The Role of Physical Prototyping in Participatory Design with Older Adults

An Exploration of Form and Materials in the Design of a Robot for Older Adults

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Abstract— **How can older adults actively participate in the design processes of assistive robots designed for their homes? We have organized workshops with a group of older adults who worked actively with materials and physical prototyping to design a fetch robot for the home. We present the basics of the workshop materials, how the workshop was performed, and findings on the role of physical prototyping from the workshops.**

Keywords — robots; human-robot interaction; physical prototyping; older adults; participatory design

I. INTRODUCTION

Assistive technology, such as robots, is designed and implemented to help older, retired people to stay independently at home longer. In the Participatory Design tradition, one of the core values and points of origin is the ideal of democratic design of technological artefacts [1]. In this paper, we delve into how material exploration in physical prototyping workshops may facilitate the participation of older adults [2] in the design process of robots in the context of their homes.

The older adults participating in our workshops were experts on their homes and daily practices, but their expertise and interest regarding design and robot technology varied. We were interested to see if physical prototyping could enable their participation in design.

This work is part of a larger research project called Multimodal Elderly Care Systems (MECS) aimed at using robots and future sensors to help with monitoring events in the home and aid people living longer independently longer. Previous work by the MECS project includes long-term user testing of vacuum cleaner robots in the home of older adults. Some of the participants in our workshops had been part of this study [3] and thus had some experience with robots in the home. The results in terms of the design and material preferences and ideas of our participants will go into a further study in the project and be developed further in prototypes by the MECS research group. In this paper, we will review our workshops in terms of how physical prototyping and material exploration affected the level of participation.

In the next section, we outline related work on facilitation of participation when designing with older adults and robots in the home. In Section III, we describe our method: how we conducted the workshops and how we prepared and presented the samples of shapes and materials that we used. Section IV presents the results from our workshops, and in Section V, we discuss the main findings regarding what we learned from working with older adults through physical prototyping and material explorations before we conclude the paper in Section VI.

II. RELATED WORK

Participants' limited in-depth knowledge of a design project [4] may make it difficult for them to gain an overview of the possibilities in the design domain, and hence challenging to be creative within the design problem. Joshi and Bratteteig [5] suggest that elderly users should be enabled to participate in mutual learning and co-construction activities on their own terms. They describe a successful mutual learning process as the possibility for both groups to extend their creative and imaginative capacity and build on each other's ideas to design concrete artefacts. To participate on their own terms, the participants should be able to express themselves in their own language, without having to adopt the professional terminology of the design team in which they participate [5]. This may include the opportunity to show and do rather than to tell.

To express their tacit knowledge and their everyday lived practice, Brandt et al. stress the importance of being able to make things that give this practice a presence in the world. Telling about one's practice may become "generative also of that which has not yet been experienced" [6]. Physical artefacts have also proved useful in participatory design workshops to trigger unexpected and additional stories from the participants [7]. Participatory prototyping and generative tools have been central in the making activities since the beginning of participatory design [6]. Generative tools are two- and three-dimensional visual components that non-designers can use to express their ideas and dreams for future scenarios of use [6].

Robots designed to aid in the home include domestic robots such as vacuum cleaning robots and lawn mowing robots [8.] Robots have also been suggested as a form of assistive technology that can help care workers by being present in the home of older, retired people when care workers cannot. [9] What can robots do in these situations? Asking the opinion of older adults themselves, one survey found that older adults feel a robot could help in recovering from a fall or retrieving objects that were hard to reach [9]. One attempt to categorize robots targeted at older adults at home found that robots must offer something that makes the people independent and goes beyond being a tablet on wheels [10].

 ISBN: 978-1-61208-686-6

III. METHODOLOGY AND METHODS

A. Co-construction on the participants' terms

The goal of our workshops was to engage older adults in the co-construction of a robot. We wished to gain insight into how older adults would prefer for the robot's appearance and feel in the home, with special attention to the materials it could be constructed from, rather than realistic technical implementations.

Due to the varying degree of interest and expertise in robot technology among our participants, one of our main aims in the workshops was to explore ways to enable an exchange of ideas and expertise between the participants and the designers through telling and making. We designed a material exploration workshop featuring a variety of traditional materials to encourage the participation and co-construction on the participants' terms, visualizing some possibilities in the design domain and enabling creativity.

