

# Co-refining interactive systems with older adults from function, form and interaction

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# Co-refining Interactive Systems with Older Adults from Function, Form and Interaction

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Designing interactive systems that are pragmatic, attractive and easy to use for older adults is challenging. Participatory design, as an approach to enhance the mutual understanding between designers and end users, has been proved to be useful to improve the quality of design for older people. However, PD research has long been criticized for extensively dealing with the early-phase design while putting less emphasis on the later stages. In this paper, we argue for the importance of collaborative refinement when designing interactive systems for older adults. Through a case study, we describe our experience of co-refining the preliminary design of an interactive system with older participants from three perspectives: function, form and interaction. We also explored to adopt some potential PD methods and conclude by discussing the effectiveness of the chosen approach and methods.

Keywords: participatory design, older adults, interactive systems, refine

## Introduction

Global population aging and the rapid development of novel technology lead to an increasing demand for interactive systems to enhance older adults' quality of life by promoting their independence and social wellbeing. However, designing interactive systems that are pragmatic, attractive and easy to use for older people could be challenging due to the lack of mutual understanding. In the past decades, we have witnessed a new design movement shifting from designing for users to designing with users (Sanoff & Henry, 1990). Participatory design (PD) was initially proposed as a set of approaches to involve workers in the development of technology to increase worker autonomy, skill and task variety (Tollmar & Konrad, 2001). Since many PD approaches put low requirements on users' ability and beforehand knowledge, they have been extended and increasingly adopted in designing with marginalized groups such as older people. Although it is hard to find a fixed methodological description, most PD methods are often characterized as a multi-phase process that includes three key stages (Kaulio & Matti, 1998; Vink et al., 2008): the early phases (exploration, idea generation, etc.), the middle phases (concept refinement, detailed design, etc.) and the later phases (user trial, assessment, finalization, etc.). Theoretically, the end-users are expected to be involved throughout the whole process. However, many PD studies and practices have long been criticized for extensively dealing with the early phases while putting less emphasis on the later stages, especially the refining process (Tollmar & Konrad, 2001). Most research only slightly mentioned the refinement from a holistic perspective. It is reasonable because general participants can actively engage in the early-phase PD activities and contribute their ideas clearly, so the refinement is usually treated as an effortless transition from ideation to evaluation. However, we believe the refining process would be much more important when designing interactive systems with older adults. First of all, the early-phase PD techniques that are available for older people are limited. Haigh (1993)



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described the design challenges caused by the aging process of vision, hearing, hand function and mental aspects. Many PD techniques that used to be effective to generate concepts could be difficult for many older people such as sketching, drama and paper modelling. Secondly, many interactive systems to be designed are unfamiliar to older users, so the design subjects in the early phases are usually difficult for them to understand or propose clear ideas. Therefore, the contributions of the early phases would be much less than collaborating with younger participants. In most cases, designers need to collect older participants' related demands and interpret them into system specifications. It is not a smooth process because these proposals are usually ambiguous or even in conflict with each other. Designers need to screen them and make assumptions to develop preliminary concepts. However, the process of interpretation and screening is mainly based on designers' own cognitive and physical ability (Wilkinson, Christopher, & Antonella, 2014), which might lead to a deviation from older users' real needs. Therefore, the refining process is very important to maintain the consistency between designers and older users in the PD process of interactive systems. Moreover, it would be much easier and efficient for older participants to criticize existing proposals than imagining a future design. However, few PD studies focused on how to effectively refine the early-phase design with older people. Related knowledge about the methods and techniques are also limited. Through a case study, this paper describes the refining process of an interactive system designed for nursing home residents to support their independence and social interaction. We explored to adopt a model proposed by Frens, et al. (2003) as a general principle to collect and analyse the data from the perspectives of function, form and interaction. We also explored to use some potential PD techniques to involve older users in the refinement. The findings of this study can demonstrate the effectiveness of the selected PD approach and techniques. They also provide new insights into some key features of interactive systems that are valued by older users.

