Towards Participatory Prototyping with Older Adults with and Without Cognitive Impairment: Challenges and Lessons Learned

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Abstract: Technology is often not accessible to older adults, especially to those with low digital literacy or cognitive impairment. One premise of participatory design is that involving stakeholders including potential users during the whole process of design and development can result in solutions that are more accessible and make more sense to a target population. However, involving older adults in the design process is not straightforward, especially when they have little or no experience with information technology or some form of cognitive impairment, such as early stages of dementia. We investigate how to facilitate the participation of older adults with and without cognitive impairments in the phase of low-fidelity prototyping. We report on participatory design activities conducted in a non-governmental home for older adults with low socio-economic status and present lessons learned and challenges for planning and conducting participatory design that complement the literature in this subject area. For example, participants showed they are capable of some level of abstraction, although literature indicates that older adults with cognitive impairments have difficulties in abstract thinking.

Keywords: Participatory Design, Design with older adults, low-fidelity prototyping, cognitive impairment, dementia

1 Introduction

Ageing is a process that can be understood as sequential, individual, accumulative, irreversible, universal, deteriorating a mature organism, affecting all members of a species, turning its members less capable of dealing with stress from the environment, and thus increasing their chance of death [11]. Generally, ageing can be accompanied by a certain decline in cognitive capacity, which however not necessarily interferes with everyday life. Apparently, this alteration is due to a reduction of the information processing speed and due to changes in cognitive functions such as memory, attention or executive functions [22].

Dementia is not a disease but a term that describes a group of symptoms caused by different diseases or conditions. “Dementia is a syndrome – usually of a chronic or progressive nature – in which there is deterioration in cognitive function (i.e. the ability to process thought) beyond what might be expected from normal ageing. It affects memory, thinking, orientation, comprehension, calculation, learning capacity, language, and judgement. Consciousness is not affected. The impairment in cognitive function is commonly accompanied, and occasionally preceded, by deterioration in emotional control, social behavior, or motivation." [13].

Older adults with cognitive impairment might experience a reduced ability to interact with digital devices such as computers or smartphones and applications. Together with probable motor impairments, reduced vision and hearing, certain devices and services become quickly inaccessible to older adults. Older adults are often described as technology-averse, although they accept new technologies, albeit differently than younger adults [23]. The processes of perceiving the utility of a technology and overcoming the fear of "breaking things" might be different from younger adults, but older adults also want to use technology if they consider it beneficial [2], [19].

The inability of a person to use some technology is a consequence of a design failure [24]. A design that is inadequate for people with certain special needs results in society disabling these people. Designers need to keep in mind that their reality might be quite different from that of an older adult, which might impact fundamental aspects such as the metaphors used during design. The diversity within the population of older adults is enormous and greater than the diversity among younger adults [19]. Generalizing findings from younger to older adults is complex if not impossible, and thus design should always be conducted explicitly considering older adults as potential users.

Participatory design (PD) is an approach to design that includes users and other stakeholders into the design process [10], and thus seems appropriate to create solutions that are accessible and make sense to older adults. The objective of this paper is not to argue that PD is the best approach for designing in this context, but rather to investigate its possible advantages and limitations.

A design process can be separated into different phases, e.g. problem identification and clarification, requirement analysis, design, implementation, and evaluation [21]. The focus of this work is on the phase of design, and more specifically on low-fidelity prototyping. Low-fidelity prototypes are often used during the early phases of design and can be sketches made on paper or using other materials that allow quick drafting. Low-fidelity prototyping is a low-cost method to explore and evaluate ideas without already focusing on details of a final, polished product [27].

Although other authors have reported on PD with older adults with and without cognitive impairments [1], [5, 6, 7, 8, 9], [15], [19, 20], [25], few reported on low-fidelity prototyping with these participants as co-designers as opposed to informants or evaluators [8]. The objective of this work is thus to contribute to filling this gap.

We describe seven activities conducted with a group of older adults that included people in early stages of dementia. We conducted these activities in a non-governmental home for older adults with low socio-economic status. To be eligible to move in, candidates cannot have economic means to sustain themselves autonomously.

We present lessons learned and challenges for planning and conducting PD activities. A common theme of the lessons and challenges is that the inclusion of older adults with cognitive impairment into the process of low-fidelity prototyping is complex, especially when participants have little or no experience with technology use. Apart from adapting prototyping techniques to the abilities of the participants, careful planning is required to present an explain concepts related to technology design and use.

The remainder of this paper is structured as follows: section 2 presents related work; section 3 characterizes the design context; section 4 describes the seven activities and obtained results and analyzes and discusses them; section 5 synthesizes the lessons learned; section 6 identifies challenges for planning and conducting PD activities; section 7 concludes.

2 Related Work

Older adults differ from younger adults in the ways they use digital technology [3]. People with cognitive impairments face difficulties when interacting with digital devices or services [4]. Designers often seem to ignore older adults as a target audience [2], possibly trying to simplify the design process by focusing only on a subset of user needs, or physical, sensorial and cognitive characteristics [1].

