International Journal of Mobile Human Computer Interaction
Volume 8 • Issue 2 • April-June 2016

Making Space to Engage:
An Open-Ended Exploration of Technology Design with Older Adults

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ABSTRACT

Designing for older adults can be complex. Often, designers struggle to understand people who share a very different life context. At the same time, older adults can have difficulties imagining future technologies for themselves. This creates challenges for design processes bounded by time and outcome expectations. In this paper, the authors explore a long-term, loosely structured and open-ended research process where they provided participants with prototypes to use for as long as they wanted, and only as they wanted to. By working with their own relatives and friends and moving away from structured procedures and external agendas, the authors made space for both participants and designers for deep engagements with the artifacts and process. Participants were able to better understand technology and shape it to their needs. Researchers were better able to understand and iterate on the technology designs. The authors' findings suggest that this approach might be especially appropriate for designing for and with older adults.

KEYWORDS

Design Research, Digital Photo Frames, Digital Photography, Mobile Interface Design, Older Adults, Research through Design, Technology Probes

1. INTRODUCTION

Older adults are a growing demographic age group who have a low adoption rate of technology when compared to younger adults. According to Charness, Fox, and Mitchum (2010), only 25% of people between 75 and 84 years, and around 5% of those 85+ years are computer users or have occasional access to the Internet. To increase the adoption of technology by older adults, researchers in Human-

DOI: 10.4018/IJMHCI.2016040101

Computer Interaction (HCI) have investigated the design of technologies for this particular user group. One strand of research has focused on making interfaces *usable* for older people, providing user interface design guidelines (Al-Razgan, Al-Khalifa, Al-Shahrani, & Alajmi, 2012), and discussing *Inclusive Design* approaches (Wobbrock, Kane, Gajos, Harada, & Froehlich, 2011). Another research strand has been concerned with creating technologies for older people to increase the quality of life, for example, by overcoming isolation (Garattini, Wherton, & Prendergast, 2012) or by providing tools for creative activities (Waycott et al., 2013). In this article, we contribute to the discussion of how to create technology for older people that is useful, usable, and used in practice.

Designing useful technologies requires a deep understanding of the issues and needs of older people. This can be hard to obtain, because the life context of older adults is probably distinct from that of the designers. For example, older adults are likely to face age-related changes in their body (e.g., in their vision), different family configurations (e.g., with grand-children), and different working situations (e.g., retirement) than the designers. Furthermore, the reduced experience of older adults with technology can make it difficult for them to imagine future technologies (Massimi, 2007), rendering idea generation and discussions less effective.

Approaches such as *Co-Design* (Sanders & Stappers, 2008) and *Technology Probes* (Hutchinson et al., 2003) have gained increasing attention as ways of bringing older people into the design of technologies to address such concerns (e.g., see (Vetere, Davis, Gibbs, & Howard, 2009; Waycott et al., 2013)), but these are often within quite structured and time-bounded shorter-term engagements. As noted by Subasi, Malmborg, Fitzpatrick, and Östlund (2014, p.70), “we are still learning how to approach design in the area of aging”.

Contributing to this exploration of how to design technologies for and with older people, we report here on a particular type of open-ended design engagement with family members and close friends. Within the spirit of *Research through Design* (RtD) (Zimmerman, Forlizzi, & Evenson, 2007), we designed two main prototypes, *PhotoFrame* and *SimpleCamera* (including *MessageTripod*) and invited four older participants (three relatives and one friend) to use them for as long as they wanted, and only as they wanted to. These artefacts enabled the participants to communicate using photographs for up to 60 weeks (at the time of initial submission, and use is still on-going).

We argue that the open-ended, unstructured and undemanding nature of this process (no strong expectations or constraints due to external agendas) was valuable in providing a space for both the older participants and the designers to learn from one another in an open and authentic dialogue. The open-endedness ensured that all parties were enabled with the time and confidence they needed for familiarizing themselves with the design endeavour and for deep engagement. Participants were able to understand technology better and adapt it to their needs, routines and spaces. Designers were able to learn about their participants’ authentic needs and iterate the prototypes.

The artefacts we created can be seen then as starting out as types of Technology Probes (Hutchinson et al., 2003), where we had the initial goals to understand the communication needs of older people in their own settings, to explore their engagement with this particular type of technology, and to inspire design thinking about possibilities enabled through these experiences. During the 60 weeks, we iterated on the designs in response to the growing understanding and use of the artefacts by the participants in their everyday lives. As such, the current versions of the artefacts embody the design decisions and the knowledge we gathered while optimizing the devices to the participants’ needs.

The contribution of this paper is two-fold. On the one hand, we suggest the benefits of using an open-ended and loosely structured exploration of technology to enable older people to imagine future scenarios and contribute to shaping them. On the other hand, we present the prototypes and the design knowledge as embodied in these created artefacts, accompanied by insights from the longitudinal case studies.

We start this article by reviewing previous work, both regarding our design approach and existing studies on digital photo sharing for senior users (Section 2). The third section describes the project and the prototypes, which resulted from the design process (PhotoFrame and SimpleCamera). Section 4 details the research design, participants, and main findings from our long-term deployments. We then discuss the results, which point to the value of implementing an open-ended and loosely structured research process. We conclude this article by highlighting opportunities for future work.

This paper should be useful to researchers and designers developing technology to be used by older adults.

2. BACKGROUND

As mentioned in the previous section, designers can have difficulties in understanding the issues and needs of older people. Researchers have used different (co-)design strategies to help participants reflect about their everyday issues and how technology may help in those situations. Vines et al. (2012), for example, presented concept cards to participants, displaying provocative design concepts and prompting participants to talk about issues in existing banking systems. Rice, Newell, and Morgan (2007) used *Forum Theatre* and professional actors to enable older people to imagine the experience of using certain technologies.

While providing interesting ways of familiarizing older participants with novel concepts and supporting them in anticipating technology use in everyday life, these techniques don't allow senior people to actually use an implemented system. This poses the question about whether the imagined or proposed technologies will later be used by senior people when they are implemented, in particular in the long-term.