## Related work

There have been many studies in the area of participatory design involving older people, most of which were described as case studies. Šabanović et al. (2015) presented a project to develop socially assistive robots with the elderly diagnosed with depression. They found that older adults were willing and have the ability to engage in PD process, but conventional hands-on participation might be a challenge. Wilkinson et al. (2014) explored how to apply PD approaches in the process of commercial product development through designing an intelligent mobility aid and wheelchair. They addressed the importance of including elderly users during the early discussions to facilitate new concept generation. Veldhoven et al. (2008) focused on designing acceptable assisted living services for the elderly and presented a design vision by illustrating three cases. They summarized three main barriers for elderly users to use new technology as complexity and learnability, lack of perceived benefit, compatibility issues. Seale et al. (2008) explored the use of the focus-group method to help older adults identify their mobility-related problems and put forward new ideas. They found that the participants were able to propose existing and new solutions, but the composition and process of the methodology should be further developed by validating the choice of tools. Kanis et al. (2011) conducted a preliminary study to design ambient assisted living systems for monitoring the daily activities of elderly residents, which proved that traditional use-centred design methods could hardly help older adults to visualize ambient assisted living scenarios. Regarding specific techniques, organizing group design activities such as future workshops and brainstorms were common solutions. Besides, video demonstration was frequently used to quickly provide a concrete vision for older people via showing existing solutions and illustrating future scenarios (Šabanović et al., 2015; Iacono et al., 2014). It can also provoke creative responses and critical discussions (Raijmakers et al., 2006; Lindsay et al., 2012). Some studies also found that hands-on techniques, though some of which were challenging for older adults, were more successful than verbal explanations or demonstrations. Conventional hands-on techniques include sketching, card sorting, collage, paper prototyping, etc. Some studies also explored novel techniques by providing live demos and creating interactive simulated scenarios to actively engage the participants (Kanis et al., 2011). These studies, as mentioned above, mainly focused on elaborating the early phase to generate initial insights and concepts.

As mentioned above, limited studies mentioned how to involve older people in the refinement of preliminary design. Even fewer described it in detail. Prototyping was reported as one of the most common techniques in this phase, especially sketching and paper prototyping (Vanden et al., 2006; Muller & Michael, 1992; Massimi et al., 2007). Demirbilek and Demirkan (2004) conducted a series of research to involve elderly end users in housing design and proposed the USAP (Usability, Safety, Attractiveness Participatory) design model with 5 phases. The second phase is defined as concept refinement in which elderly users are invited to criticize, correct and modify the sketches of the early-phase design. But there were also studies reported that the

seniors had trouble to draw or engage in paper prototyping activities (Vanden et al., 2006). Besides, digital mock-ups were often used to refine interactive products and systems. Ellis, et al. (2000) described their refining work with older users to increase the usability of an existing website. They used the cooperative prototyping method to engage the participant in a circle of page viewing, discussion and comments, reformatting, and further viewing by using a HTML editor and browser. Massimi (2006) and Botero (2013) translated paper designs of an interactive memory aid into digital ones with PowerPoint for the adjustment of elderly users. Different from the early phase, the adjustments were conducted in individual sessions for in-depth feedbacks. Hands-on activities were also proved to be effective to refine the interactive systems for older people. Stappers et al. (2009) presented preliminary ideas to the participants in the form of storyboards, play-acting, and low-profile prototypes to encourage spontaneous suggestions.

By looking at the prior work, we found that some PD methods that are effective to generate preliminary concepts also have potential to be applied in the refining process. However, given the different emphases between the two stages, there is still a need to further explore and develop proper techniques and methods to co-refine interactive systems with older people.

## **The preliminary design**

This paper aims to explore how to collaborate with older users in the refinement of interactive systems through a case study. The preliminary design was from an ongoing project aiming to involve older users in the design process of an interactive system in public spaces of nursing homes. The purpose of the system was to support residents' self-entertainment and promote their social interaction by digitally augmenting residents' newspaper-reading experience. In the early phase, we collaborated with eight residents and developed a preliminary design and a prototype. As shown in Figure 1, the system comprises multiple units installed on different tables in the public space of nursing homes. Each unit consists of newspapers with special marks (coloured circles), a tangible tool and a nearby digital display. The marks indicate the interactive areas on the newspapers. These areas are specially enhanced by modern technologies for printed matter recognition. By placing the tangible tool on the marks, residents could get access to corresponding digital content from the screen. The digital contents are real-time images or videos searched from related websites. The digital interface is very simple. It directly displays digital videos or images with brief descriptions in digital texts. When no one uses the system, the screens would display nothing to avoid disturbing. As shown in the storyboard, the envisioned system was designed not only to support individual entertainment ('After 01' in Figure 1) but also to encourage communication and enhance mutual understanding ('After 02' in Figure 1). Although most features were designed based on participants' reflections in the early phase, the preliminary system was constructed with many assumptions and indefinite features that need to be confirmed or challenged in the refining phase.