PD gives participants a voice by considering their individual needs and experiences. However, engaging older adults in the design process involves some challenges [19]. It is necessary to frequently remind participants of the meeting topic. Designers might overanalyze contributions of participants, introducing a complexity not intended by the participants. Older adults might have difficulties imagining future technologies or intangible concepts. Designers need to keep that in mind when appreciating the individual contributions to the design process (cf. also [8], [25]). Some PD methods might need to be adapted.

Lindsay et al. [19] proposed the following approach for including older adults in PD: stakeholder identification and recruitment, video prompt creation, exploratory meetings, and low fidelity prototyping sessions. The video prompts were intended to trigger the curiosity of the participants and to create discussions that supported the exploratory meetings that informed the low fidelity prototyping sessions. The goal of the prototyping sessions was to identify more requirements related to features of the device to be designed. The sessions followed the PICTIVE process [26].

The following three studies investigate how to include older adults in the processes of idea generation, creativity and design critique. Davidson and Jensen [20] investigated whether older adults whether a design critique of existing applications before the phase of ideation supports creativity. The authors found evidence that a design critique before ideation is detrimental to creativity. Massimi et al. [28] used critique before design to try to increase creativity of the older adults, discussing photos of PDAs before a brainstorming session and the subsequent prototyping. The authors concluded that older adults conduct critique more easily than design.

Uzor et al. [29] conducted a study whose main objective was to involve older adults in the design of multimodal tools for effective rehabilitation. The participants were involved in activities such as personal experience discussion, scenario and persona creation, evaluation of prototype games, and sketching proposals of new games. The study presents evidence that seniors can play a significant role in the design of rehabilitation games.

Different from our work, Lindsay et al. [19], Uzor et al. [29], Massimi et al. [28] and

Davidson and Jensen [20] did not involve participants with cognitive impairments or not explicitly mention whether or how these were involved in prototyping activities.

Lindsay et al. [8] investigated how to create an empathic relationship among designers and participants with dementia. They designed a safe-walking device for people with dementia. At the outset of the project, the authors tried to understand the everyday life of the participants as well as differences between participants and designers. Initially, the authors analyzed participants' accounts about experiences relevant to the problem domain. Subsequently, they incrementally produced individual prototypes with the participants, which allowed an exploration of the participants' thoughts and experiences without requiring abstract thinking.

During the design stage, Lindsay et al. [8] conducted four meetings with the older adults. Of the six participants of the first stages, only the two who were most engaged in the process and the subject participated in this stage. During the first two meetings, the authors presented sketches of different ideas as well as storyboards to discuss these ideas. During the third meeting, the participants tried to create paper prototypes of the device interface (the authors did not report on the result of this meeting). During the fourth meeting, the final prototype was presented.

Slegers et al. [15] developed a system to register eating times of older adults with dementia using PD. Their process involved three phases: ethnography, ideation and conceptualization, and prototyping. The contact between designers and participants with dementia occurred in two ways. During the ethnography phase, the designers observed participants in their homes and in a psychiatric hospital, and accompanied a psychologist visiting participants with dementia at home. To understand the difficulties of people with dementia in everyday life, the authors conducted an activity based on the MAP-it method [17] with the older adults and their caregivers. The results of this activity informed the prototyping of an application for caregivers, during which only caregivers participated, but not the participants with dementia.

Holbø et al. [7] investigated how to design a safe walking device considering the needs of older adults with dementia. Conducting interviews and PD workshops, they identified factors that influenced the participants' attitudes towards these devices and how they expected these devices to help them. The design process comprised two phases. During the preparatory phase, the authors conducted interviews with relatives and caregivers, initial meetings with the participants with dementia, and created photo recordings of daily activities, to better understand the routines of older adults with dementia, their families and their caregivers. Subsequently, they conducted PD workshops to better understand the personal experiences of the participants with dementia, how dementia affected their possibilities to do outdoor activities, and how a technological device might facilitate these activities. During this phase, the authors used the photos from the first phase to discuss daily activities. Next, they used Lego figures and a neighborhood map to help the participants describe relevant experiences. Last, researchers, older adults with dementia and their caregivers created low-fidelity physical prototypes and used them to play out scenarios, identifying requirements as the participants reflected over possible uses of a safe walking device. The research was conducted with three older adults with dementia, and each activity was conducted individually with each participant and their families and caregivers.

Hendriks et al. [6] argued that traditional PD methods are not very appropriate for people with dementia, since they require specific approaches that consider their different cognitive and psychiatric symptoms (e.g. deterioration of memory or aphasia; depression, hallucinations or delusions). Based on literature about PD with older adults, with people with dementia and with people with symptoms related to dementia, the authors proposed six subgroups of guidelines to support the process of PD with older adults with dementia. To evaluate these guidelines, they conducted PD sessions with female participants with dementia aged between 70 and 95, as well as their family members. The sessions were focused on problem clarification and design suggestions, and were conducted with an individual person with dementia and their family members. The proposed guidelines or best practices do apply to PD in general and are not restricted to older adults with cognitive impairment. Furthermore, they do not focus on planning specific activities such as prototyping or evaluation.