2.1. Deploying Technologies to Support Older People and Communication

It is not surprising then that Technology Probes (Hutchinson et al., 2003) and similar technology deployment approaches, have been extensively used with older people as they can provide researchers with experience-based feedback from participants who use their design proposals and artefacts (e.g., Vetere, Davis, Gibbs, and Howard, 2009). It seems that older adults particularly benefit from actual deployment, because they make future scenarios sketched in technology more tangible, enabling older people to provide feedback that will ensure a technology is used in everyday life. However, as we will see in the following examples, Technology Probes tend to be used within shorter-term timeframes and according to well-structured research procedures.

Supporting communication and overcoming isolation of older adults has often been the focus of HCI projects using Technology Probes. For example, Garattini et al. (2012) proposed tablet applications, facilitating access to websites, Internet telephony, messaging or chat systems. Others focused on more lightweight forms of communication such as sending photos, similar to our design proposals (PhotoFrame and SimpleCamera). Vetere et al. (2009), for instance, deployed a *Cultural Probe* named the *Magic Box,* which led to the *Collage* device for remote intergenerational play. The *Collage* enabled grandparents and their grandchildren to exchange photos and messages captured by mobile devices and displayed as a collage on LCD screens at their homes. The researchers deployed the device within one family over the course of eight weeks and found that "[t]hey teased each other by sending photographs and text messages that were intentionally unusual or ambiguous, leading to interpretatively rich interactions between participants" (Vetere et al., 2009, p.176).

Similarly, Dijk, Dadlani, Halteren, and Biemans (2010) studied how institutionalized patients or older people communicated with their families using digital photo frames (located at the bedside) and camera phones (operated by family/friends) over 6-7 weeks. The technology aided the patients in reconnecting with their loved-ones despite distance, sometimes despite their severe injuries. The older people of the nursing home enjoyed their photo displays as they provided "food for talk" when socializing. Gaver et al. (2011) also explored a photo-based device, the *Photostroller*. This device displayed random photos with specific topics from the Internet, and was piloted for two months in a nursing home. Their findings confirmed the observations of Dijk, Dadlani, Halteren, and Biemans (2010) that picture displaying devices can trigger social conversations. Baecker, Sellen, Crosskey, Boscart, and Neves (2014) also explored tablet-based systems "to reduce social isolation and loneliness" of older people, using a series of short-term deployments and pilot tests.

Recently, researchers also shifted their attention from providing older users with tools for consuming media to empowering this user group to produce and share their own digital content. Lindley (2012), for example, investigated how a home messaging system could enable an older person to post messages and make scribbles for the other members of the family (the *Wayve* system), during the course of a three-month deployment. Waycott et al. (2013) picked up the idea of the *Collage* (Vetere et al., 2009) and continued studying older people as the producers of digital photographs in the collaborative assembling of photo collages (Vetere et al., 2009; Waycott et al., 2012). In a four week study, they found that "there may be important opportunities for digital technologies to enable those in the 'oldest old' age group to express themselves in new creative ways" (Waycott et al., 2013, p.46).

These projects suggested new tools for older adults to communicate. Besides these opportunities, the different studies showed the potential of studying technology for older people by deploying it in a real context. There was a common activity of instantiating design ideas in technologies, and then putting them into use by older people for some weeks[1]. There is no doubt that this can be a very positive way of gaining an understanding of the context of older people. However, such studies might also be restricting their potential because they rely on (short) structured projects, with well-defined project goals and deliverables, and with recruited participants who sign up to participate in specific study activities (e.g., interviews at regular intervals) that have been defined *a priori*.

We suggest a similar approach, but with less structure and, more importantly, with more time for mutual learning. As we will discuss below, our approach uses Technology Probes to expose participants early to implemented systems[2], but doing so over a long duration, where both researchers and participants have time to learn about the technology, think about what it is useful for, and how it might change in the future to better adapt to daily life.

2.2. Research through Design (RtD) in HCI as a Method for Inquiry

The work reported in this article is based on the assumptions and values of RtD (Frayling, 1993/94; Gaver, 2014; Zimmerman et al., 2007), a specific category of *Design Research*. To explore a longer engagement of such technology, we combined a "RtD way" of approaching a situation with iteratively developed Technology Probes and an open-ended unstructured process. Given this openness and the intimate access we would be asking from participants, we chose to recruit participants from our close network of family and friends, to ensure participants were willing to provide us with a chance to explore and learn from their use of technology.

The RtD school of thought is increasingly gaining momentum in HCI. In fact, RtD embodies a number of features (discussed below), which make it a strong candidate for conducting research on the design of technologies to be used by older people in their everyday life.

RtD is an iterative process of framing a problem, and proposing new designs and solutions. This can also enable the Design Researcher to observe and study socio-technical systems in a different way than, for instance, as accomplished by "pure" ethnographic observations without design interventions. Figuratively speaking, the Design Researcher creates her or his "own world" or socio-technical system, usually reflecting a desired or more appropriate state than the existing reality. In our work, we "cautiously approach" this "world" by using iteratively deployed Technology Probes. Building these probes and providing them to participants afforded us the opportunity to reflect on our actions and design decisions, which is generally considered a crucial component of practice-based Design Research (Schön, 1983).

There is no standardized way to conduct RtD. Although there are shared understandings and philosophies, there is no shared definition of RtD nor is there a shared expectation regarding its role in knowledge production (Gaver, 2012). However, RtD researchers generally agree on the importance of the created artefacts. An important part of the generative nature of RtD is that design practitioners seek inspiration in design examples. Hence, the created artefacts and prototypes carry implicit and tacit knowledge, that is, insights from the Design Research process, which is embodied within the product and cannot be expressed in words (Zimmerman et al., 2007). In line with this, we include a rich selection of images for illustrating the outcome of our practice-based research process and to communicate the knowledge, which is engraved in our artefacts (see Figure 1 and 4).