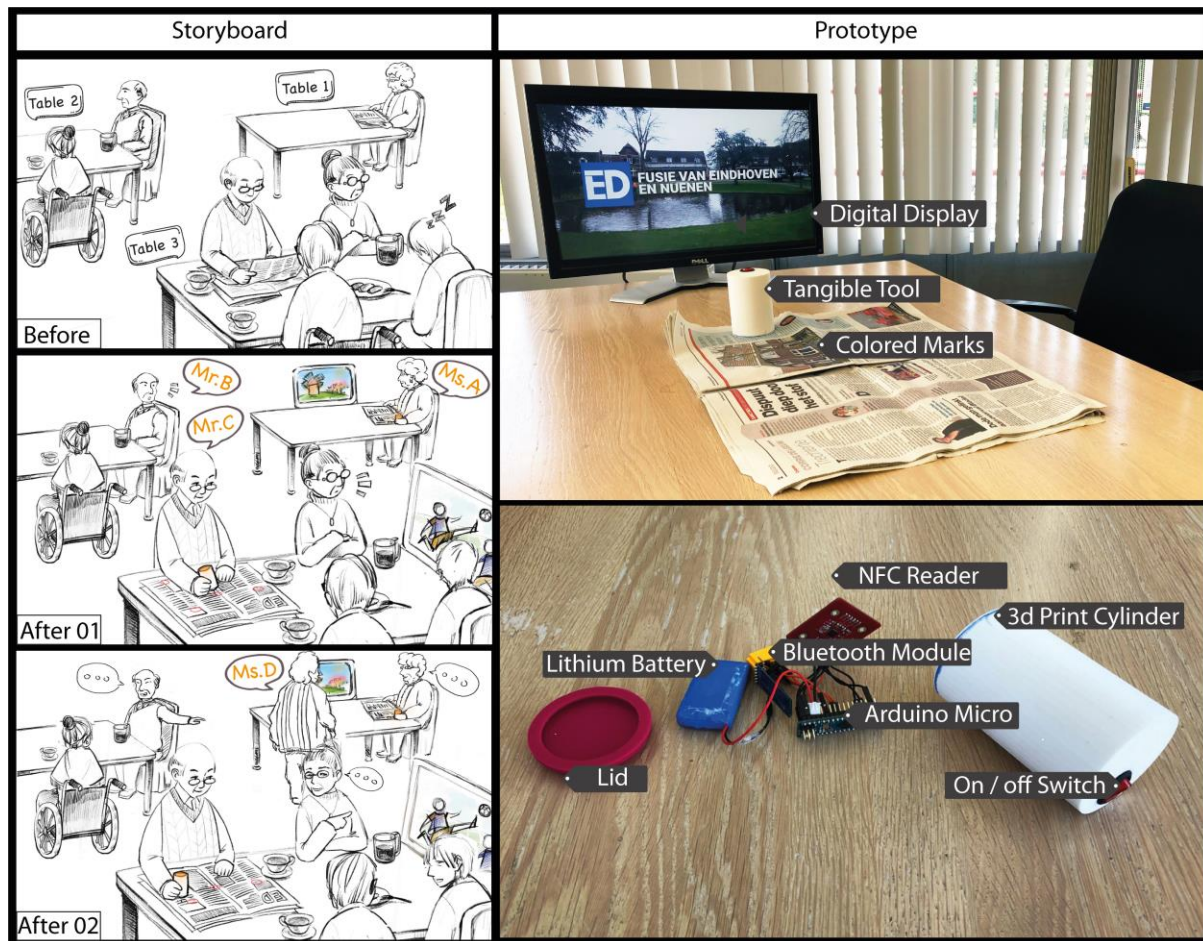


Figure 1: The preliminary design is presented as a functional prototype and a storyboard (the first scenario depicts the current situation in care homes. The last two scenarios illustrate the situations after the system is applied.)