B. Pilot workshop: A purpose for the robot

We conducted a pilot workshop with one participant. This workshop took place in the home of the participant. After the pilot workshop, we adjusted the assignment to be more specific, from constructing *a robot* to constructing a robot with a dedicated purpose, a robot to fetch and carry objects. This emerged as an important theme as the pilot workshop did not proceed as expected. The materials we brought were discussed, but not explored by touching or examining them, and no prototyping was done. The procedure derailed from our plan when Patricia (not her real name) insisted on a more concrete and personally useful purpose than what we originally proposed working on: *a robot*. The derailment started a conversation about what this purpose could be. Patricia was concerned about the value of the robot, as she initially could not imagine any need for a robot in her home. After exploring this issue together, we arrived at the idea of a fetch robot that would prove to be a valuable point of departure for the following workshops.

C. The workshops

Subsequently, we ran two workshops in the library of an independent living facility in Norway with a total of seven participants aged 75 to 92 years old, one of whom participated in both (see Table 1).

TABLE I. OVERVIEW OF PARTICIPANTS

Activity	Participants (P.)			
Pilot August	P. 1 Female Patricia			
WS1 September	P. 1A Female Aimee	P. 1B Female Anca	P. 1C Female Angelica	P. 1D Female Antonella
WS2 September	P. 2A Male Bruno	P. 2B Male Basilio	P. 2C Female Brenna	P. 1D Female Antonella

In preparation for workshop one, we posted flyers in the living facility a few days prior. The posters promoting our workshop were displayed alongside other voluntary activities to avoid misusing the power of recruiting participants through independent living facilities' platforms and staff. Four inhabitants showed up to our first workshop session, and they all participated for the full length of our planned session, and, by their request, for 15 more minutes.

Exactly one week later, we held our second workshop. Two men and two women participated from beginning to end in the second session, one of which had participated in the previous session as well.

D. Workshop Materials

To facilitate material explorations of robot design we brought a set of materials that we believed the participants would be comfortable with, such as traditional materials commonly found in the interior design of homes, see Figure 1. We brought samples, swatch books with colour and texture samples for textiles, textile ribbons, yarn, crocheted and knitted textile samples, veneer from different woods, different self-adhesive foils and films, including aluminium foil, coloured wooden pearls, pipe cleaners, coloured paper, corrugated cardboard, acrylic glass, wooden rods, duct tape, wood glue, ordinary scissors, textile scissors, pens, marker pens/felt tip pens.

One of the things we observed in the pilot workshop was that prototyping a robot with no structural building blocks was troublesome. To minimise crafting tasks that were demanding in fine motor skills and still provide the participants with flexible choices regarding material samples, we prepared building blocks in the form of cardboard and veneer boxes and shapes to represent robot bodies and wheels. See Figure 2. We made the boxes from scratch to standardise the height of the boxes to prepare material samples that could easily be fitted onto the base boxes. We tailored the other material samples like textiles to this measure.

Figure 1. Workshop setup

 ISBN: 978-1-61208-686-6

Figure 2. Top: Basic shapes. Bottom: Laser cut wheels

IV. RESULTS

A. Pilot Workshop

As mentioned in Section III.B, Patricia initially could not imagine any need for a robot in her home. We suggested that she could think about possible needs of her acquaintances. Thinking about a friend with severe tremors in her hands that made it difficult to carry coffee cups across the floor, made Patricia think of a robot that could fetch and carry items. This, in turn, made her think of her own problem with reaching things that were placed on top of tall shelves, especially the problem of dropping things that were difficult to get a hold of. She then suggested that a robot could sweep the floor after accidents with breaking objects, carry things, pour coffee and fetch things from hard to reach shelves.

Patricia wanted the hypothetical robot to be easily cleaned. She also expressed a wish for a robot that would not be camouflaged, but visible, something simple and nice, not requiring extra work, not shiny but matte. She explained that she believed that older adult participants required several repetitions of information, the possibility to try out and experience what they are being told in small steps and increments of information and task instructions to be able to follow and understand the new activity properly.

We decided to bring this concept of a fetch robot to our workshops. Considering concrete and useful purpose appeared to be a necessary step preceding prototyping.