3. PROJECT DESCRIPTION: APPROACH, MOTIVATION, AND PROTOTYPES

3.1. Approach and Motivation

Our project was motivated by two of our participants, Manuela and Lisa (properly introduced later), who were struggling to find ways to communicate more often with each other. Their conversations about, for example, making more frequent phone calls, writing letters, or sending more photographs "rang a bell" in our head as we were aware of the literature in this area. As mentioned previously (see Section 2), photography fulfils important social functions such as documenting shared history, reminiscing, staying in touch, and *communicating* (Chalfen, 1987; Kindberg, Spasojevic, Fleck, & Sellen, 2005).

Figure 1. A-I: Artefacts developed during the RtD endeavour. J-K: Photos captured by participants.

This challenge led us to embark on a design process that was open-ended and had a loosely structured research agenda, apart from wanting to empower older users through digital photography (c.f. section 1 and 2). In terms of epistemological positioning, our approach is located within a *Constructivist* tradition, successively collecting and building an empirically grounded body of knowledge around the prototypes and the ways our participants interacted with them. We made use of increasingly available and powerful prototyping tools and techniques such as *Arduino*, 3D-printing and developer APIs for mobile phones to make *real* user experiences immediately accessible and *tangible*. This also enabled us to quickly iterate and redesign, putting in action whatever made sense for the users, and was technically feasible. The result of this process was a set of technologies (PhotoFrame, FrameCam, MessageTripod; compare Table 1) that were used in everyday life by four senior participants (aged 67, 72, 86, and 89 years) for approximately one year (60 weeks maximum to the initial submission date of this draft). The resulting prototypes, as described in the next sections, embody the design decisions and *materialized* learning we constructed while optimizing the devices to each individual's needs.

3.2. Prototype Description

PhotoFrame I is a digital photo frame that displays pictures sent by family and friends. It was prototyped using a *Galaxy Nexus* smartphone, with a custom-made application and operating system modifications, and inserted into a 3D-printed case and stand. The pictures are uploaded for display using FrameCam, an Android as well as web application created for that purpose. Figure 1A (orange circle) and 1B display the PhotoFrame I prototype as it was deployed at Ina's and Lisa's houses (participants to be introduced in detail in section 4.1).

PhotoFrame II is the follow-up version of the PhotoFrame I device. It features a larger screen (7 inch display as opposed to 4,65 inches), an enhanced case, and another stand built with wood and cement, to give it a more "polished" look and feel (see Figure 1C).

SimpleCamera I (see Figure 1D) is an "Internet photo camera"[3]. It captures photographs and shares them online with only a few touches. Optionally, an accompanying audio message can be recorded and sent as a photo annotation.

Improvements in design and usability led to SimpleCamera II (see Figure 1E-G), which now features a docking station made out of cement and including wireless inductive charging for convenience. After capturing a photo, one can select between multiple predefined addressees (delivery via email or to another PhotoFrame/SimpleCamera II device). Audio annotations, as introduced with

Table 1. Overview of prototypes and deployments (Key: *…on-going deployment)

Prototype Name	Used by	Duration
PhotoFrame I (cf. Figure 1A orange circle and 1B)	Manuela	52weeks
PhotoFrame I (cf. Figure 1A orange circle and 1B)	Lisa	52 weeks
PhotoFrame I (cf. Figure 1A orange circle and 1B)	Ina	60 weeks*
PhotoFrame II (cf. Figure 1C)	Manuela	8 weeks*
PhotoFrame II (cf. Figure 1C)	Lisa	8 weeks*
SimpleCamera I (cf. Figure 1D)	Manuela	24 weeks
SimpleCamera I (cf. Figure 1D)	Lisa	24 weeks
SimpleCamera II incl. MessageTripod (cf. Figure IH-I)	Manuela	8 weeks*
SimpleCamera II incl. MessageTripod (cf. Figure 1H-I)	Lisa	8 weeks*
SimpleCamera II (cf. Figure 1E-G)	Beata	8 weeks*

SimpleCamera I, were removed from the device as this function was rarely used by participants. SimpleCamera II also introduced the ability to switch into photo display mode. That is, when not taking photos but sitting in its docking station, the device shows the images of the local gallery as well as all online photos that have been sent to SimpleCamera II (either from FrameCam or another SimpleCamera II), acting then as a PhotoFrame device. SimpleCamera II as owned by the oldest participant Lisa (89) also had an additional hardware button for capturing photos (see Figure 1F orange circle) for extra accessibility and to make this interaction more tangible.

To support the sending of photo-captured notes, we added MessageTripod (see Figure 1H and I) to complement SimpleCamera II.

4. STUDY: PARTICIPANTS, RESEARCH PROCESS, AND FINDINGS

In this section we present the overall research process and research story. The section also includes the report of the field study (participant feedback). We chose this form of presentation to better draw out the research *process*, which enabled us to create technology that was *used* for a long time.

4.1. Introduction of the Participants

We engaged four senior participants with physical prototypes (PhotoFrame, SimpleCamera, MessageTripod). They are represented in Table 1 by fictional names (Manuela, Lisa, Ina, Beata). All four participants are female and retired. Three of them live alone at home. None of them had used computers or smartphones prior to the study. Manuela and Beata own feature phones (mobile phones with hardware keyboards but without "smart" applications). Lisa and Ina have mobile phones designed for people with special needs (bigger buttons, emergency button, limited functions, etc.). Manuela, Lisa, Ina are family of the first and second author of this paper. Beata was a close friend of the family of the first author. Their short profiles are as follows:

- Manuela is 67 years old and has, as all other participants, no experiences with computers of any kind. Contrary to the other study participants, she lives together with her husband. Manuela has active social relationships, and enjoys day trips and travel. She has one son and no grandchildren;
- Lisa is the oldest of our participants (89 years old), but her good health allows her to regularly leave the house to meet with friends and family, to go for a walk, and to go shopping. Manuela is the daughter of Lisa. In addition, she has one son and one grandchild;
- Ina (86 years old) also enjoys good health and has the same positive attitude towards aging like Lisa. In fact, Ina's and Lisa's profiles are similar with regard to their daily activities. One difference is that Lisa lives closer to her family than Ina;
- Beata is 72 years old. She has four children and 7 grandchildren. Like the other participants, she has no severe medical conditions or disabilities. Beata leaves her house at least three times a day for taking the dog for a walk and doing the shopping. Despite her big family, she doesn't have much contact to them in person, because her children moved to distant cities. However, she talks to at least one of her children on the phone on a daily basis.