## Method

We used the combination of potential PD techniques and social research methods suggested by Pilemalm (2007). The PD techniques include critical discussions on video demonstrations, storytelling, hands-on experience, collaborative prototyping and sketching. The social research methods include semi-structured interviews and observations. Given the difficulties for many older participants to understand and propose suggestions on system specifications from technological perspectives, we used the model proposed by Frens, et al. (2003) as a general principle to guide the design of interview questions, data collection and analysis. This model defines the interactive products through its form, interaction and function, and has also been used to design interactive systems that are pragmatic, attractive and easy to use (Frens et al., 2009; Hengeveld, 2011). For a better understanding, we converted this model into three questions from older users' perspective: "What should the system be able to do?" "What should the system be like?" and "How would I use the system?" According to the model, these questions could not only correspond to different system specifications, but also inherently relate to each other. The data collected included audio-recordings of the interviews, the sketches and the photos taken during each session. The data were transcribed and analysed using thematic analysis techniques, and the findings can guide the refinement of the preliminary design from the three dimensions of the model.

### Settings & Participants

This study was conducted in the canteen of a nursing home in Eindhoven. It belongs to a national caring organization that has set up 22 similar nursing homes distributed in this city. The canteen is the main public area where most residents would like to stay when they go out of their private rooms. We firstly acquired permission from the managers, and then the residents were randomly invited individually in the canteen.

Given many participants' reading or writing difficulties, consent was given orally before each session. Five residents agreed to participate. Table 1 gives an overview of their basic information. Reading Frequency refers to their frequency of reading newspapers in public spaces in the nursing home. All of them had the basic hand function to eat independently, but only P5 could walk independently.

Table 1: the basic information of the participants (reading frequency: frequency of reading newspapers in public spaces. Sometimes: 3-4 times a week; rarely: 1-2 times a week.)

Participant	Gender	Age	Length of Residence	News Source	Reading Frequency
P1	F	82	9 years	TV, newspapers	Always
P2	F	92	11 years	TV	Never
P3	M	65	1.5 years	TV, newspapers	Always
P4	F	70	2 years	TV, newspapers, smart phones	Rarely
P5	M	84	5 years	TV, newspaper	Sometimes

## Procedure



Figure 2: the materials used in this case study

### 1. Introduction (5 minutes)

We started each session with a brief verbal introduction to inform the participants that we hope they could help us to further develop and refine our preliminary design of an interactive system that could present related digital information when they were reading newspapers in public spaces. They were encouraged to express any comments, suggestions and questions at any time.

### 2. Demonstrations of related existing solutions (10 minutes)

After the short introduction, we showed the participants six videos of some existing technologies or systems to augment paper interfaces and ask their opinions during each demonstration. The purpose was to enhance their understanding of such systems and give the participants a wider vision of current solutions to avoid restricting their minds within our own design. The six videos presented three kinds of solutions that were

already available on the market but designed for other contexts. Table 2 gives an overview of the solutions from the three aspects mentioned above. After showing all the videos, the participants were asked to compare them, choose the solution they like or dislike, and then describe the reasons. During this, we presented six cards that represent each video to help them recall.




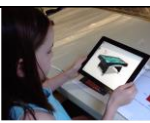
### 3. Demonstration and experience of the preliminary design (15 minutes)



In this stage, we presented the preliminary design by showing the participants a 1-minute animation converted from the sketched storyboard (Figure 1). The video demonstrated the different scenarios before and after the design applied. We explained the details and asked their opinions simultaneously. After this, we offered the participants the functional prototype to experience for 10 minutes and provide further feedback. We prepared four pieces of digital content related to the printed content from a local newspaper according to the residents' preferences reflected from the early phase. They were a piece of entertainment news, a current event that took place in their neighborhood, real-time weather information and an image of crossword puzzles.

### 4. Collaborative refinement (30 minutes)

In the final step, the participants were asked: "if you could change anything about the design, what and how would you like to change?" Then, they were encouraged to describe their ideas from function, form and interaction. The designers would help to quickly embody their proposals by sketching. In addition, we prepared three boxes of design references to facilitate their refinement on physical interfaces (Figure 2). The first box contains some daily objects that are often used on paper including a stapler, a magnifier, a stamp, a glue tape roller, a marker and a glue stick. The second box contains some physical electronic interfaces such as a mouse, a remote controller, a small gamepad with a joystick, a pen-like scanner and a gun-like scanner. In the third box, we prepared some electronic components such as some buttons, dials, joysticks in different forms and sizes that can be added to other devices. The participants could select their preferred forms, describe functions they liked to add and show the designer how they would use them. Regarding digital interface and interaction of the system, we used a media player and a live-programming environment (VVVV in this case) that is characterized by real-time rendering and simulation to quickly visualize the participants' proposals on the screen. In this step, the participants and the designers interactively engaged in a cycle of discussion, revising and previewing.