Although some authors investigated how to design with or for people with dementia [1, 2], [6], [8], [14], [18], we encountered few examples (e.g. [7]) of involving older adults with cognitive impairments in the stage of prototyping. Furthermore, guidelines, recommendations and insights identified by the respective authors are relatively abstract. Especially regarding prototyping, these authors did provide few details as to how the employed methods and techniques worked with the participants with dementia.

3 Characterizing the Design Context

We conducted our activities at *Lar dos Velhinhos de Campinas* (LVC), a non-governmental institution for older adults with a more than a 100-year history located in Campinas, State of São Paulo, Brazil. The activities were conducted by two researchers and occurred once or twice a month, in accordance with the participants' availability. Each activity had a duration of 60 to 90 minutes, occurred in the early afternoon, and terminated when afternoon coffee was served. The activities were mostly conducted in the room of occupational therapy at LVC's geriatric center and were always accompanied by the same occupational therapist. At the beginning of each activity, past activities were remembered. All activities were filmed, and one researcher took annotations. The research activities were approved beforehand by the ethical review committee of the researchers' institution as well as by LVC's coordination board. All activities were discussed beforehand with some of the LVC staff.

The older adults participating in the activities live at the LVC and were invited by the occupational therapist to volunteer as participants. Some of the participants aged between 69 and 92 showed cognitive impairments such as different stages of dementia. The number of participants in the seven activities varied from five to twelve. The variation in the participation was due to individual health-conditions, well-being, and parallel activities. The educational level of most corresponded to 4th grade elementary school. One participant graduated high school, and some were functionally illiterate, participating in reading and writing classes at the LVC.

All participants were residents at the LVC and needed to accept and follow the institution's rules and regulations. Most participants had a humble upbringing, many did not have family or friends and thus rarely received visitors. Some had health problems that prevented them from participating in some encounters. Sometimes, participants arrived emotionally upset, and even crying, e.g. because of missing family members or friends. These and other circumstances were always considered when planning and conducting our activities with the intent to provide a pleasant activity.

At the beginning of the first encounter, the ethical review committee approved consent form was discussed and read jointly. Of the participants that showed symptoms of dementia, none required a legal representative, and all could sign the consent form. Although this is outside the scope of this paper, an important question is to what extent people with cognitive impairments can consent to participating in research activities and remember that they consented. Apart from writing consent forms in easy to read, plain language, in appropriate font size, as well as reading them aloud and discussing them with the participants, an approach that might help remembering might be to make video recordings of the discussion available. During our activities, we did not make those recordings available (the residents of LVC did not have easy access to a playback device), but orally remembered participants at the beginning of each activity why we were there and that they could leave the activity at any moment (some participants left activities when not feeling well, but generally returned for the next session).

The activities we report on in this paper are part of the master-level research of one of the authors, the prime objective of which is to investigate how to include older adults with cognitive impairments into PD processes. Our design process was open, i.e. at the outset we did not have a specific objective other than designing something that would make sense within the context of the LVC.

During previous activities that involved storytelling, questionnaires, games, as well as interviews with participants, caregivers and other LVC staff [16] we already had started to familiarize ourselves with the LVC as well as with the participants, their physical and cognitive abilities and limitations, their preferences and needs, their life experiences, as well their "profiles" as potential users of digital technology.

The participants, as well as many other residents of the LVC, had little to no experience with digital technology. Although the LVC has a computer room accessible to all residents, hardly anyone uses it. Of our participants, only two possessed a feature phone, most had no experience with devices such as microwave ovens or video recorders, and many did not use the TV remote control.

We identified that the LVC residents often faced difficulties adapting themselves to their new home after moving there, communicating with other residents, and following LVC rules and regulations. We observed that the participants loved to look at photos and that this activity instigated conversation among them, even after having stopped looking at the photos. Looking at photos individually or in groups might stimulate communication, might have a potential to help in the adaptation process (e.g., using photos of interesting places and events of the new home, as well as photos of the old home) and even might promote accepting and remembering house rules and regulations (e.g., by storytelling). We thus decided to design some device for displaying photos, focusing on features that might stimulate conversation.

4 Towards Participatory Paper-Prototyping: Seven PD activities

The activities described in the remainder of this section focus on possibilities to include the participants in low-fidelity prototyping activities. Not all activities were directed at prototyping a “photo viewing device”, some explored general techniques or dynamics of low fidelity prototyping.

Based on challenges pointed out in the literature, the goal of the first activity was to evaluate a prototyping technique to promote accessibility and creativity. Analyzing the activity, we perceived limited overall communication among the participants. The goal of the second activity was to better understand how the participants communicated during collaborative, goal-directed activities. After that activity, we identified “photo viewing” as a possible target application. The goal of activities three and four was thus to evaluate to what extent existing online photo viewing applications made sense to our participants, while at the same time evaluating how they used two different prototypes (simple paper and executable with a dedicated physical input device). After these activities, we accepted “photo viewing” as a relevant and adequate application and perceived the participants had difficulties understanding the purpose of design activities as well as the meaning of graphical interface elements. The remaining three activities presented in this paper thus yielded at gradually exposing the participants to prototyping graphical user interfaces.