In sum, all participants have had about the same limited experience regarding computer technology. Similarly, all of them enjoyed good health and were free from disabilities that could restrict their interaction with the devices. The age span (67-89 years) was rather high and in most of such populations one should expect a rather large deviation in capabilities. However, this was not the case in our sample. Where restrictions were relevant, we responded to this by implementing corresponding modifications (c.f., MessageTripod).

In addition, twelve friends or family members of our participants received the software FrameCam for sending photos to the participants' screens. These additional twelve people were also interviewed and asked for their feedback. The first and second author also sent pictures on various occasions to the PhotoFrame. Therefore, the research process also has some autoethnographic features (Holt, 2003), that is, we placed ourselves directly within the context of the study by participating in certain interactions (sending photos). We see this as resonating well with RtD, which draws on personal reflections and experiences made by the Design Researcher (Schön, 1983).

4.2. Methods for Gathering User Feedback

For gathering feedback on technology use, we employed qualitative and quantitative methods. In particular, we used an informal ethnographic interview approach within the context of our everyday interactions with the participants, where we engaged in naturalistic conversations to hear about their experiences with the probes and to gain feedback about our designs. After these conversations we made notes of our interviews and of our own experiences. On some occasions, we used audio and video recording devices to record opportunistically the interactions of our participants with the prototype. Overall, we talked explicitly to every participant at least once a month about the design project, often times more than once. As indicated in the previous section, there were also twelve friends or family members involved using FrameCam to send photos to the prototypes of Manuela, Lisa, Beata, and Ina. In general, we applied the same set of methods to them, but less regularly. While we provide a brief account of their perspective on the project, their experiences with FrameCam and sending photos is out of the scope of this paper. All this material was collected, together with an online log file record (see next paragraph), on a central repository for later analysis.

In addition, we collected log file data. The logged user interactions comprised photo browsing activities, the sending and receiving of photos, and switching on or off the devices; this data was transmitted by the photo frame in almost real time to our server (see Table 2). In addition, PhotoFrame I also included information in the log regarding when users were taking a look at the screen (*Eye-contact-log*; see Figure 3). This feature was implemented by standard computer vision algorithms (i.e., the standard API for face-detection provided by Android) that used the front-facing camera of the phone (about 1 cm next to the display) to detect whenever a person looked at the device. This setup provided the opportunity to unobtrusively monitor (almost in real time on our server or "offline" with a SD card) how often the participants interacted with the device (i.e., by looking at the device) without entering touch input. As PhotoFrame I was the first prototype to be deployed, tracking when people potentially looked at the photo display enabled us to get a sense of how often the device was used. Figure 3 shows a plot of the data that we recorded for Lisa and Manuela on our server. This illustrates the kind of information we gained from the Eye-contact-log[4].

Throughout the whole deployment process, we as the researchers and autoethnographic participants, discussed and exchanged our *field* experiences. We continuously analysed our recorded notes and material in search for actionable input to designs as well as emerging themes or patterns of use.

Table 2. Aggregated log data of PhotoFrame I+II and SimpleCamera I+II. Note: Online logging was deactivated on Ina's device due to her instable Internet connection

Participant	Devices Available	Days Switched On	Photos Received	Photos Sent	Photos Browsed
Manuela	420 days	379	259	65	794
Lisa	420 days	409	247	57	1453
Beata	56 days	56	55	*13*	102
Ina	420 days	*Not logged*	*25*	*No camera*	*Not logged*

4.3. Participant Feedback and General Response to the System

In general, the prototypes were well received. Manuela, Lisa, Beata and Ina enjoyed having novel means for communication. We received mixed feedback from the twelve friends and family who operated FrameCam. Broadly speaking, they could be divided into two groups: one group recognizing the value from FrameCam and the possibility for conveniently connecting to another person using photos; the other group soon stopped sending photos, although they nevertheless appreciated the underlying concept. Interestingly, members of this second group were the same people who generally tried only on rare occasions to "pick up the phone" and get in touch with their older family member/friend. On the contrary, those who used FrameCam more often also generally invested more time in looking after the corresponding person.

While these were very interesting insights, the use and design of FrameCam and the corresponding challenges are out of the scope of this paper. Rather, we concentrate on the perspective of our older participants Manuela, Lisa, Beata and Ina. In fact, their high acceptance and appreciation was the driving force behind extending the research process and making a number of adaptations to further optimize the systems according to their needs. The overall structure of this process, including important cornerstones and design actions, is illustrated in Figure 2. Table 2 provides an overview of the log data, which was recorded during the study to give us an idea of the systems' actual usage. We go on to describe the overall design and research process, and explain each specific design decision. We complement these explanations by making use of quotes from the participants.

4.4. Overall Research Process and Design Decisions

After our initial inspiration based on Manuela and Lisa's conversation about staying in touch more often (previously discussed), we developed some design concepts based on the literature and brainstorming. We then took some months of intensive sessions of sketching (see Figure 4A as an example of sketches from a later stage of the design process), 3D-modeling with CAD software and exploring different implementation options on mobile devices, after which we came up with the first prototype we named PhotoFrame I (see Figure 1A and B). We sense-checked our drafts and concepts on different occasions with the participants, but we did not directly involve them in the design activities in line with our approach to conducting RtD (as opposed to, e.g., Co-Design).

4.4.1. PhotoFrame I

PhotoFrame I was offered to Manuela, Lisa and Ina, as something they might like to try out but with no obligation and no time restrictions. In the end they used it for up to one year. During this time the

Figure 2. Overview of research and development process. Light green (light grey in a black and white version) boxes: Names of artefacts/redesigns. Blue (dark grey) boxes: Changes compared to preceding prototypes.