Table 2: the demonstrated existing solutions

Solution	Form	Function	Interaction	
			With physical interface	With digital interface
Interactive tabletop with projection		Recognize pages by codes, track paper position, project interactive animations on the page and table	Flip the pages, move the papers	Touch and drag projected elements
Interactive tabletop with multi-touch table		Recognize cards by code, track card position, display interactive information around cards on the screen	Put the cards on the screen, move the cards	Touch and drag digital elements on the screen
Augmented Reality book with PC and camera		Recognize pages by the camera above, track paper position, display digital effects above the page on the screen	Put the book under the camera, flip pages, move the book	None
Augmented Reality book with tablet		Recognize printed images with the embedded camera, track image position, display interactive animations above the image on the screen	Hold the device, point it at the page, flip papers, move the book	Touch and drag digital elements on the screen

Pen-like handheld scanner		Recognize printed texts, display interactive information on the screen	Hold the scanner, slide it on the paper, press the button	Touch digital buttons on the screen
Gun-like handheld scanner		Recognize printed codes, display interactive information on the screen	Hold the scanner, point it at the code, press the button	Select functions with the mouse, input information with the keyboard

## Findings

### *What should the system be able to do?*

In Step 2, the participants' function-related feedbacks were very limited. The videos of the existing solutions were more likely to trigger their comments about form and interaction because it was much more direct and vivid to understand. Even though we kept explaining during each demonstration, it still seemed to be difficult for the participants to understand what these applications could actually do because they were designed for the younger generations and other contexts. *"I am too old for this. I can't learn this."* P2 said. Their reflections were mainly about different ways to recognize printed content. When watching the videos of the augmented reality books, P5 said people living here were not familiar with computers and smart phones, but it might have future because the dynamic digital contents would attract more people and could save the time of reading. He also said: *"However, people here would not like the cameras pointed at their tables. They would feel their privacy (has) been violated."* P4 liked the solution of handheld scanners and said it reminded her of the barcode scanner from the supermarkets. *"People here can use this to select the articles they like and project them on the screen."*

In Step 3, the participants could propose more ideas on content selection especially after they experienced the prototype. Local news was their common interest, which was consistent with the insights from the early phase. They also had some personal interests that could represent the preferences of similar groups. P1 liked puzzles and she thought the system was helpful for her to solve puzzles together with her friends. P2 addressed the importance of real-time content because many people here liked to read and talk about sports news. P3 thought the design was suitable to be used in small groups, and people could choose their preferred subjects. P4 preferred entertainment news because sometimes there were live performances in this canteen. Many People liked it, but they need to pay for them. P4 also suggested that the system could be used not only on newspapers, but also on magazines, photos, flyers of advertisements and even postcards. *"I have a sister living abroad. She sometimes sent me postcards. Maybe I can see her with this!"* P4 said. P5 said the preliminary design was much easier for him to understand than the videos of other solutions. *"Of course, it relates to personal preferences. Some people like reading newspapers. Some people don't."* He said, *"But I think such thing is important to provide different things for people here to spend their time. Their life is too structured. No future, no challenges. They don't know how to spend their days and the next days."*

In Step 4, the collaborative explorations could trigger the participants to explore what else the system could do besides the very basic functions of the preliminary design. They tended to compare it with the devices that they were familiar with such as televisions and radios. The result showed that all of them wanted to control the volume of digital content. P1 said the canteen was too noisy to hear the videos sometimes. *"I cannot hear it unless I sit close to the screen."* She said. P2 emphasized the importance of sound due to her poor sight. She said it was also very important when using the design in groups. *"The volume needs to be loud if the group is watching it, but it may disturb others if it is too loud."* P4 also expressed her need to adjust the sound personally. She suggested the system could connect to some personal hearing devices so that everyone could set their own volume. P3 and P5 hoped they could control the volume with very low efforts. *"I lost one leg last year. I don't want to walk to the screen and bent over to control the sound if I can do it sitting here."* P3 said. The participants also proposed other potential functions to meet their various needs. P1 and P4 were inspired by the remote control and thought it would be nice if they could pause the video. P1 thought the pause function would trigger people to discuss. P4 though the pause could let her take a break if there was too much