4.1 Activity 1: Redesign of a TV Remote Control

The objective of this activity (cf. Fig. 1a) was to explore a limited set of Styrofoam® cutouts as prototyping material, investigating its accessibility, creativity potential, and whether it is suitable for creating various design alternatives. This activity consisted in the construction of a low-fidelity prototype of a TV remote control that participants could understand and use. Participants were divided into groups of two to three and asked to build a remote control using the materials provided by the authors. Each team received a kit of Styrofoam® cutouts which included different “empty” remote control bases and different button sets in different shapes and colors. In previous activities, we had perceived the participants’ difficulties of drawing something “from scratch”, even concrete objects such as a TV set or a flower. Furthermore, some participants had difficulties holding a pen or drawing on paper, hence the exploration of this kind of material during the activity.

One of the original eight participating older adults left the activity shortly after the start. The remaining participants designed remote controls in three groups. The resulting remote controls would not have been fully functional, and the participants had difficulties or were unable to describe or explain their designs. In two of the two-person-groups, one participant chose and arranged all parts while the other only observed. In the first group, the participant put duplicate volume controls on the remote control. Although he stated that he could not see the labels on the buttons, he stated to have chosen them because of their high contrast. In the second group, the designing participant tried to get the other’s opinion, however without success.

The three-person-group tried to communicate and choose the buttons together. The researchers were unable to understand the button layout (there were duplicate buttons and number buttons mixed with other controls), and the participants were unable to explain it. One participant stated, “I don’t understand anything. I’m doing, but I’m not understanding”.

a) b)

Fig. 1: a) Redesign of a TV remote control; b) Creating a photo poster.

After designing their remote controls for approximately one hour, each group tried to simulate the use of the remote control of another group, i.e. pretending to turn on the TV, change channels or volume. One control did not have an “on/off” button, thus the participants were unable to simulate this task. The creator of the control explained that the TV would be switched on by pressing one of the number buttons, but could not explain how to switch it off.

Many of the standard remote control labels did not make sense to the participants and did not help to identify the button functions. One participant felt uncomfortable for not having used a remote control before. Throughout the activity, he repeatedly stated that next time he would “do better”.

Although some of the participants never used a remote control before, all groups assembled a remote control from the parts handed out to them. However, none of the created prototypes could have been transformed into a functioning prototype. We did not conduct a comparative activity with a prototype drawn on paper, but from our experience with the group, they would probably have had more difficulties drawing a remote control from scratch. The activity allowed us to better understand the advantages and disadvantages of prototyping based on assembling ready-made parts.

An advantage is that physical prototype assembling might be more inclusive than prototype drawing. Arranging the parts requires less fine motor skills than drawing on a sheet of paper, and, with the right materials, might even be conducted with people with visual impairments. Arranging the parts also allows for easier exploring and reconfiguring than erasing lines drawn on paper or starting over with a new blank sheet. Furthermore, for designing in a domain unfamiliar to the participants, this technique provides concrete starting points, as opposed to a blank sheet of paper.

A disadvantage of this technique is that such prototypes are restricted to the available parts. In this concrete instance of a remote control, the prototypes did not lead to insights that could not have been gathered without PD. A possible adaptation of the technique would be to design the parts in a previous PD activity or allow the ad-hoc design of parts during the session.

Our main interest in this activity was to investigate whether the technique was feasible in principle, which we could affirm, and how the participants interacted with each other. With no facilitator instigating conversation, and no otherwise imposed "rules", as expected, the participants hardly communicated. The only communication that took part in some groups was of the form "Is it OK to put this piece here?" to which the other participants always agreed.

4.2 Activity 2: Photo Poster

The objective of this activity (cf. Fig. 1b) was to investigate whether and how the participants communicate and coordinate during a creative process. During this activity, participants were divided into two groups of five and asked to create a poster telling the "story" of one of the previously conducted activities. As materials, participants could use a large sheet of paper, color pens, glue, and choose between sets of photos from one of the previous activities printed on plain paper. Each group chose a different set. The authors participated as facilitators. At the end, each group presented their poster to the other group, telling the story.

One of the groups managed to organize itself in a way that allowed each member to give their opinion and to participate in some way in the creative process. One participant with tremors in the hands could not draw but actively commented on the others' drawings. After some time, a more passive participant was given the task to hold and distribute the pens and other utensils, and thus possibly felt more like a part of the group. In the other group, one of the participants dominated the activity, while the rest seemed to accept this. Two of the participants arrived emotionally upset, one of them crying. Both insisted in participating, but did not contribute actively to the group. The two groups presented their results with enthusiasm. One of the main presenters, who generally is very articulate, seemed to be nervous. The main presenter of the other group got a bit "carried away", and it took some time until the researchers and other participants managed to get their focus back to the group.

In contrast to the previous activity, the researchers participated in the groups and instigated communication among the participants. In this activity, the participants communicated more among themselves than during the previous activity. Since we worked in groups of six participants including the facilitators, effects of group dynamics became visible, i.e. strong personalities dominating the group (not necessarily consciously), or quieter participants contenting. Since in many cultures, older adults are very respected, balancing the group dynamics can become a delicate matter. Another common event occurred during this activity: two participants were very emotionally upset at the beginning of the activity, but were eager to participate. It is not always possible to console upset participants, and postponing the activity to the next encounter is often not an option. Activities should thus be planned considering indisposed or distracted participants, and facilitators be prepared to do more than just conducting an activity.