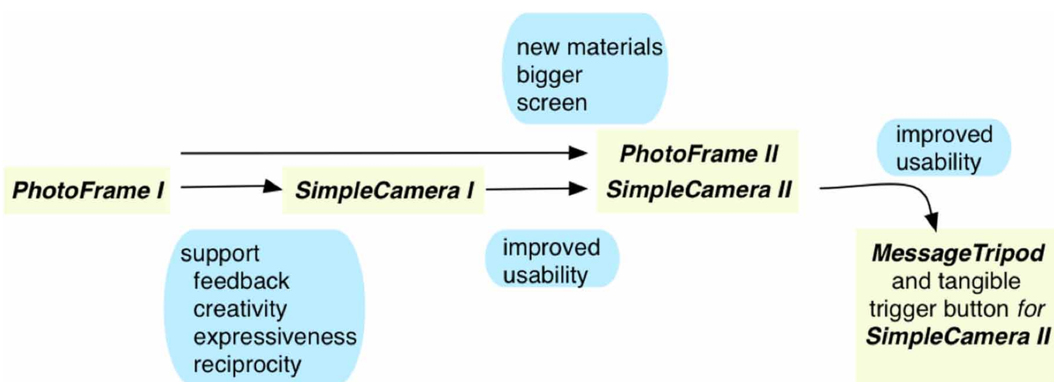
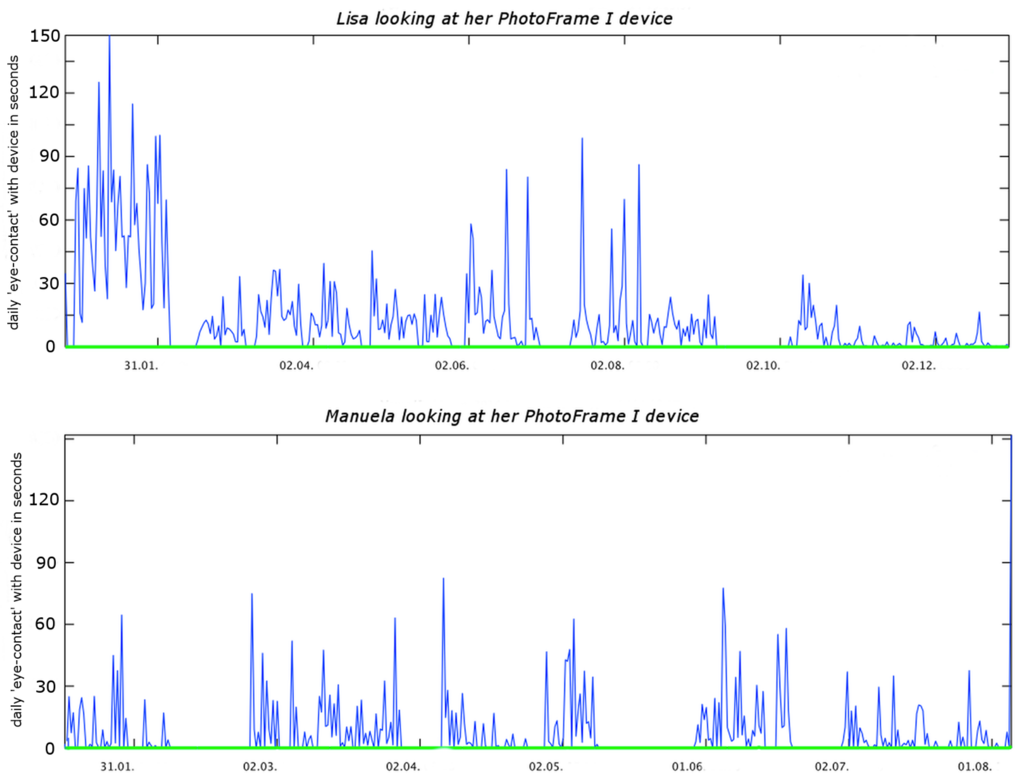


Figure 3. Eye-contact-log data as recorded by PhotoFrame I of Lisa (top) and Manuela (bottom). This data reflects how often someone looked at PhotoFrame I (accumulated for each day) and was recorded by computer vision (face-tracking) algorithms. Please note that the top figure displays a log duration of one year and the bottom figure shows a duration of 8 months (eye-contact-log was deactivated for the last four months of Manuela's device due to technical reasons).



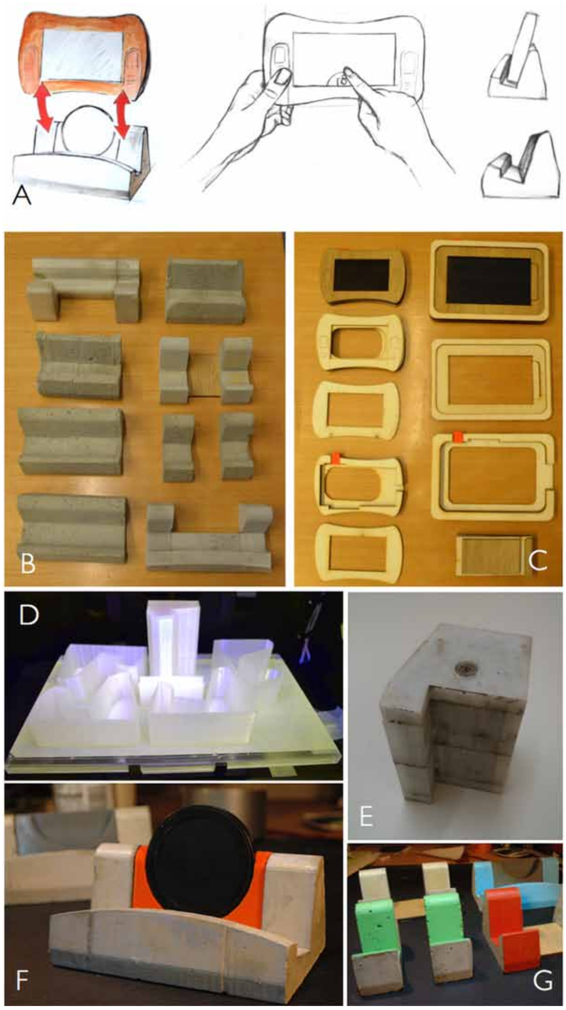
participants made use of the device almost on a daily basis (see Table 2 for descriptive statistics of interactions and Figure 3 for an illustration of the Eye-contact-log).