digital information. Besides, P1 also wanted to switch the images displayed because she was curious about all the details. P4 asked if she could zoom in and zoom out the images. P5 suggested that partly rewind would be useful because people would easily miss the interesting part due to their sensory impairments and unstable environmental conditions. However, although we encouraged them to propose as many ideas as they could, all the participants repeatedly reminded us not to add too many functions. "*You must keep it simple. Just basic functions or people here will not use it.*" P2 said.

### *What should the system be like?*

In Step 2, the participants' form-related comments were very general and similar to what P4 said: "*It is beautiful! I like it.*" But when we asked how they would feel if we applied these solutions in this area, their attitudes changed. All of them held the view that the videos looked very nice, but people here do not like things look technical here. "*They look too futuristic. People may get curious, but most of them always keep a distance from the innovations.*" P5 said. Most of their critical comments focused on physical interfaces. All of them thought the devices in the videos were too complicated, including P4 who could use smart phones. P1 thought the interactive tabletops could be useful when the caregivers host activities, which could develop their brains, but it would not be suitable to use independently. P1 and P4 reflected that the screens of smart phones were too small to watch. Tablets were much better, but they were too heavy to hold. Comparing with interactive tabletops and augmented reality books, the handheld scanners were easier for them to understand because they had seen them before. However, they did not like the technical appearance. Besides, they were not friendly to older adults. P3 and P5 said that it was difficult for many people here to keep holding devices. Besides, P5 said he did not like the barcodes on the paper, which looks too abstract. "*I don't like it and don't trust it.*" He directly said. P2 said she could speak for most residents because she has lived here for a long time. She emphasized that people here fear unfamiliar things. They would not use or share it if it looked too technical.

In Step 3, the animated storyboard and our simultaneous explanations provided them a general understanding of the design. They all agreed that the canteen was the ideal location to install it because this was the most popular space in this nursing home. P1 suggested the information should be displayed on bigger screens than the laptop we used. P2, P3 and P4 liked the idea of distributed units because they used to share one big display in the whole space when there were some activities. But many people could not watch or hear it very clearly, and different people had different interests. These complaints also reflected in the early phase, which further confirmed our design decisions. P4 also suggested that these displays could be folded under the table when not being used. Most of their feedbacks still focused on physical interfaces. Although we asked them about digital interfaces, most of them only wanted to watch images or videos from the display. They hoped to keep digital information as simple as possible. When experiencing the prototype, all of the participants except P3 had difficulties to find the marks on the newspaper when they were holding the tangible tool. But they could quickly understand and use independently when we pointed them out. They suggested that the marks should be clearer and more obvious. P5 said: "*Maybe a different colour. Maybe a different shape.*" Regarding the tangible tool, most participants were basically satisfied with its current form, especially its size and weight. Some participants also propose their opinions for improvement. P1 said the tool looked too much like a coffee cup, which would easily lead to residents' confusion. Besides, the size should not be too small, otherwise people would not notice it or feel difficult to find it. P2 hoped it could be more attractive because the current form was too ordinary.

In Step 4, we encouraged the participants to propose specific solutions to refine the current physical and digital form based on their requirements in previous steps. However, it seemed they had little enthusiasm on the digital aspects. All their feedbacks still focused on keeping them as simple as possible or use their familiar interface like televisions. P1 suggested there could be some simple instructions on the screen to guide people to use it. Regarding the physical aspects, it also seemed difficult and stressful for them to describe their own solutions than criticizing videos or the preliminary design. The reference objects turned out to be very helpful to facilitate the process of the collaborative refinement of the physical interface. After trying the objects, they selected their favourite form. As shown in Figure 3, P4 thought the tangible tool could be like a pen while the other four participants selected stamp as an ideal shape. P4 made the choice because she was attracted by the video in Step 2. She thought the shape was very comfortable and easy for her to use. Besides, if the system were installed on many tables, it would be convenient to carry it to other places. However, P2 and P5 hold a different view that there were usually normal pens on the tables, which would make people mix them up and feel confused. P2 also expressed her concerns about security: "*The pen was too small to be found on the table,*