4.3 Activity 3: Evaluation of a Low-fidelity Paper Prototype

The objective of this activity was to evaluate to what extent common interface elements of "simple" web-based photo viewing applications made sense to the participants, and whether they understood the content of the digital "photo album". During this activity, the participants interacted with a paper prototype of a photo viewing application. The photos used in a prototype were of a parade in which some LVC residents participated during a national holiday. The prototype was modeled imitating common web-based photo viewing services and had five types of possible interactions: show the next/previous photo, recommend, like, or comment on a photo. The participants were divided into pairs and asked to view the available photos and to explore the different buttons. One facilitator read the photo descriptions aloud when displaying a new photo. Comments could be written on paper with a pencil. After the interaction with the prototype, the researchers conducted a quick debriefing trying to evaluate how each pair of participants understood the prototype.

Since most of the participants had never used a computer before and thus probably did not understand the meaning of most of the interface elements, the participants had great difficulties using the prototype. One of the participants was observing attentively the other groups, but when it was her turn, she also had great difficulties. The participants could not distinguish buttons or active interface areas from inactive ones, and even when buttons were labeled, they did not understand their meanings. One participant, who participated in almost all activities, but who often seemed to lose interest quickly, understood that the "next" button advanced the "slideshow", and pressed this button repeatedly, seemingly to "get over" with the activity. Despite the difficulties interacting with the prototype, the participants were highly engaged with the photos and talked excitedly about them during as well as after the activity.

Although many participants had never used a computer before and thus probably did not make the connection between the paper prototype and a computer application, they could explore the prototype to some extent, and some partially concluded the task of viewing the photos in the prototype. This indicates that evaluating paper prototypes might be useful even if users have no or little experience with digital devices and cannot establish a relation between a paper prototype and a computer application. The "social" functions of the prototype (like, recommend, comment) did not make sense initially, since at first, the participants did not understand that someone who uses the device after them will see the results of their actions. Later some participants began to understand the functionality of commenting.

All participating older adults remained seated during our activities, and many had limited mobility. Thus, paper prototypes should be small enough to be explored while seated. Inclined tabletops can make the areas of a prototype more accessible.

This activity also provided arguments for accepting the idea to design a photo viewing application. Even with difficulties using the prototype, the participants enjoyed viewing the photos and talked to each other lively, including after the activity and with participants who had not used the prototype.

4.4 Activity 4: Evaluation of a Prototype of Physical Input Device

The objective of this activity (cf. Fig. 2a) was to explore the feasibility of a dedicated physial input device as technological platform, and to evaluate to what extent the participants understood different interface elements, as well as the application content. The activity consisted of interacting with a photo viewing prototype similar to that of the previous activity, using a physical input device that required touching physical interface controls. The prototype was developed in Scratch[1] and used a Makey Makey[2] based input device. Upon touching any of the controls, the prototype provided auditory and visual feedback. We divided the participants into pairs and explained the purpose of the application, remembering the previous prototype. We then asked the participants to freely explore the application, and debriefed them similarly to the previous activity.

All tangible controls of the prototype were labeled with text and icons. Although participants could read the labels, they did not understand the controls' functionality and initially pressed the controls exploratorily. One participant with motor impairments only pressed the nearest controls.

Although, in comparison with the paper prototype, the prototype of the physical input device had five explicit physical controls, and although the participants understood quickly that they had to press the controls to provoke some change in the application, they had great difficulty

a) b)

Fig. 2: a) Evaluation of a physical prototype; b) Wireframing tutorial and hands-on Exercise.

interacting. Few of the participants could switch photos purposefully, most did not understand that the "next" and "previous" controls displayed the next and previous picture. Only one participant could match the physical controls to actions on the screen.

One participant asked his partner which control changed the photos, and got the correct answer. Diverting the gaze from screen to physical control, pressing the "recommend" instead of the "next" control, and looking back to the screen, another participant thought the photo had changed, only to perceive it had not after reading out and remembering the photo description. Yet another participant thought, the controls had different functions for her and her partner, possibly because both managed to switch photos, one using the "next" and the other the "previous" control.

Despite the difficulties using the prototype, comparing a "traditional" photo album

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[1] Scratch - https://scratch.mit.edu/

[2] Makey Makey - http://www.makeymakey.com/

and the prototype, one participant exclaimed, "[The physical input device] is great, even better! You have to keep turning over [the pages of a photo album], but [in the physical input device] you just hit here and [the next photo] already appears".

Compared to the previous activity, this one was easier to some extent, since the participants had already been exposed to the concept of a prototype and since the interaction controls were now explicit physical objects. The interaction with the prototype was made difficult due to usability problems that could not be fixed in time, as well as due to unfavorable lightning conditions and high background noise during the session.