Patricia also felt that it seemed futile for her to try and design a robot. “I can’t imagine that I can make a robot. It’s too utopian. I’m just grateful that someone else is taking care of building robots”

B. Workshops

Aimee shaped a prototype (Figure 3, E) with great attention to function. The robot would be waterproof so that it could wash her back and withstand spills. It would be white to match her furniture. It would nearly have the height of a human, to reach the upper cupboards. It would be round so it could navigate among all the plants in her home. Tasks came to Aimee’s mind during the prototyping. The robot could also stir the sauce, empty the dishwasher, water plants, clean windows, fetch things, vacuum, carry hot and heavy cups of coffee to her chair, open bottles and lids, pour from heavy containers,

During a conversation between Aimee and Anca concerning the purpose and function of the robot, Aimee suggested that her robot could be a dancing partner, and a hairdresser as Anca had expressed a wish for this previously.

Anca embraced the suggestion of a dancing partner and hairdresser robot. She constructed long arms for the robot (Figure 3, F) that would enable it to dance and style hair.

Angelica was inspired by the challenges a friend had told her about. She then recalled that they shared one of these challenges: reaching the upper cupboards. She then fashioned a long grabbing arm with a member of our project group. The prototype (Figure 3, G) was dressed in aluminium foil and acrylic glass to represent stainless steel and glass to match her modern interior design. A green patch of fabric was carefully chosen to match her green curtains but was later disregarded because she wanted the design to be extendable to other households beyond her own. Glass would be installed in one side of the robot because she wished to see the inner workings of the robot as it worked and moved. “I think that will make it more familiar and personal, to see that it starts working when I’m calling on it”, she explained. By the end of the workshop, she was proud of her design, and she told us that the experience had been fun.

Antonella constructed a prototype (Figure 3, K) with a smooth wooden exterior, represented by aluminium foil with a wood image, to represent a wooden surface that would be easy to clean. Antonella modeled edges along the top to represent a board with raised edges to keep things from falling. She also added a textile bag that would keep a pen and her glasses which she often spent time looking for. Antonella expressed satisfaction in having crafted the prototype and asked if she could also join our second workshop, which she did.

 ISBN: 978-1-61208-686-6

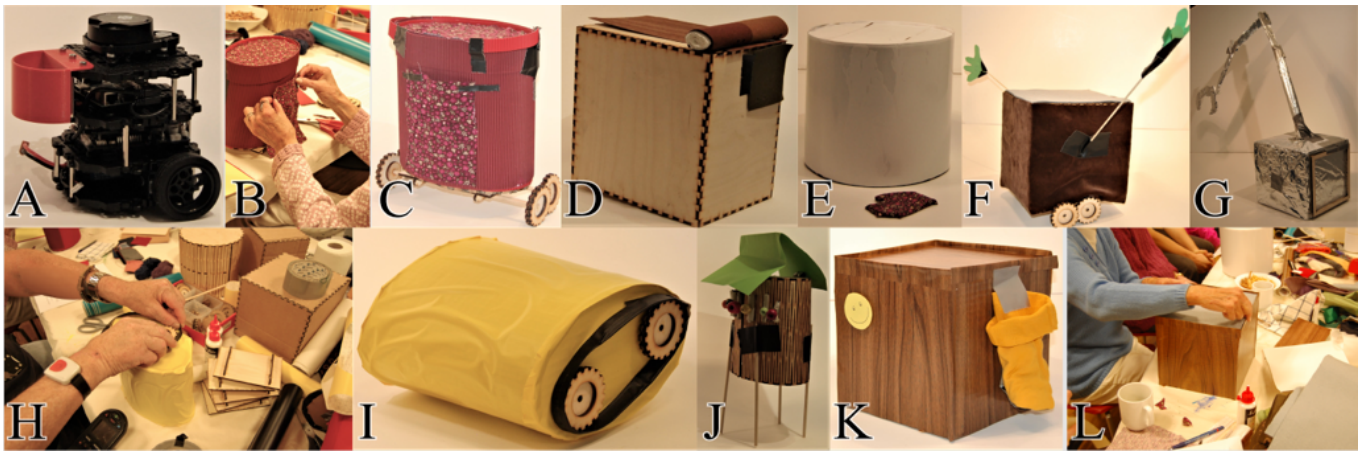

Figure 3. A: "Burger" robot with a 3D printed "backpack" for demonstration, B: Antonella, C: Antonella, D: Brenna, E: Aimee, F: Anca, G: Agelica H: Bruno, I: Bruno, J: Basilio, K: Antonella, L: Antonella

Workshop 2 had the same aim and setup as workshop 1. Here, Bruno made a prototype (Figure 3, H and I) exploring the implementation of robot locomotion. He constructed a detailed mechanical conceptual solution. It included pumping water in a tube, connected to a belt, connected to two cogwheels on the side of the robot. This could shift the center of mass to roll the robot forwards. Shifting the center of mass could also be used by the robot to "stand up", by shifting the weight to one side. This form of movement would also allow the robot to navigate tricky passages and corners in small spaces like the residents' apartments. He decided on plastic as a material, as it is common and durable. He chose the colour yellow to awaken visual interest. He said that he would lose interest if it was too dark. Yellow plastic would also match his surroundings. The yellow foil was to represent yellow plastic in the prototype. He did not wish to solve the implementation of the robot fetching things but expressed that he imagined an excavator-like arm that would stand still relative to the body of the robot.

