Developing assistive health robots for older adults: An international four-year project and participatory design case study

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***Abstract*—Participatory design refers to the involvement of future end users in the design, development and evaluation of products. In robotics, participatory design can help to develop acceptable and useful products that solve real-life problems. This four-year international project acts as a case study for participatory design, in which a robot for mood stabilization and cognitive improvement for older adults was developed. Six phases were conducted in collaboration with 119 experts, carers, relatives and older adults. The final dailycare robot featured cognitive stimulation games and reminders to support independent living. The robot was found to be acceptable and useful for health-related purposes, such as reminding when to take medications. The project exemplifies how a participatory approach can be employed in robotics design. It also highlights the importance of testing robots with end users and in their intended contexts.**

I. Introduction

Declining health is a normal part of ageing, but poses challenges for supporting older adults with independent living. Brain training, social engagement and ageing-in-place may help to support cognitive functioning [1-3], while reminders for activities and medications [4,5] may support independence. Assistive technologies can also help, including cognitive stimulation games/activities [6] and robotics.

Robots for older adults include companion robot Paro [7,8] and bingo facilitator Tangy [9]. Assistive robots include Care-O-Bot [10] and Hector [11], which provides reminders, home-based support and also delivers games. While promising, many researchers ask participants to imagine using robots after only seeing them and often only provide a one-off session to test a robot [12]. Older adults also experience underrepresentation or restricted involvement in technology design, as proxies (e.g., caregivers) may instead be involved [13]. This can result in the development of robots that are not entirely acceptable.

Participatory design is an alternate method of designing products. Instead of the innovation, design and development process being restricted to experts (e.g., engineers and roboticists) it includes future users as the experts [14,15]. For older adults in particular, participation may help to avoid deficit framing (e.g., ableism and ageism) and instead promote empowerment [15,16]. Participatory design is also contextually-dependent, by acknowledging that people best experience systems/products when interacting with them in their personal and preferred spaces (e.g., at home or work) [17]. Within robotics, participatory design may help to produce robots that are useful and acceptable. This is crucial for ensuring that older adults can and want to continue to use technologies [13]. Importantly, robots need to be evaluated in the contexts for which they are intended, as this is essential to encountering real-world challenges [18,19].

The objective of this four-year collaboration was to design, develop and test/evaluate a dailycare robot and cognitive stimulation robotic games, for use within older adults' homes. End users were expected to be older adults with mild cognitive impairment (MCI), mild dementia (MD) and various health-related needs (e.g., impaired mobility, vision and hearing).

II. Methods and Key Findings

A participatory approach was used across six phases (Fig. 1) with methods selected iteratively and based on the findings from previous phases [17,20]. The University of Auckland Human Participants Ethics Committee approved the studies.

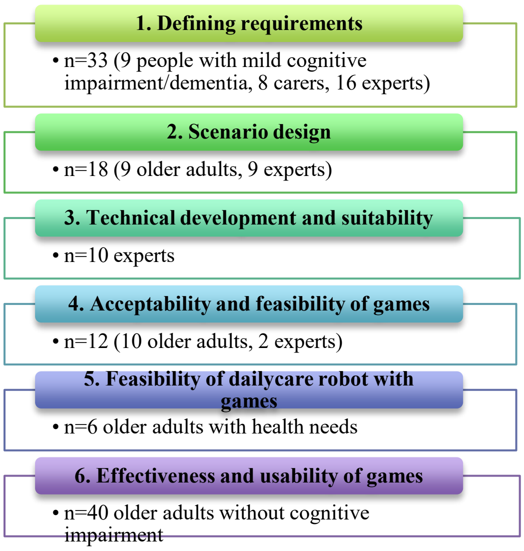

Figure 1. The six robot design phases conducted over four years.

