.g., iPod and iPhone), gifts or legacies (e.g., crystal bracelet and grandfather clock), handicrafts (e.g., photo frame and walking stick), and toys (e.g., toy dog and watermelon lantern). The objects and the traces were formed by various kinds of materials ranging from physical materials that could be directly perceived to hybrid materials that contained hidden digital information.

Participants in this study indicated they used two strategies when choosing these objects. The first involved browsing through cherished objects in their living spaces and examining them for traces of use and skill. In some cases, they had to disregard a cherished object because it did not have obvious traces on it. The second strategy started from the participants' memories of traces, prior to looking for that object, which might have been hidden somewhere in their everyday lives. For example, N thought of her cherished wooden walking stick because she just could not forget that her younger brother split the end of the stick many years ago. These human traces served as a memory cue, linking to an event specific episode or to a particular lifetime period in participants' autobiographical memories.

Sometimes the participant could not remember where the object was and had to ask for help from others. For example, N's father, who made the walking stick with her when she was nine during a family trip, helped her find the stick. She did not know the walking stick was still with them until her father told her that he brought it to their new home for her when they were moving. In that prompted conversation, they reminisced about the trip that they had been through and their attempt at fixing the split end together. Traces seem able to serve as a path for us to make sense of the whole picture of related contexts.

Co-constituted Materiality, Functionality, and Meanings

Most of the chosen objects and traces were physical. Only three of the total 21 objects had digital traces, i.e., photos on the iPhone and songs on the iPod and the rewritable CD. We categorized the traces of use and skill mentioned in participants' accounts and started our discussion focusing on two intertwined properties, *materiality* and *functionality*. We presented them in the way highlighted and valued by our participants; therefore, a few traces that did not result completely from human activities such as faded photos and weather-beaten paint were kept in our analysis.

The first type of traces were *material* changes to objects, which included changes in the form, color, texture, or state of material of the original objects. For example, cracks in a crystal bracelet, the worn texture of a toy, the peeled-away color of an album cover (Figure 6), and a printed and framed digital photo: these were traces coming from constant use, inappropriate care, accidents, or intentional modification. Material changes might incorporate different materials from other things or humans. For example, sweat stains accumulated on a necklace, entries written in a car logbook, and songs burned on a recordable CD. These were traces accumulated from day-to-day physical contact, routine collection and recording, or as a result of creation and making.

Table 2. Participants' cherished objects with human traces in the field study.
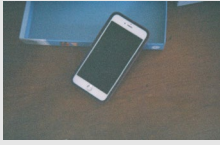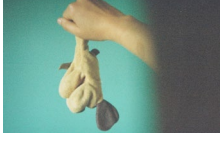
Participant	Object 1	Object 2	Object 3
M	Crystal bracelet (scratch, crack)	Photo frame (printed and framed digital photo)	Watermelon lantern (broken switch, reinforced wire)
P	Necklace (oxidized chain, finger print)	iPhone 6 Plus (migrated photo, finger print, drop scratch)	Portable vacuum (dirt, tangled hair, scratch)
V	University photo ID (faded photo)	Car logbook (maintenance log, worn)	High school tie bar (repaired)
T	LP album (peeled cover, warped record)	iPod Classic (transferred song, no boot, scratch)	Father's business card (handwriting, crease)
J	Guitar pic (scratch, engraved, sweat stain)	Rewritable audio CD (burned song, scratch, marking)	Mother's guitar (marking, scratch, repaired)
G	Grandfather clock (repaired)	Bamboo tray (broken binding)	Plant stand (weather-beaten, propped base, appropriated laminate)
N	[Picture N/A] Motorbike helmet (scratch)	Toy dog (worn, squished)	Homemade walking stick (split end)

Figure 6. T's LP album cover had been peeled away, because his daughter had used it as a toy. T had kept this birthday gift from his mother which was given to him not long after he was born 39 years ago. Photo taken by T.

The other type of traces related to the *functional* change of an object, due to breakdowns or improvements in an object's functionality. For example, a warped and unplayable long-playing (LP) record, the broken light switch of a Chinese handheld lantern, and the propped base of a plant stand were functional changes that accompanied material changes (Figure 7). Some functional changes resulted from unnoticeable or unknown material changes. For example, the malfunction of G's grandfather clock and its repair with help from an antiquary once changed the functionality without noticeable changes on the outside, at least for G.