Brenna said that the elliptical box in our kit was to slim, and too short. She did not want to have to bend to reach the objects the robot would be transporting. She pointed out that the table we were using in our workshop was at an appropriate height (70–75cm). She then chose a rectangular wooden box but expressed dislike for the sharp corners. Therefore, she rounded the corners by covering paper towels in fabric and placing it on top of the prototype (Figure 3, D) to represent rounded edges. She specified that three sides should be covered in dark green, smooth, dust repelling, easy to clean, and easy to keep clean. She commented that the boxes of wood and cardboard we brought with us were too rough, would gather dust, and be difficult to keep clean.

Antonella (who had participated in workshop 1) chose an elliptical base for the prototype (Figure 3, B, and C); she covered the base in red-purple flexible cardboard and assembled wheels for the robot prototype. She would have preferred covering the prototype in a single colour, but we did not bring enough. She further developed her design from workshop 1, and she added a pocket for her glasses and raised edges along the top to prevent things from falling down.

Basilio made a prototype (Figure 3, J) with 4 legs and a pointed top. The top could be folded down to a shelf. The side of the robot would be full of colourful lights, represented by the wooden colourful beads. The robot had a rectangular box as a base. He told us that he was fond of wood and that it was pretty. He told us that he thought it was fun and nice to participate in the workshop, he had not done anything similar previously, but he would want to do it again.

C. *Material explorations*

We noticed that the participants were not moving around the table and remained seated in their original positions through the workshop, and therefore assisted with fetching tools and materials. Some participants used wheelchairs that made moving around the table difficult. Others had pain. Some participants may also have refrained from exploring the piles and boxes of materials out of courtesy.

Some of the more successful material samples to present for the participants in terms of the extent to which the participants engaged with the samples presented to them, were textile swatch books. These consisted of equally cut pieces of textiles bundled together according to qualities and sorted by colour. These presented the participants with a chance to get an overview of the possibilities regarding textile colour and texture without engaging with large sets of materials at once. The same was true for a small collection of knitted and crochet samples, although these were larger and were not easily moved across the table. They were, however, explored by the participants who sat close by to them.

From the initial requirements formulated by the participants during their telling and making, the materials steel, aluminium, and glass was identified as missing in our samples. We did bring aluminium foil, which served as different types of metal in the prototypes, as well as one piece of acrylic glass which was reused as glass in two prototypes.

The design choice to bring ready-made basic forms, to partly prepare samples of material proved to be a good decision. Even if the samples could have been more varied in

 ISBN: 978-1-61208-686-6

terms of sizes and forms, the partially prepared samples that fitted the basic forms helped make less demands on fine motor skills. The participants expressed a clear preference to delegating most of the physical work to us. Each participant was assisted by a researcher in many making tasks, such as cutting. Reducing cutting of fabric to one cut made it possible for some participants to do this themselves.

V. FINDINGS

Considering how older adults may be enabled to participate actively in designing robots for the home through physical prototyping, two themes recurred in our notes from the workshops. Throughout the workshops, it was clear that the participants needed to understand the purpose, context, and function of the robot clearly before being able to generate ideas about how it should look. The participants in the subsequent workshops needed to further explore the stated purpose of the fetch robot and understand it in the context of their own lives before they could start designing the robot. They wished to reconcile the purpose with the needs of their homes and daily lives. The thought of having a robot in the perceived limited space of their apartments made them concerned whether the robot would really be useful to them. The lack of a clear purpose for the robot made it difficult, if not impossible, for the participants to start generating ideas and building a prototype.

Secondly, nearly all the participants questioned their ability to contribute to the design of robots. They felt like they did not have the right technical competence for designing robots, and they told us that it seemed futile to try to contribute new ideas to a group of researchers who were devoting their work to robot design. However, during the workshop, the participants understanding of their environment and experiences resulted in them contributing many ideas of what a robot can do in the home and what it could look like.