A. Phase 1 (2016): Defining requirements

First, the requirements of this multi-stage project were defined. This required exploring which functions the dailycare robot needed to perform [21]. Nine older adults with MCI/MD, eight carers/relatives and 16 experts in MCI/dementia participated in semi-structured interviews (30-60mins). Data were analyzed thematically. Experts then wrote down how the interactions might play out, while designers drew up cartoon-like strips to help design conversation flow.

Participants wanted the robot to provide reminders for daily living (76%, 25/33). The experts also thought it could help with therapeutic tasks (e.g., tracking health/wellbeing) and delivering physical (100% 16/16), social (81%, 13/16) and cognitively stimulating activities (81%, 13/16).

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B. Phase 2 (2017): Scenario design

To help design the scenarios, the Silbot robot [22] was programmed with the scenarios from phase 1 [23,24]. The scenarios included assistance when waking up, mood and safety checks, medication reminders, therapeutic interventions (exercise and cognitive games) and calling for assistance in emergencies [23,24]. Nine older adults and nine experts in aged care (10+ years experience) watched videos of the Silbot (Fig. 2) and responded to questions about the appropriateness of the scenarios. Two experts were involved in phase 1.

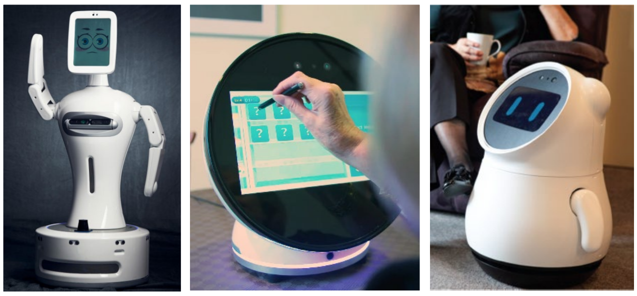

Figure 2. Silbot (left), Bomy 1 (middle) and Bomy (right).

Participants suggested showing text on the robot's screen, having a bigger screen and buttons and speaking slower. They also believed the robot could be a companion. Some questioned the robot's humanness and purpose of the arms, which could be distracting (Table 1). Additional functions could include more reminders and personalized reminders.

TABLE I. SUPPORTING QUOTES FROM THE FINDINGS

Phase	Quotes
2.	The arms are distracting. It would be really important to see what a person with dementia would do with it, what grab them? (Expert)
3.	I think it goes a little too fast for an older person. (Expert)
4.	• I think the content was good. My initial impression was that it was an engaging game. (Expert) • The game was good to keep the brain engaged. (Older adult) • The game is quite repetitive which makes it boring. (Older adult)
5.	There were things like blood pressure [reminders] that were really useful. (Older adult)

C. Phase 3 (2018): Technical development and suitability

The next step was for 10 experts to interact with Silbot autonomously, in order test the robotic system with behavior generation [24]. The behavior engine could be integrated with Robocare's platform to allow it to provide various dailycare services (e.g., medication reminders). It drew on findings from phase 2, as more reminders were added and the speech was slowed and simplified. After interacting with the robot for 30-60 minutes, experts were interviewed, which were analyzed thematically. The experts had existing relationships with the research team, as half had participated in phase 2.

The experts were satisfied with the scenarios, simplicity of the interaction, clear screen, big buttons, voice activation and perceived the robot easy to use. Some wanted the speech to be even slower/louder (Table 1). Again, some thought the arm movements, flashing lights and facial expressions could overload people with MCI. Experts wanted more reminders. It was evident that Silbot may not be the most appropriate robot to use, given its somewhat human-like appearance and arms. This informed the development of a new robot.

D. Phase 4 (2019): Acceptability and feasibility of the games

Findings from earlier phases indicated that cognitive stimulation games could also be delivered on a dailycare robot. We used games that were developed in Korea with neurology experts and had been tested by our research partners, as they were effective in reducing age-related thinning of the cerebral cortex [25]. Stationary robot Bomy 1 delivered six games using a touch screen and Google's text-to-speech service (Fig. 2). Three games also used magnetic blocks.