Nevertheless, the participants seemed to be engaged and commented positively about the experience. Although this was probably partly due to being exposed to some new technology for the first time, one participant who is often less motivated, and who was not going to participate in this activity, curiously approached the table where a pair of other participants was interacting with the prototype to see what was going on.

4.5 Activity 5: Wireframing Tutorial and Hands-on Exercise

The main objective of this activity (cf. Fig. 2b) was to explain the concept and importance of prototyping, and to introduce the participants to techniques of creating paper prototypes. Secondary objectives included introducing some interface design concepts such as "buttons", "placeholders" or "features". Finally, we tried to further explore how participants understood the abstract vs. the concrete and the tangible vs. the intangible aspects of prototypes and user interfaces.

This activity was divided into three stages: explaining the concept of prototyping, exemplifying the importance of prototyping, and creating a wireframe-like prototype. The concept of "prototyping" was explained using PowerPoint slides, variants of a simple, concrete paper prototype, and a high-fidelity prototype on different smartphones. Using these three media, also the concept of a "button" was introduced, e.g. participants held a smartphone in their hands and experienced what happened when they pressed a graphical button on the phone's touch screen.

To illustrate the importance of prototyping, we used a paper prototype of a computer screen that had an image at the bottom center of the screen. We posed the task to color the image, and the tools to complete the task were color pencils representing a color-fill tool of image editing applications. In one variant, the pencils where placed at the top left corner of the screen, similar to the position of the tool in a toolbar. The other variant had the pencils beside the image. The participants perceived, that both alternatives worked, but that the second alternative was much easier to use.

During the third stage, the participants were asked to create a layout of an "about me" page, similar to online profile pages, yearbooks or friendship books. To give the participants a concrete task, we asked them to replicate an example of the previous PowerPoint presentation: a screen that contained a person's name, a photo, a text and three buttons for changing the background color, changing the photo and reading the text. The participants received a blank sheet of paper and rectangular snippets representing placeholders of each interface element. Subsequently they were asked to fill in a factsheet about themselves and explained that one of the researchers would create an “application” using the layouts of and information about each participant.

All seven participating older adults managed to create a layout, three without help. One participant with low vision created his layout without being able to read the labels on the placeholders. After being prompted by a researcher and being read the labels, he changed his layout slightly. Two participants had help from the occupational therapist, which resulted in her creating almost the complete layouts. Another participant had difficulties understanding the activity, and did not know how to arrange the placeholders, even after being given hints and examples by a researcher and another participant.

Based on the individual abstract paper layouts and the factsheets, one researcher created the digital, concrete “about me” screens and presented them at the beginning of the following session. Seeing the results evoked positive reactions. One participant was excited and amazed seeing her photo and her personal information on the screen.

Although in previous activities the participants engaged in tasks similar or related to prototyping, we only introduced this and other concepts such as “features” and interface elements like “buttons” during this activity. The challenge of introducing these concepts is similar to working with generally digitally illiterate people. We used a mix of real-world and digital examples, as well as demonstrations and hands-on exercises and experiences, and tried to use a language that could be understood by the participants. For example, the concept of design tradeoffs was translated to “often there is no right or wrong; and some things work better for some people and worse for others” and demonstrated by the height and position of power outlets and light switches in the room (in our country there are no mandatory building standards for placing these).

We did not expect that the participants understood and remembered the concepts after one activity, and during the hands-on wireframing task most did probably not yet understand the utility of a wireframe. However, although some had difficulties executing the activity, the participants could make the connection between the concrete layout and the wireframe (or “drawing of boxes”).

4.6 Activity 6: Newspaper Collage

The objective of this activity was to explore whether and how the participants understood the transition between a concrete newspaper layout and the abstract representation of a wireframe. During the first stage of the activity, the participants created the front page of a newspaper, gluing paper clippings (text snippets, and cutouts of photos and other visual elements, all taken from a real newspaper front page) on a blank sheet of paper. Each participant received between 8 and 15 clippings from a different newspaper. The participants were encouraged to create their own layouts. After that, we asked them to take a second sheet of blank paper and draw boxes for each element glued on the first sheet, in its respective position.

According to the occupational therapist, most of the LVC residents like to create collages. Three of the six participants concluded the activity without any help. One participant had initial difficulties, even receiving hints, examples and explanations, including from another participant. As during the previous activity, the occupational therapist helped two participants, substantially influencing the outcome. One participant with motor impairments had difficulties conducting the activity autonomously, but when offered help could identify the pieces and indicated where to put them.

The participants had difficulties in the second part of the activity, designing a "wireframe" based on the layout they had created. Two participants could create a wireframe, albeit with difficulties. One participant filled the sheet of paper with boxes that did not correspond to the layout; she was unable to explain what she had drawn.

The participants liked to create collages and thus showed no difficulties executing the activities. Of course, they executed the activity different from a group of people without visual and motor impairments. Creating a wireframe from the individual layout was difficult for most, probably due to fatigue at the end of the activity and due to the relatively high number of elements in the collage.

As to the usefulness of this technique, e.g. the tradeoff between simplicity and creativity, similar observations as for the Styrofoam® cutout assembly apply, although using additional material such as pens, scissors, colored cardboard and magazines or newspapers, it would be easier to create new content on the fly.