*and people will easily take it away.*" P3 remarked that many people could not properly use pens due to shaking hands. P1 was satisfied with the shape and size of the stamp. She thought it was important to freely move it around like playing chess. In addition, it was easy to draw residents' attention because they had never seen stamps on the tables before. P2 thought the shape of the stamp could motivate people to place the tool on papers. P3 and P5 also liked the shape because it was effortless to pick up and drop down than other objects. Furthermore, P1 and P5 thought the stamp looked much nicer because the most tools related to paper were for work or study. *"It is strange to use these because people here do not study or work anymore."* P5 said. He also pointed out that no residents would prefer assistive tools like the magnifier that might make them feel stigmatized. None of the participants proposed material-related requirements unless we asked. Most of them preferred plastic tools than wooden ones because the plastic was easier to clean if it would be used by many people. P2 and P5 also thought using wood was too old-fashioned.

### *How would I use the system?*

In Step 2, the participants' interaction-related comments were very similar to each other. All of them claimed that touching or dragging on digital screens was too complicated for them. P1 said: *"My granddaughter taught me many times, but I still cannot use it (tablet)."* The tangible scanners were much easier for them to accept and understand. The interaction with the pen-like scanner was more preferable because holding the gun-like scanner in the air was very difficult for many older people, not to mention they needed to point the scanner at a certain area on the paper.

In Step 3, all the participants could quickly understand the basic interaction of the system from the storyboard animation. After quick instruction, they all could use the prototype independently although some of them have difficulties to find the marks. They agreed that the interaction was friendly for older people because it was effortless and required much less accuracy than the scanners in Step 2. However, when asked to develop more interactions that could integrate the functions and forms that they proposed previously, none of them could propose solutions by themselves.

In Step 4, given the participants' difficulties to design interactions, we had to play a more leading role in this part by proposing more possibilities and visualizing their ideas by sketching. We found the participants relied on the objects in the boxes very much for inspiration and reference. As shown in Figure 3, adding big buttons were the most common solution for the functions like "on-off", "play-pause" and "switch images". Most of them preferred to put the buttons near the handles so that they could easily press them when holding the tool. But P5 thought it would cause many maloperations when picking up and moving the tool around, so he chose to put the button at the bottom. As for the linear functions such as controlling the volume and rewind, P1 and P3 were inspired by the mouse wheel and proposed to adjust the volume by scrolling a gear embedded in the handle. P5 also wanted to add a wheel at the side of the pedestal of the stamp to rewind the videos. P4 suggested adding a special button. People could press its two ends to turn up / down the volume. P2 was inspired by her experience of using old radios. She thought it would be nice to rotate the handle like a knob. Besides sketching, we also simulated the digital feedbacks with fast programming tools (VVVV in this case) and media players to create more concrete scenarios for the participants. P5 gave up adding the rewind function after he watched the simulated effects. *"It is too sensitive. The images are always changing. I guess people may not like this."* He said.

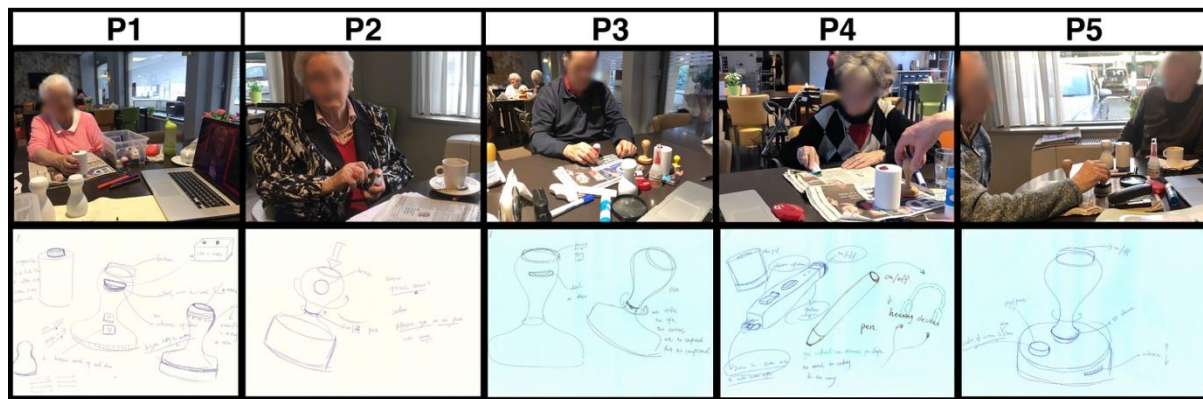


Figure 3: All the participants tend to refine the system through its physical features.