This phase explored the acceptability and feasibility of the cognitive games [26]. Ten older adults with normal cognition or MCI attended game sessions over five weeks. Consistent with participatory design [17], the sessions were held in retirement villages. Participants responded to a questionnaire at the end of each session about their satisfaction with the games and robot, while observational data were collected through video-recordings of participants. Two experts in aged care also helped with the data collection, by observing participants playing the games and providing feedback.

Experts thought the games were appropriate for people with MCI/MD. Participants also identified benefits, such as engaging their minds and fostering concentration and focus (Table 1). Some issues hindered usability, including issues with the blocks, unclear instructions and speech (language, accent and pronunciation). Some found the games boring (Table 1).

E. Phase 5 (2019-2020): Feasibility of dailycare robot/games

Robocare developed dailycare robot Bomy for the project (Fig. 2). Bomy hosted the system from phase 3 and the games from phase 4. Suggestions for improvement raised during the previous phases were made: the language was simplified and reflected words used in the New Zealand (NZ) culture, button sizes were increased, instructions were made more precise and movements were made quieter and simplified. Bomy's arms did not move and the reminders could be personalized.

The feasibility study explored the usefulness and perceptions of the robot by older adults who had normal cognition, MCI or other health needs [27]. Consistent with participatory design, the robot was used independently by six older adults in their homes for one week. The robot delivered six games and nine personalizable reminders, including waking up, going to bed, medications, playing robot games, going out and visits. Participants were interviewed on their experiences.

Participants were accepting of having the robot in their homes and found it fun, useful and a companion. The personalized health reminders were valued (Table 1). Some suggested that more technical support be provided and that technical improvements be made (e.g., blocks slow to respond).

F. Phase 6 (2019-2020): Effectiveness and usability of games

A multi-site, two-armed, parallel-design randomized controlled trial explored whether using the robot cognitive games for 12 weeks results in cognitive improvement compared to untrained controls. All six games were used, as the issues reported in phase 4 were resolved.

Forty older adults with normal cognition were recruited (20 from South Korea and 20 in NZ). Additional interviews with those in the intervention group in NZ (n=10) aimed to test the feasibility of using the robot. Participants in the control group continued their daily routines for 12 weeks, whilst those in the intervention group played the robot games twice a week for 12 weeks. Depression [28], anxiety [29] and cognition were measured at baseline and follow-up.

Quantitative data are still being analyzed. Qualitative results showed that the games could be a valuable addition to existing cognitive stimulation activities [30]. The robot was easy to use and participants observed improvements in their own cognition, including memory. Issues identified in the earlier version were not reported, thus had been resolved.

III. Discussion

This project highlights the importance of stakeholder involvement and exemplifies how a participatory design approach might be employed. Ongoing participation by older adults, retirement villages and experts (some of whom participated in multiple phases) was important to meeting user requirements (as defined by stakeholders). This contests the traditional design process, which requires engineers/developers to imagine health needs [12,31] or consists of searching for a problem for a product to solve, after creation [24].

Contextual considerations were important in our approach, whereby the phases were conducted in retirement villages or in homes of older adults. This is crucial to participatory design as it is most effective when products are designed and evaluated in the environments where end users spend their time [17]. It also helps to overcome previous limitations in robotic design and testing, where interaction is limited [12].

The participatory approach also promoted collective ownership and avoided deficit-framing [15,16] as the dailycare robot was presented as a tool that could be used to support older adults, without compromising their independence and autonomy. This was tested through unrestricted and unsupervised use in phase 5, highlighting that the dailycare robot was useful for supporting health and wellbeing through reminders and cognitive stimulation games.

IV. Conclusion

Overall, by centralizing the perspectives of 119 older adults, experts and relatives, the design of the robot was user-friendly and the functions were useful. Future design work of health robots could include other direct and indirect users, such as health providers and other family members (e.g., children).

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