4.7 Activity 7: Bedroom of Dreams – Collective Low-fidelity Prototyping

The objective of this activity was to explore the process of collective prototyping, as well as creativity during the prototyping process. Initially, one of the researchers drew a floor plan of a room shown on a photo, as well as a floor plan of the room where the activity took place. These floor plans were discussed to identify which element on the plan corresponded to which element in the room or photo. Next, we asked pairs of participants to draw the floor plan of one of the pair's shared bedrooms (the residents live in shared rooms with up to four people per room), indicating the position of furniture.

We divided the participants into two groups and asked them to collectively create a floor plan of their "bedroom of dreams". The authors participated as co-designers. To fuel the participants' imagination, we showed a set of 17 bedroom photos, ranging from classic to modern and futuristic bedrooms. The participants of each group then designed a floor plan, adding elements one after the other and completing approximately two cycles. Subsequently, the floor plan was discussed within the group, with the possibility to include additional items, and then presented to the other group.

All participants could conclude the first part of drawing their bedrooms, although some preferred to draw alone instead of in pairs. Furthermore, some participants expressed concerns stating they did not know how to draw. Within each pair, participants drew without communicating much. One pair claimed their rooms were identical, which they are in an abstract sense (number of beds, types of furniture), but not in the concrete sense (position of each piece of furniture, decoration).

At the beginning of the second part, the design of the "bedroom of dreams", some participants thought they had to draw a floorplan of one of the rooms in the photos shown to them. After further explanation, the two groups could draw their floorplan. One participant preferred not to draw but asked the other participants to draw her ideas when it was her turn. Another participant did not understand that this was a collective floor plan and always wrote or drew objects she would like in her own room, even if somebody already had drawn that object.

The first group produced a feasible floor plan and expressed content during the group discussion. The second group perceived their room was quite crowded, had unnecessarily repeated objects and an unsatisfactory layout. One of the participants, who had great difficulties drawing and was relatively quiet during this phase, participated eagerly in the discussion, pointing out flaws and sharing her opinion.

Although initially some participants seemed to be intimidated by having to draw, both the individual/pair and the group activity went well. The activity allowed all participants to contribute according to their strengths. Some preferred to ask others to draw for them, but since drawing was round-based everyone had their time and space to contribute. Those who could not express themselves visually could contribute orally. To further increase accessibility, it might be worth investigating a mix of drawing with collage in future iterations of this technique. Compared to other activities, including those where the authors actively participated, this one had the most and most natural conversation among participants. A future challenge will be to apply the technique to a domain or design problem the participants are less familiar with.

During individual or pair activities, some participants usually finished much earlier than others. During time-constrained round-based techniques such as brainwriting it is difficult to find the right timing, given the great differences in participants' abilities. The time-unconstrained round-based process solved timing problems we observed during other activities or anticipated with different techniques [35].

We could not affirm with certainty whether the photos shown before the group part of the activity supported creativity or ideation. However, on each of the two floor plans some elements appeared that were not present in the participants' rooms nor in the LVC, but that appeared in some photos.

5 Lessons Learned

Differently from the studies presented in section 2, the goal of our work was to include participants as co-designers in the phase of low-fidelity prototyping, and to detail how this was done. Based previous findings from the related literature, and considering our concrete design context, we adapted some methods and experimented with alternative techniques. For example, we did not include design critiques of existing applications, since most participants had never used a computer before. On the other hand, we discussed all created artifacts and perceived that participants could criticize them and provide arguments for their critique.

Including older adults in PD processes is no trivial task, especially when some participants have cognitive impairments. Of the related work presented in this paper, few tried to include older adults with cognitive impairment in participatory prototyping activities. The activities presented in this paper had to consider the joint contexts of ageing, cognitive impairments, and digital illiteracy. In the following, we present lessons learned so far, divided into six themes. The objective of presenting these lessons learned is not to prescribe actions but to support researchers and designers in reflecting about and taking better informed trade-off decisions.

Planning Activities:

- Simple might not be simple enough. Even after trying to simplify activities, e.g., by reducing the number of Styrofoam® pieces in activity 1 or the number of newspaper snippets and their formats in activity 6, participants might still have difficulties.
- Planning activities that introduce something new building on something the participants already know makes them more comfortable and confident. E.g., in activity 6 we used a technique the participants already knew from occupational therapy.
- On the other hand, planning an activity that requires knowledge of a previous activity might not always work, since due to personal health and well-being, there might be a substantial fluctuation of participants between encounters (cf. the sequence of activities 5 and 6).

Group Activities:

- The presence of a facilitator in the group promotes communication (cf. activities 2 and 7).
- The presence of a caregiver or other person the participants are familiar with (e.g. relatives, or LVC staff in our case) promotes communication and can elicit knowledge "external" participants such as researchers would not be able to access.
- Caregivers and other additional intermediaries also might have a better feeling how to motivate more passive participants and how to funnel the contributions of very active or agitated participants (cf. activity 2)
- However, the influence of these additional intermediaries must be considered carefully (cf. activities 5 and 6; this topic is also discussed in [15]).