As is evident from the log files, there was no considerable decline in use over the duration of the pilot. The PhotoFrame device was switched on during most of the days of the study (note Table 2 for statistics). The only time the devices were shut down was when the person was travelling or not at home for a couple of days. This also explains the most prominent time periods where the devices were not used. Interestingly, Manuela and Lisa changed their strategy from always having the screen turned on to switching it off to save energy when not in use. According to them, it took them some weeks to gain confidence in operating the device until they incorporated this strategy. However, after this initial phase of exploration, the prototypes felt familiar to them and were used as naturally as the remote control for their TV set. Besides a potential novelty effect, this switching off the screen to save energy can also account for the slight decline in Figure 3, if there should be any relevant decline at all.

Manuela and Lisa used their frame as a digital photo album, which resulted in the browsing of their received photos hundreds of times (794 and 1453 according to the log files). Ina used the device more like a traditional picture frame, changing pictures less frequently. Interestingly, the display of pictures on Ina's frame was not random (see below excerpt), and the location where she chose to place the picture frame was well integrated with the remaining physical pictures in her place (see Figure 1A). The PhotoFrame was also used as a display for special events, such as anniversaries:

I have put that picture on the frame, because today is his birthday [grandchild].

Figure 4. A: Sketches of the prototyping phase. B-G: Photos captured during the design process.



Besides great praise for PhotoFrame I, we also received critique and suggestions for improvements. While both Manuela and Lisa enjoyed obtaining photos a lot, they regretted not being able to answer these “photo greetings:

I am always very happy if someone sends me a photo greeting. I would prefer to answer immediately and to say ‘thank you’. Unfortunately, this is not possible. So I try to remember to mention this particular photo the next time I see the person who sent it (Manuela).

4.4.2. SimpleCamera I

The feedback about not being able to thank someone for the photos motivated us to conceptualize different mechanisms for allowing the users of PhotoFrame to respond to incoming photos, and hence, to add *reciprocal* interaction elements. Therefore, we decided to deploy an additional Technology Probe (SimpleCamera I, see Figure 1D) allowing the capturing and sending of photos in a straightforward way (i.e., responding to and thanking somebody by sending images). In fact, SimpleCamera I could be used with a very reduced number of clicks and interactions. This prototype enabled users to capture photos, attach optional audio recordings, and send this captured data to a predefined set of family members and friends.

In terms of user feedback and the number of photos taken, SimpleCamera I was a success. During the first 6 months of use, Manuela captured 44 photos and Lisa 40 (around 7 each month). Table 2 displays the total number of images taken (65 and 57) with both SimpleCamera I and its successor SimpleCamera II (see Figure 1E-G). As evident from the participant-captured photos, SimpleCamera was also an appropriate tool for supporting Manuela's und Lisa's self-expressiveness and to create engagement. (We will return to this observation within the MessageTripod section below.)

One aspect, which we seemed to have been neglected in the first design iteration (PhotoFrame I and SimpleCamera I), was the aesthetics of the hardware. For instance, while we as its creators thought that the 3D-printed aesthetics of PhotoFrame I and its docking station appealing and modern, Manuela and Lisa confessed after a while that it did not integrate well into the décor of their homes. They preferred a more *homely* design, which matched with their furniture and did not call attention to the device. In addition, the 3D-printed material of PhotoFrame I (Figure 1A, B) did not appear to be "of good quality", because of its "plastic look" (Lisa) and because of its rather low weight. In addition to this critique about the aesthetics, Manuela and Lisa had some usability issues with the software of PhotoFrame I. They stated that in specific situations, having a larger screen would be convenient. Another minor issue reported was that on some occasions they covered the camera lens with their hand by accident.

4.4.3. PhotoFrame II and SimpleCamera II

With this feedback in mind, we developed another iteration. On the one hand, we built PhotoFrame II (see Figure 1C) using new materials, and with improved software usability and a larger screen. On the other hand, we redesigned the camera device into SimpleCamera II (Figure 1E-G), also featuring new materials and a redesigned user interface. We captured this process in a series of images (see Figure 4A-G) to illustrate the different steps taken in order to create artefacts that had the *right look and feel*. This was a lengthy process of experimentation, trying out ideas as sketches, trying different materials and shapes, and testing different technologies. Figure 4A shows some sketches from the early prototyping phase of SimpleCamera II, Figure 4B and C give an idea of the different shapes of docking stations and screen casings that were tested. Finally, Figures 4D-G illustrate the manufacturing process of the docks for SimpleCamera II and PhotoFrame II in detail: 3D-printed molds (4D and E), cement dock for SimpleCamera II with built-in inductive charging antenna (round and black structure in Figure 4F), and some finished and different coloured docks for PhotoFrame II (Figure 4G).

Lisa was happy with the new design iteration and described the devices in the following way:

The devices look more expensive now. The stone [concrete] stand makes it very robust. It stays in place and I really like the wood [finishing]. It makes a better impression than the first model. (…) I like having a large screen. I keep the large screen [PhotoFrame II] in the living room and the smaller one [SimpleCamera II] in the kitchen (Lisa).

PhotoFrame II was given to Manuela and Lisa. SimpleCamera II was provided to Beata, who joined the study two months prior to the write-up of this manuscript, and also to Manuela and Lisa (cf. Table 1 for an overview of study participants and durations). Ina did not receive a new device, as she was accustomed to PhotoFrame I and saw no need for a change.

Hence, Manuela and Lisa now own two devices, PhotoFrame II and SimpleCamera II. The functions of the earlier camera device (SimpleCamera I) were extended and as a result SimpleCamera II now featured the same capabilities as PhotoFrame II, except for having a smaller screen, being able to additionally send photos, and being more portable due to wireless charging (see also Section 3.2).