Figure 7. G's plant stand that was made by her husband. The base was a reused piece of laminate surface taken from their old kitchen countertop and propped up by wooden sticks underneath. Photo taken by G.

The accumulation of digital contents on physical objects acts as a kind of human trace that might not be physically perceptible but nevertheless remains accessible as a *virtual possession* and can represent meaningful parts of our selves (Odom, Zimmerman, & Forlizzi, 2014). For example, the songs on J's rewritable audio CD, which was a gift from his father, represented the time and effort that his father spent monthly finding specific versions of each song while recording this CD for him. The value of these kinds of traces might be transferable from object to object. For example, a subset of the digital photos in P's new iPhone was transferred from her previous mobile phone. These digital traces are highly dependent on an object's functionality. The songs on

T's iPod Classic, for example, could not be played again because the device was no longer bootable. Although these songs were no longer accessible, they were still remembered by T because this iPod was his first portable music player and a gift from his wife, and he had spent a lot of effort into transferring songs from CDs onto it. The effort involved in creating traces helped him consolidate memories in his mind.

The participants' awareness of the fragility and value of their chosen objects increased when material or functional changes were noticed on their cherished objects. This awareness might change the existing way they used the objects in order to prevent them from further damage. In addition, they might also now have reasons to preserve them. For example, J's CD had been left in a CD book in a car for six years. Heat and constantly playing created markings and scratches on it. He then saved and transferred these songs into digital format and stored them in the *cloud* so that he could access them through his mobile phone anywhere. He only played the original CD for nostalgic purposes. He changed his behavior in order to replicate the same functional goal because he had perceived material traces on the object . While the function of the digital component was replaced, the original physical object maintained its significance.

Connected Self and People

Accumulated traces on an object sometimes turned out to be representations of a participant's repetitive interactions with that object during a specific life time period. These traces made the object unique and moved it from the commodity sphere into a closed sphere of personally *singularized* things (Kopytoff, 1986). Objects could also become heirlooms with a *biography* that held the owner's personal values and beliefs. This kind of trace connects personal memories of an object and a part of a participant's personal identity, representing their sense of self and a sense of who they were, who they are, and who they will be. For example, the maintenance records in V's car logbook were created during his first year at university. He was proud of the maintenance. It reminded him of his responsibility as well as how he traveled around and discovered Sydney. He would like to pass this logbook on to his son, teaching him to be a responsible and active citizen. It also led us into an understanding of how his car became his *object of independence* (Vaisutis et al, 2014).

Traces can connect a person's memories about different people and different places; on the other hand, traces can connect different people's memories about the same thing. Traces such as reused materials from other objects can connect memories of places where these materials had been, and where they will be in the future. For example, the base of G's plant stand was a piece of laminate board (laminex) taken from the countertop in her very first kitchen and was reused by her husband when he made this plant stand for her (Figure 7). The pattern of its surface reminded her of fashion in kitchen materials and how it had changed over the past 60 years. The reused material brought her warm memories about her husband's skill in making things, especially for her. Every time her oldest son saw this board, the

unique pattern always reminded him of the kitchen and of their first home, which is part of their shared memories. *"Even if the timber completely deteriorates, I know the green floral laminex will not, so I will have a memento to keep for the future"* (G).

It is interesting that participants did not want to repair or remove the unique material traces of use. In contrast, they wanted to repair the traces that were functional (e.g., the broken light switch of M's lantern and T's iPod), or when they viewed the object and traces as being a gift from others (e.g., J's mother's guitar and G's grandfather clock). G's grandfather clock was inherited from her father and passed down to her older siblings one after another. G is the youngest in her family. Although she was glad when she finally could keep this clock in her house for her family, she was sad about no longer being able to see her siblings again. To her this clock is priceless and not-for-sale. However, she was wondering if she should pass the clock on to her children because they do not have similar memories about the clock the way she does.

Probe Selection and Usage

Participants created traces of use on our probes to help us understand how human traces on people's cherished objects affect us. During the capturing phase, participants chose the tools and materials that they were familiar with, or could make sense of, sometimes provoked by the properties of the probes. Some participants, for example, did not want to record patterns by rubbing a pencil or imprinting on clay because that might leave scratches or stains on the fragile surfaces of their cherished objects. Stamping was a relatively slow method to capture thoughts when compared to writing thus it was not used by some participants, but it helped some participants easily create aesthetically refined texts with emphasis. This functionally limited method of capturing thought provided an opportunity for deep reflection, time to pause, and time for consideration within their thought processes. In the end, in addition to the developed photos they had not seen yet, stamps were the most popular token that participants chose to keep.