## Discussion

Our findings demonstrated that the participants were willing and had the ability to collaborate with designers in the refinement of interactive systems. The three perspectives were not only easy to be accepted by older participants but also useful to be a general guidance for the designers.

Overall, this study showed the importance of the selection of the site. Robins (1999) proposed two approaches: *“Bring the designers to the workplace and bring the workers to the design room.”* Although design room has the advantage of easier access to equipment and technical experts, we believe participatory activities with older people should take place where the system will be applied because the real-life settings can reduce their efforts of imagination and take the environmental factors into account. Furthermore, researchers indicated that older people were more vulnerable to their surroundings (Fowles, 2000; Carstensen et al., 1986), so it is important to create a free and comfortable atmosphere given their physical inconveniences. In addition, although this study could not prove individual activities were better than group activities, we agree with Neustaedter (2006) and Sanders’ (2010) studies indicating that individual sessions are more appropriate to design completely new systems and work better in detailing stages. It mainly because the refinement requires older participants’ in-depth involvement rather than collecting parallel ideas, which is hard to be ensured through group sessions. Our prior work also revealed the problem that older people with better health and stronger personalities would easily be dominant in conversations and influence other group members. If it has to involve multiple participants simultaneously, we suggest involving more designers and experts to support each participant. In addition, we found it is very important for the designers to keep paying attention to the participants’ energy consumption. The duration of each step should be more flexible according to participants’ different physical situations, which could also show the superiority of individual sessions.

This study also provides detailed implications of the methods for collaborative refinement with older people. Although the video demonstrations of existing solutions have been frequently used in the early-phase PD activities, we believe it would easily create preconceived impressions that might constrain older participants’ creativity due to their limited understanding of novel technologies. This study demonstrated that showing existing solutions was more appropriate in collaborative refinement with older adults. We found that the videos were able to broaden participants’ minds and provoke their critical discussions. The key was to make simultaneous explanations and ask open questions during the demonstrations because it was very difficult for them to remember the details even though we prepared cards to help them recall. Besides, we learned that it was important to control the length and number of videos. Designers should select the most representative solutions and keep each video short. We presented 6 videos in this case, which seemed to be beyond some participants’ ability to process the new information. They appeared to be uncomfortable when watching the last few videos, which certainly affected their contributions in this step. From the data we collected, we found the videos were more likely to trigger participants’ comments on the form and interaction than the function of the systems. The reasons could be that they were unfamiliar with the technologies or the contexts, and some functions could not be directly shown through videos even though we explained. The animated storyboard was very useful to help the participants quickly understand the usage scenarios of the preliminary design. However, such understanding still seemed to be very superficial. It might be because the storyboard could not fully illustrate some functions and details. It might also be because sketched animations are not as easy to

understand as live-action videos. The hands-on experience of functional prototype proved to be very effective for the participants to fully understand the concept and facilitate them to refine the system. We could tell the obvious differences between the participants' facial, verbal and bodily reactions before and after they experienced the prototype. We also found that using functional prototypes was more likely to trigger participants' ideas on functions. It seemed that such prototypes could effectively reduce the participants' efforts of imagination and increase the fun of creativity. In Step 4, the participants' major efforts were spent on embodying their preferred functions in suitable form and interaction, which was very challenging even for younger people. Although there was no fixed procedure, we found that all participants started with refining physical interfaces because they thought it was the most important and familiar part. The design references turned out to be very useful, even though we had concerns about the side effects to constrain their ideas. To minimize the side effects, we suggested that the selected related design references should be representative and have diverse features. As for refining digital features, the participants showed little interest and confidence. Although sketching has long been a widely accepted technique in participatory design, we found it was not as effective as expected when refining the digital aspects of interactive systems for older people because it is abstract, static and non-interactive. The live-programming platform (VWVW) that we used to simulate some digital feedbacks and effects proved to be helpful for the participants to preview the result. Therefore, we identified the need to develop more related hardware-software toolkits for rapidly visualize concrete, dynamic and interactive design proposals for older adults.

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