Creativity:

- Although concrete examples such as photos, videos, or stories might prime participants and limit creativity, they might need them to get started (cf. activity 7).
- Collective prototyping facilitates creative contributions of participants who have difficulties during individual activities, e.g. due to insecurity or cognitive or motor impairments (cf. activity 7).

The concrete vs. the abstract:

- Although literature and our experience indicate that older adults with cognitive impairments have difficulties in abstract thinking, the wireframing activities and comments such as "our rooms are all the same" show that they are capable of some level of abstraction (cf. activities 5, 6, and 7).
- On the other hand, when presented with concrete examples such as stories or scenarios, they might have difficulties recognizing whether these are real or fictitious.

Sharing back results:

- Sharing back results not only promotes motivation and engagement of participants, but is also important to remembering and thus providing more context to subsequent activities (cf. activity 5; this topic is also discussed in [7]).
- If results are rather abstract (e.g. the drawing of a wireframe), participants might

not recognize their own work. To promote recognizing, tangible results could be personalized, e.g. by signing or by showing photos or videos of the process (cf. activities 5 and 6).

Usability and Accessibility:

- Prototypes and applications obviously need to consider guidelines related to ageing, cognitive impairments and digital literacy. In practice, this means that pilot evaluations, even with expert researchers or designers, might be of limited use. Some basic problems might only be detected with the participants, and activities should be planned accordingly.
- When conducting prototype evaluations or other activities, participants might prefer to remain seated throughout the whole activity.
- A TUI with explicit, physical objects for input and output might facilitate the interaction, especially if the person has little experience with digital devices. Of course, if the objective of design is related to digital inclusion, designers should balance the trade-off between simplifying interaction with one artefact and promoting digital inclusion (cf. activity 4).

6 Challenges for Participatory Design Activities

When including older adults with cognitive impairments into the design process, designers face the challenge of having to adapt many methods and techniques that do not adequately consider the cognitive limits and capacities of participants [6], [8, 9]. Additional challenges occur in different dimensions.

Mood swings are a symptom of cognitive impairments. Changes of participants' emotional states occurred during various activities and consequently influenced results. Leading with these changes is a delicate matter. There is no recipe for avoiding mood swings or mitigating their impacts. Since mood swings also occur during the use of a design solution, we believe it is important to embrace them during design. Activities should be planned considering the possibility of mood swings: activities might take longer than expected, or might need to be repeated during another encounter. Subsequent activities in one session should not overly depend on each other.

Although it might be beneficial or necessary to include caregivers, family members or therapists in the process, they might interfere in the activities and influence results by trying to "help" other participants. Again, there is no recipe for avoiding this influence, but it should be acknowledged and considered during analysis. This interference is not necessarily bad, and after all, researchers and designers also influence outcomes.

In any design activity, it is important to make clear that participants are not evaluated. We found this challenging in our context. Some participants were quite preoccupied with "doing it right" or "living up to our (non-existent) expectations". This might have induced unnecessary stress. So far, we found no better way to mitigating this than to be aware of this fact, explaining repeatedly that there is no right or wrong, giving examples of ourselves doing things that might be considered "imperfect", as well as encouraging participants and making it clear that all contributions are important.

Due to health or well-being, not all participants participate in all activities. This has an impact on planning activities that depend on individual results of a previous activity.

Many activities that seem simple and quick to a designer might require a high cognitive and time effort from the participants. Furthermore, some participants might conduct activities significantly faster or slower than others. Activities should be planned accordingly, e.g. avoiding parallelism and the need for synchronization points.

7 Conclusion

The purpose of this paper was not to find "the best" method for designing for our "target population", but to explore whether and how they can participate in PD activities such as low-fidelity prototyping. This is reflected in the fact that initially we did not even have a target product to be designed, but tried to identify one that made sense in the concrete context of the retirement home where we conducted the activities.

PD with older adults with cognitive impairments is an area with many open questions, especially regarding participation during prototyping. In this paper, we presented activities, identified challenges and formulated lessons learned that answered or at least clarified some of these open questions.

Regarding the literature in the area, we experienced some similar challenges (e.g. [5]), and complemented guidelines (e.g. [6]). The contribution of this paper is to have further clarified challenges and synthesized lessons learned focused on practical issues arising during design activities, with the objective to support researchers and designers.

The biggest practical challenge we faced was to deal with the fluctuation in the group due to health or well-being. A methodological issue was related to pilot testing, which seems to be more limited when the "user population" is less well understood. A conceptual and methodological issue was related to creativity and the continuum between the abstract and the concrete. While giving concrete examples possibly limits creativity, it might be necessary to get started. Practical and social issues were related to group dynamics, to the possible sentiment of feeling evaluated, as well as to the "reflex" to "assist" the older adults instead of letting them do things in their own time and way.

Some of the presented activities were not directly related to prototyping, and those related to prototyping were not necessarily related to prototyping an actual product. However, the employed methods and techniques were similar to "real" prototyping, and we thus believe that the presented results are useful to other researchers and designers in similar contexts. Our next steps are to further explore collective prototyping to co-design and co-evaluate a photo visualization system to be deployed in the LVC.

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