We found that choosing tools with functional limitations and by using evocative materials participants were provided with an opportunity to select and re-interpret what was meaningful, and sometimes to hide parts they did not want to see. For example, one expert in the exploratory study tried to take a picture only showing his teddy bear's head, which had been partially bitten apart from its body by his dog. He wanted to show off the part that remained good and to pretend the whole toy was still intact by only including the head in the viewfinder of the disposable camera. Because of the 10-second limitation and the unclearness of the recording quality, participants did not use the SoundTag to record narrations of their episodic details. Instead, they used it to record the sounds of objects themselves (e.g., J played his mother's guitar with his pic: https://goo.gl/IcDy1Q, and G recorded the Westminster chime of the clock: https://goo.gl/SUtlNh) or obtained similar sounds from other modern sources. The expressivity of a material has impact on a participant's perception and recall. For example, T searched on YouTube and recorded a song contained on his unplayable LP (listen: https://goo.gl/Ugm97y). Moreover, doing this triggered a

nostalgic experience as the lo-fi recorder transformed the sound quality of the new source into something *"taking me back to that time"* said T. Then his story unfolded in the lounge of his childhood home, where he had vivid memories about the wooden texture and smell of the room and the unforgettable melody of the song on his first LP album, a birthday gift from his mother.

In summary, the field study demonstrated how the intertwined functionality and materiality of our probes provoked an engaging and situated dialogue enriched by personal values, emotions, and expectations. The findings from the field study revealed how human traces on objects served as memory cues, linking to participants' autobiographical memories and provided a path for us to make sense of the whole picture of their life stories and of the life stories of their cherished objects. The traces could trigger memories; memories could compensate for lost digital traces. It was the effort devoted to identifying and recording traces that consolidated memories and gave meaning to the objects. The traces embodied how participants adopted, adapted, and appropriated the objects into their daily lives. For the long term, the traces that accumulated through mundane activities or specific events made objects unique and valuable. Personal memories associated with traces helped the participants shape and form their personal values and sense of self. In addition shared experiences and memories were connected and passed on among people through traces. These findings also reflected how functional and material changes in objects could mediate the dynamic and mutually constitutive relationship which existed between the participants and their cherished objects.

Discussion and Implications

We propose a dialogical method that can provoke personal meaning making and co-construction between participants and researchers in situ in order to inquire into the dynamic phenomenon which emerges in interactions between inconstant subjects that are entangled with personal values. The research materials that mediate the conversation can be designed with paired values relating to the design questions so as to make them flexible in their adoption and interpretation. In the field study of this paper, we illustrated how our Memory Probes mediated dialogues about belongings and related remembering experiences which are ever changing. With limited, sometimes altered, functionality, the participants materialized their memories and experiences about meaningful traces on their probes in a mutually constitutive way. The participants left traces of use on the probes; the probes left memories of interactions in the participants' minds. Just as the traces on their cherished objects helped participants recall memories, recreating the traces which they found on their probes also helped participants bring back memories. Records of the traces on the probes also helped the researchers re-experience the dialogues which had been co-constructed with the participants.

In the following sections, we reflect on the study's findings and shed light on two themes which emerged. We do this with an intention of opening up further discussion and of transposing the use of probes for other research needs. The first theme came from

the *transactive nature between traces on objects and memory.* The second theme was built upon our experiences of *slow understanding with limited but expressive information.* The first theme has implications for designing products that can participate in our everyday meaning-making and be cherished, kept, and passed down. The second theme has implications for designing tools to understand retrospective user experience where artifacts serve as mediators to enrich situated interpersonal conversations.