We drew and laser-engraved two thumbs on SimpleCamera II as an indicator for how to hold the camera in the hands. This is a small but efficient design feature, which keeps our participants from occluding the camera's lens with their hands. For Lisa, our oldest participant, we performed an additional (smaller) iteration on the hardware design of SimpleCamera II. As she sometimes had difficulties in triggering the camera shutter with the provided software button and focusing on her target at the same time, we integrated a hardware pushbutton, which supported her in holding the camera still by providing tactile feedback.

Manuela and Lisa enjoyed having both devices available and positioned them in different locations in their houses (see Figure 1C and 1E). Both devices were constantly switched on (when they were in the room where the display was located) and incoming images were immediately displayed. Beata, who only owned SimpleCamera II, also left her device switched on and placed it in her home office.

Besides sending photos from SimpleCamera II via email, Manuela was also able to send photos directly to her mother Lisa's SimpleCamera II device (and the other way round). This option was happily used by both of them for either sending photographs of people or objects (e.g., flowers), or for sending photos of handwritten notes, leading to an increased personal exchange between mother and daughter.

4.4.4. MessageTripod

The number of pictures taken by the participants indicates the success of the SimpleCamera devices. Common triggers for use as shown across the collected images were sharing of experiences, giving virtual presents in a somewhat tangible way (for instance, by capturing a photo of a flower bouquet), documenting visits of friends/family, "just capturing photos of things that look nice" (Manuela, e.g., Figure 1J), and sharing messages such as photos of newspaper articles (see Figure 1K as an example). In summary, we were surprised by the expressiveness and creativity involved in using SimpleCamera as evident by the use of the camera devices. In addition, our participants, who had never used email on a conventional computer before, utilized the application as a "substitute for email" (Beata) by taking photos of handwritten notes and sending these messages to predefined recipients. The oldest of our participants, Lisa, used SimpleCamera II for this purpose, too. However, she experienced some difficulties in framing the piece of paper with the note on it (and triggering the camera). Therefore, we created MessageTripod as a simple static construction for the easy framing of text notes. MessageTripod keeps the camera in place and at the right distance. It features an additional "mini-whiteboard" underneath it, which allows her to quickly put down some notes and send them captured in a photo (see Figure 1H-I).

5. DISCUSSION

In this paper we introduced findings resulting from a RtD project, which was organized without strict time constraints, outcome expectations or end criteria. In addition to this particular setting, all participants were relatives or close friends. Overall, our participants enjoyed using the provided prototypes on a regular basis. The PhotoFrame I+II devices supported a more *passive* form of communication, that is, receiving photos sent by FrameCam and SimpleCamera II. This kind of communication was greatly appreciated according to our senior participants. In addition, the sending of "photo-greetings" (i.e., photos sent as post cards) was valued by the users of FrameCam/SimpleCamera II, and perceived as being "lightweight" and "without-obligation" (Beata).

Lisa, Manuela, and Beata appreciated using SimpleCamera II for capturing and sending their own photos. Similar to the work of Waycott et al. (2013), we were able to engage senior users in creative activities by providing digital photo tools. When using SimpleCamera II for verbal/written communication (i.e., taking photos of written notes), Lisa and her daughter Manuela preferred employing MessageTripod for framing the messages. They engaged in photo-message conversations with each other, that is, Lisa sent Manuela a captured note and received a photographed message in return (or vice-versa). In addition, the participants also sent other family members or friends captured text or conventional photos, which they received in their email inbox. According to the participants involved, our devices overall had a very positive effect on their communication. On their account, they communicated more often, as they now possessed a novel and lightweight channel for getting in touch. In addition, in accordance with Dijk et al. (2010), the exchanged photos served as "food for talk", that is, the prototypes not only depicted novel channels for communication, they were also the topic of conversations.

As one can see from the pictures, the participants appropriated the technologies into their particular settings. In Figure 1A we see, for example, that the photo frame is sitting in the middle of the other pictures, as if it was a printed picture. In other words, the frame mobilized the best of both digital and print photography, enabling participants to see one picture at all times, but also to change it, might they prefer another one.

5.1. Making Space to Engage

The open RtD approach led to the design of five different prototype systems and is still an on-going process. Overall, the designers' hands-on experience in creating artefacts (see, for instance, Figure 4), driven by authentic needs, and the participants' experience in using the probes were equally important. This led to improvements as documented in Figure 2, for instance, bigger screens, new materials, better usability and enhanced possibilities for creative engagement.

We suggest that certain particularities in our endeavour enabled us to uncover insights, which might have been left unrevealed using a more conventional research approach and strict boundaries. These particularities have to do with the factors of (1) time and (2) trust:

1. As is evident from the deployments, it was crucial to allow the participants unpressured *time* to familiarize themselves with the technology. For example, it was only after a while that Manuela and Lisa felt confident enough to switch the screen on or off to save energy. In a shorter deployment period with a strict agenda they might have never have felt comfortable enough to switch off the screen, and so would not have adapted the technology to their needs. Another related observation was that Manuela and Lisa only admitted (*or learnt?)* as time passed by that they would rather prefer a more homely and higher-quality hardware for their photo devices (as implemented later by PhotoFrame II and SimpleCamera II).

Similarly, having enough time was equally important for us as designers and researchers. Without the need to deliver research reports, and without the constraints of a structured project timetable, we were able to select the most comfortable and appropriate situations for gathering feedback in causal settings. In addition, having enough time was important in creating the prototypes both for being able to implement the products (proper prototyping can consume a lot of time) and not least for receiving design inspiration. Thus, "letting things grow" over time improved the quality of our prototypes, as it made space for us to engage in "reflection in action" (Schön, 1983) while considering our (auto)ethnographic observations at the same time. Eventually, this allowed us to react differently to each participant's own needs and design choices. As described in the findings, Ina decided to stick with PhotoFrame I, while Manuela and Lisa articulated new demands. As the project had no strict boundaries or a predefined study plan to deliver a specific device, we were able to custom tailor individual solutions.