Regarding the method of material exploration and participatory prototyping, we found that the criteria for the choice of materials reported by the participants could be categorized broadly in aesthetic and functional concerns. The aesthetic concerns revolved around how the technology would fit into the existing and specific interior decoration of their homes. A related criterion was that the materials match current standards available in trade, that the product would match similar technology and that the materials were readily available in the production line. Several of the participants expressed concern about the functionality of the materials, especially regarding the maintainability of the robot. Most important to many participants was that the robot surface would be easy to keep clean. Some also stressed the need for visibility in terms of materials contrasting the relevant contextual material like the floor.

VI. DISCUSSION

A. The need for a clearly understood context and purpose for the design

Many of our participants started out focusing on the realism of the robot design in terms of both the perceived need for and value of the robots, as well as their own ability to contribute to robot design in a meaningful way. They needed to first understand the purpose and be convinced of the value of the robot before they were willing to engage in the physical exploration. The purpose of the fetch robot seemed to be a purpose most participants could reconcile with their own needs in some way, and fetching items was also a popular suggestion in a survey among older adults [10]. We achieved this in the workshops by having a researcher pair up with each participant to explore the story of the participant. Even if the conversations went across the table between several researchers and participants, the one-to-one working pairs seemed important for the gradual development of a purpose and a context emerging from each participant. The literature emphasizes the role of physical prototyping for enabling stories about practices, understanding and mutual learning [5], [6]. We have experienced that telling and making operate in tandem and that the stories are also necessary to enable physical prototyping.

B. Material explorations

Our main aim with the workshop assignment was to explore the look and feel of a robot in the home, but this proved to be secondary to the purpose and value of the robot for our participants. While we could identify several criteria of choice of materials for the design of a robot in the home, as outlined under findings, these criteria often emerged during the conversation, and less so during the exploration of our material samples. The material samples were more often chosen and examined based on the aesthetic and functional requirements that emerged from the stories of the practice and the homes of the participants.

The design choices we made initially regarding what material samples to bring to the workshop and how to present them might have both limited and opened the design space in terms of new design ideas [1]. The form and positioning of the material samples and tools in relation to the participants may have influenced the extent to which any given material was explored. This suggests that the placement of samples of the available materials and tools should be given thought in the panning of physical prototyping workshops with older adults. It might have been useful to prepare samples of all available materials in small collections that the participants would be able to handle to compare the whole selection in one overview. This would imply preparing multiple equal sets of samples, and then offer to assist them in fetching larger quantities of the chosen materials as the participant reviewed the samples and got ideas for compositions. Tools should be available and placed in a handy distance so that all participants could see all the tools available to them.

C. Creativity and technical feasibility

While the participants started out focused on the realism of the assignment, most were able to use their imagination freely during the prototyping activity. Many of the participants developed their prototypes beyond their initial needs and requirements, such as dancing partner robot and hairdresser robot. In this phase of the design process, we were interested in the look and feel of the robots rather than the technical feasibility of the suggestions, and we encouraged

 ISBN: 978-1-61208-686-6

creativity and fantasy in the prototyping. As we explained in our findings, Section V, several participants questioned the value of their prospective contribution to design ideas for robots. To share their expertise with us, they needed us to share our domain knowledge with them, so that they could understand the problem area and the possibilities they had in generating design ideas for robots in their homes. In the further exploration of this method, it would be interesting to introduce digital and technical components to visualise the technical possibilities and limitations of robot technology to this user group.

VII. CONCLUSION

We have reported from two workshops where we have used participatory prototyping and material explorations to facilitate participation in the design of robots for the home with older adults. Our findings suggest that while it is important to provide a context for the design of a robot at home, the development of the story about the robot in this context and in the daily life of the participants is essential to successful prototyping. A story of a robot placed into their life makes the basis for generating ideas about design. In our workshops, the activity of telling proceeded and informed the making and the material explorations. Due to the low mobility of the participants, the material exploration became more complicated, hence the presentation and forms of the material samples and tools provided in the workshops were important.

ACKNOWLEDGMENT

This work is partly supported by the Research Council of Norway as a part of the Multimodal Elderly Care Systems (MECS) project, under grant agreement 247697. We would like to thank the staff and residents at the living facility and Ingeborg, Jo Herstad, Suhas Govind Joshi, Tone Bratteteig, and Åsmund Dæhlen.

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 ISBN: 978-1-61208-686-6