Transactive Nature Between Traces on Objects and Memory

In this throw-away society, human traces are symbols of the extended life potential of objects (e.g., G's reused laminate) or inherited talent in a family (e.g., J's mother's guitar) or the uniqueness of a cherished object separating it from similar objects made in mass production (e.g., N's stuffed toy dog). If we see objects as parts of our human network, then we are also taking part in their *social lives* (Appadurai, 1986) where *object traces* will also be left on us when we interact with those objects. The *object traces* which attach to us are positive and negative memories which we keep, or forget, which contribute to our skills, to our sense of self, to our common ground with others, and can provide guidance for our foreseeable future (Bluck, 2003). Traces on objects can aid us in remembering and our memories can imbue objects with more complete pictures of the events which took place in particular stories. Our memories are complements to fading features on objects and can connect fragmented or deteriorated information when we recollect them. There is a *transactive* relationship between human traces on our cherished objects and memories in our minds (Tsai et al., 2014). Similar to digital traces stored in malfunctioning hybrid objects, our memory can also suffer from functional decline with cognitive impairment and aging. Objects living with us continuously accumulate traces from daily activities which can serve as potential memory cues. They are resourceful complements to our memory and the way in which this takes place could benefit from further research. Therefore, we think the following implications should be addressed when we design artifacts that can live and co-perform with us in this impermanent world where our sense-of-self is constantly shaped by the traces which we leave on each other.

Materializing Meaningful Traces

Objects should be able to accumulate perceivable traces so as to become value-laden. These physical and digital traces become anchors for our memories to connect self and others. We usually see digital objects through a functional lens and treat them as merely the replaceable parts of hybrid items (Kirk & Sellen, 2010); however, it is difficult for them to carry meaning or to attach personal significance to them when we take this point of view. If we broaden our definition of materiality and understand the digital components contained in hybrid objects as a type of perceivable trace, they can retain their own unique expression, which we think can serve as an important anchor for meaning making and accumulation in this digital era. For example, in this study the transformed sound quality through the SoundTag gave a

nostalgic expression to digital songs, and this in turn helped in the recollection of memories. Even for imperceptible digital traces such as the signal strength of Radio Frequency Identification (RFID), we can still help people perceive them through intuitive and understandable visualization methods (Arnall, 2014).

Demanding Effort to Leave Traces

The effort we put into recreating traces of use on objects helps consolidate our experience through multimodal encoding and retrieval. By doing so, we can preserve the more *global* qualities of experience as a perceptual unity for sense-making and transposition among different modalities (Stern, 1985). For example, collecting and burning songs on J's rewritable CD and T's iPod made these objects valuable gifts. Even though their functionality could be replaced by newer technology, the physical objects themselves could keep their personal significance and last for a relatively longer period than their digital components. We should embrace emerging sustainability phenomena in interaction design and HCI such as repair and reuse (Maestri & Wakkary, 2011) with a point of view that extends beyond functionality. By considering both the materiality and functionality of traces, we can have a clearer view about what properties we should keep and value in the product lifecycle of adopting, adapting, and appropriating.

Balancing Values in Materiality and Functionality

Designed artifacts that participate in the everyday making and re-making of self-identity should include functional and material characteristics that are both befitting and evocative. Familiar objects can be easily interwoven into our mundane lives; however, objects with subtle strangeness can increase our awareness and provoke reflection (Dunne & Raby, 2001; Garfinkel, 1991). Definite expression in the design of an object can give efficient and detailed information to its users; nonetheless, ambiguity is a valuable design resource to elicit personal voices and interpretations (Gaver, Beaver, & Benford, 2003; Sengers & Gaver, 2006). Designers have to situate themselves on these spectra of paired design values according to their design questions and their epistemological stances. Usability and accuracy should not be the only criteria to evaluate a product involved in our self-identification if we are also looking for an opportunity to enrich and thicken our limited life experiences. From the flat world view adopted in this study, the social biography of a cherished object can be seen as an extension of an individual's singularized perspective and short lifespan.

Slow Understanding with Limited but Expressive Information

The inquiry in this paper is derived from a reflexive understanding gained through an examination of traces of use accumulated on our Memory Probes in participants' lives. The probes provided limited, sometimes altered, information that reframed not only the participants' remembering but also our knowing perspectives. For example, most of the pictures taken with disposable cameras

were underexposed (see the pictures in Table 2) because those pictures were taken in indoor environments without using the flash, which had to be actively switched on and charged before use. Some pictures were blurred because they were taken within the minimum focus distance (1 meter) when participants were trying to focus on the traces of objects. Both effects extended our curiosity-driven understanding process beyond the interview sessions. We originally expected that the developed pictures would be our ground truth, which would give us answers to what we imagined in participants' stories. However, those pictures instead acted as part of the limited information source that helped us focus on what participants wanted us to see and know.