2. We hypothesize that the factor of *trust* was equally important as the factor of time. Reflecting back, we asked the participants for quite a favour given the eventual length of the study (up to 60 weeks and still on-going) and the intimacy of the relationships and data we had access to. It could have been odd, if not impossible, to dig into unknown participants' personal photos for

such a long time as we did. In doing so, we were able to receive highly authentic feedback, which we may not have obtained using strangers. In this context, featuring a mother and daughter (Lisa and Manuela) as participants was also beneficial, as this enabled us to study how two participants exchanged personal data (SimpleCamera II).

Nevertheless, it is important for us to clarify our take on "rigour" and planning. It is by no means our intention to suggest that researchers should abandon structure and careful planning in their research. Moreover, reducing structure is not always possible or practical. In reality, there are often restrictions such as timetables, deliveries or reallocated budgets. Rather, what we are trying to argue based on our data is that if there is the possibility to do an open-ended process with less structure and planning, this might be a valuable possibility for gaining insight that should not be ignored.

5.2. Limitations

The present work featured a small sample of participants who were related or friends with the researchers. This choice was connected to both advantages and shortcomings as we now discuss.

Our study was not designed to generate precise, unambiguous and confirmable statements, common to *Positivist* inspired studies. Rather, methods of inquiry like RtD were used for their potential to make *generative statements*, that is, the capability to point to possible new worlds and "what might be" (Gaver, 2012).

The sampling of participants was limited with regard to number, age and gender. Moreover, the participants Lisa, Manuela, Ina are related to this article's first and second authors. This configuration allowed us to deeply engage with the participants and receive authentic feedback about their situation. The study has also some autoethnographic aspects, as we also used the technology by sending photos. Such a setup would have been unacceptable in an experimental study, but as we were trying to gain an understanding of the setting, this was not an issue, but rather an advantage (Neustaedter & Sengers, 2012). This leads to the question, what different results the endeavour would have yielded had all participants been unknown to the researchers. The close relationships probably made participants more willing to participate or more tolerant to system failures in the beginning (Saslis-Lagoudakis, Cheverst, Dix, Fitton, & Rouncefield, 2006); however, we argue that these effects would have disappeared with time. It is hard to imagine that the authors could have constantly influenced multiple users, who communicate in pairs, to use the prototype for months, let alone up to one year, just because of familial contact. On the contrary, having technology being used by relatives created an additional motivation for getting the prototypes right (Neustaedter & Sengers, 2012). The phenomenon of the socially desirable *response bias,* including from non-related participants, is a prominent problem in Psychology research (Paulhus, 1991), and for this reason the bias of pleasing feedback cannot necessarily be avoided in Co-Design even with non-related participants.

The gender of participants might have also influenced our results, as all participants were female. Investigating this potential bias as well as the specific needs of different age groups remains for future work.

6. CONCLUSION AND FUTURE WORK

In this article, we have reported how we integrated the iterative development of Technology Probes into an open-ended and loosely structured RtD process. The consistent use of the technology by the participants for one year (up to 60 weeks and on-going) provides evidence to suggest that the design approach is effective in creating technologies that are usable as well as used in practice.

The overall goal of this project was to support senior people in (intergenerational) communication by means of photo sharing devices (PhotoFrame and SimpleCamera). Our approach enabled the participants to talk about their needs and about technology from the perspective of experienced users, in contrast to solely anticipating or guessing how they would use a certain product in a scenario.

Having relatives or close friends as participants and having no strict external research agendas turned out to be crucial in the end. First, the open-endedness enabled both participants and designers to have as much time as was needed to explore the technology space free from pressure and obligations. Second, and in line with the first argument, as trust was the foundation of our relationship with the participants, we were able to ask them for rather big favours such as considering engaging in a long-term exploration and having access to their personal photos.

In summary, we suggest that allowing a loosely structured and practice-based design research process can have value in technology design, in particular, for older people. We acknowledge that such an endeavour might not always be practical; however, we argue that when possible, this approach can generate genuine and authentic insights, which might not have been established relying on more conventional design processes.

For future work, we intend to proceed as follows: most importantly, we are going to continue the field studies (see Table 1 for deployments that are still on-going). It is likely, that yet another generation of PhotoFrame and SimpleCamera devices will be created, considering (future) findings of the on-going studies. Depending on this feedback, this might be major design revisions or just fine tuning. In addition, we plan to extend the analysis of the empirical material already collected, that is, we analyse the content of the photos *per se* in order to study *how* the participants communicated using the devices. On the one hand, we can further investigate the data of the four senior participants (photos captured by the participants, interviews, log data, e.g., the Eye-contact-log). On the other hand, we can draw on the account of the twelve additional participants, who communicated with the four senior users, and illuminate this second perspective on our prototypes. Another interesting future work is to sample more participants, this time gender-balanced and without a personal relationship to the authors.

ACKNOWLEDGMENT

We would like to thank our family and friends for their valuable input and long-term engagement in the project.

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ENDNOTES

[1] Pilots of the mentioned studies lasted between 6 weeks and 6 months, 6-12 weeks being the most common.

[2] Our approach also shares some similarity with more traditional iterative design approaches in that we then also iterate on the design for improvements once the participants indicate they want to use the technology. However, this was an unplanned course that emerged in use, compared to traditional iterative design where more deliberate early prototypes are deployed to be explicitly evolved along the process.

[3] We previously reported the concept of SimpleCamera I (Güldenpfennig & Fitzpatrick, 2013) under the name TwoButtonCamera. The present article describes additional prototypes (SimpleCamera II, PhotoFrame I and II, MessageTripod, FrameCam), empirical data, as well as theoretical reflections not related to the previous publication (all unpublished material).

[4] Please note, that the algorithms do not distinguish between different faces/people, and we understand the log as a coarse approximation for the use of PhotoFrame I. We employed the technique in the course of data triangulation and to get a sense of use. We don't intend to quantify precise daily use, but were interested in internally consistent comparisons of use and consistency in behaviour.

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