Indeed, we were not only designing for the participants but also for ourselves. The constraint we imposed on ourselves, i.e., a slow and gradual process of being exposed to revealing information, put us through a process of co-construction. We had to imagine objects and traces bit by bit using the information participants provided us with, since we did not have a global and clear view of the objects and the traces as a whole. We had to see through our participants' eyes and stand in their shoes. For example, we were expecting to see the pictures that participants took and illustrated in interviews; however, the narratives were most of the time more vivid than what was shown on the later developed photos. The participants' narratives provided in the interviews served as a prior anchor to their intention and preference, which was more important than what was really captured. It was an empathetic way of being engaged in the participants' worlds. Only by doing so could we co-construct our knowledge with participants based upon the intrinsic value of their narratives, a process which, in itself, provided insights into the participants' sense of self. We note down the following implications for designing research artifacts to mediate dialogues about user experience emphasizing personal significance and intrinsic values.

Forming Dialogues from Fragments of Created Imagery and Meaning-representation

Sometimes "the parts are greater than the whole" (Shah, 1989, p. 17) when we are inquiring into value-laden themes and connecting dots of our reality. Although we as researchers are eager to know everything, we actually are making sense of the fragmented information chosen and provided by our participants. Therefore, the information provided by evocative materials revealed in a constructive dialogue can vary depending on the balance in the relationship between the knower and the known. However, once the truth is revealed, imagination will be replaced by perceived information. The perceived details from a rich information source, e.g., a clear picture, will fulfill our sense of expectation and satisfy our curiosity (Tsai et al., 2015). For example, one of our interviewers developed visualization of a closeup only showing the teddy bear's head derived from the description of how the picture was taken which was erased when he was shown an actual picture. Once presented with the reality of the picture the earlier visualization could not be retrieved (see the developed photo here: https://goo.gl/HU8YZg).

Building Experiential Common Ground, both Narratively and Perceptually

In addition to our dominant verbal and visual apparatuses, mediated dialogues should be provided with different channels for communication among participants if we understand that our experience together is constantly taking place holistically. The social construction of knowledge of self is a dynamic and ongoing process that is built upon the common ground established in dialogue between subjects and inquirers. The common ground is established through empathic resonance, which is formed by the subject's narrative self and the inquirer's experiences elicited by evocative materials provided by the subject. The inquirer's felt experiences can then go back to enrich or thicken the subject's narrative. Therefore, we would suggest incorporating auditory, tactile, olfactory, proprioceptive, and other sensorial interactions in a co-constructive dialogue to broaden participants' felt experiences and performances in situ. In this context, limited but expressive information can be of benefit by leaving room for new interpretations as well as not overwhelming the main narrative line controlled by the subject.

This inquiry adopted a situated and interpretative stance. We did not intend to enumerate all the possibilities or give prescriptive guidelines for designing retrospective user experience probes for all situations and research needs. The heterogeneous life experiences of our seven participants, who were from different age groups, cultures, and professions, gave us only an initial understanding of the possibility of our intervention into the dynamic relationship which exists between memories and traces on objects. Therefore, future research is required to bring us deeper knowledge in other contexts for applying the Memory Probes and other possibilities for using the probes for further research.

Conclusion

The contribution of this paper is to demonstrate a dialogical inquiry approach with a set of our research artifacts termed the Memory Probes, which situate themselves on three spectra of paired design values. By taking this approach, we investigated people's retrospective user experience about cherished objects which were marked with traces of human use. Through a participatory inquiry paradigm, we engaged reflexively in a collaborative relationship with participants during a design and knowing process. The traces left on the returned probes were embodiments of the participants' connected self and social networks, reminding them of significant memories and providing them with an opportunity to re-construct their personal values, emotions, and expectations in situated dialogues with us. The inquiry revealed a transactive nature between traces on objects and memories in the owners' minds. It also informed us how a researcher's gradual understanding can be a nuance when we are empathetically engaged in the constantly changing relationship between possessions and personal memories. To resonate with the emerging sustainability phenomenon in design, we propose implications for the design of products that would participate in our daily meaning-making and

be cherished, kept, and passed down in our social networks. It was our aim to open up a methodological possibility for retrospective user experience research. Some implications are also addressed for designing beneficial interventions during value-sensitive inquiries to enrich situated interpersonal conversations.

Acknowledgements

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