Taylor & Francis
Taylor & Francis Group

Disability and Rehabilitation: Assistive Technology

ISSN: 1748-3107 (Print) 1748-3115 (Online) Journal homepage: https://www.tandfonline.com/loi/iidt20

Caregiver perspectives on a smart home-based socially assistive robot for individuals with Alzheimer's disease and related dementia

Sajay Arthanat, Momotaz Begum, Tianyi Gu, Dain P. LaRoche, Dongpeng Xu & Naiqian Zhang

To cite this article: Sajay Arthanat, Momotaz Begum, Tianyi Gu, Dain P. LaRoche, Dongpeng Xu & Naiqian Zhang (2020): Caregiver perspectives on a smart home-based socially assistive robot for individuals with Alzheimer's disease and related dementia, Disability and Rehabilitation: Assistive Technology, DOI: 10.1080/17483107.2020.1753831

To link to this article: https://doi.org/10.1080/17483107.2020.1753831

Published online: 17 Apr 2020.

DISABILITY AND REHABILITATION: ASSISTIVE TECHNOLOGY
https://doi.org/10.1080/17483107.2020.1753831

ARTICLE

Caregiver perspectives on a smart home-based socially assistive robot for individuals with Alzheimer's disease and related dementia

Sajay Arthanat[a], Momotaz Begum[b], Tianyi Gu[b], Dain P. LaRoche[c], Dongpeng Xu[b] and Naiqian Zhang[b]

[a]Department of Occupational Therapy, University of New Hampshire, Durham, NC, USA; [b]Department of Computer Science, University of New Hampshire, Durham, NC, USA; [c]Department of Kinesiology, University of New Hampshire, Durham, NC, USA

ABSTRACT

Purpose: Innovative assistive technology can address aging-in-place and caregiving needs of individuals with Alzheimer's disease and related dementia (ADRD). The purpose of this study was to beta-test a novel socially assistive robot (SAR) with a cohort of ADRD caregivers and gather their perspectives on its potential integration in the home context.

Methods: The SAR involved a programmable research robot linked with commercially available Internet of things sensors to receive and respond to care recipient's behaviour. Eight caregivers observed the SAR perform two care protocols concerning the care recipient's daily routine and home safety, and then participated in a focus group and phone interview. The researchers used grounded theory and the Unified Theory of Acceptance and Use of Technology as a framework to gather and analyse the data.

Results: The caregivers' asserted the potential of the SAR to relieve care burden and envisioned it as a next-generation technology for caregivers. Adoption of the SAR, as an identified theme, was subject to the SAR's navigability, care recipient engagement, adaptability, humanoid features, and interface design. In contrast, barriers leading to potential rejection were technological complexity, system failure, exasperation of burden, and failure to address digital divide.

Conclusion: From a broader outlook, success of SARs as a home-health technology for ADRD is reliant on the timing of their integration, commercial viability, funding provisions, and their bonding with the care recipient. Long-term research in the home settings is required to verify the usability and impact of SARs in mediating aging-in-place of individuals with ADRD.

ARTICLE HISTORY
Received 17 January 2020
Revised 5 April 2020
Accepted 6 April 2020

KEYWORDS
Socially assistive robot; assistive robotics; Alzheimer's disease; dementia; smart home; internet of things; aging-in-place

➤ IMPLICATIONS FOR REHABILITATION

- Socially assistive robots (SARs), an emerging domain of assistive technology, are projected to have a crucial role in supporting aging-in-place of individuals with Alzheimer's disease and related dementia (ADRD).
- Caregivers of individuals with ADRD who observed and interacted with a novel SAR asserted their acceptance of the technology as well as its scope and feasibility for the upcoming generation of caregivers.
- Navigability, care recipient engagement, adaptability, humanoid features, and interface design were stated to be critical factors for SAR's acceptance by caregiver and care recipient dyads.
- In contrast, technological complexity, system failure, exasperation of burden, and failure to address digital divide are detrimental to SAR's adoption.
- Several design and implementation requirements must be considered towards the full-scale development and deployment of the SARs in the home context.

Introduction

Alzheimer's disease and related dementia (ADRD) is one of the leading high incidence neurocognitive conditions in the United States with nearly 5.9 million individuals (65 and older) currently living with the disease [1]. While aging-in-place with the disorder is beneficial in terms of preserving the individual's memory, orientation and spatial awareness, the process imposes tremendous levels of care burden on family members. The burden proportionally increases as the individual's disease advances with demands on monitoring daily routines, home safety, and overall health [2]. Currently, 15 million family members provide 18 billion hours of informal care annually for individuals with ADRD [1]. With the prevalence of AD expected to double by 2050, the impending care burden, and staggering nursing home costs [1,3], innovative assistive technology is critically needed to promote aging-in-place for individuals with ADRD and to support their informal caregivers [4].

Socially assistive robots (SARs) are projected to be a promising and emerging domain of technology for care of individuals with ADRD. SARs are autonomous, mobile, and interactive machines designed for non-contact interactions to augment or support a person's social needs and cognition. Such support may be provided as step-by-step prompting, encouragement to perform tasks, reminder of events, safety monitoring, and seeking emergency assistance [5–7]. SARs have gained broad popularity in healthcare- to support intervention for children with autism [8–10] and cerebral palsy [11], provide motivational support

CONTACT Sajay Arthanat sajay.arthanat@unh.edu Occupational Therapy, University of New Hampshire, Durham, NC, USA

during rehabilitation [12], and offer companionship to elderly and those with cognitive impairments [13]. While results from pilot studies indicate SARs benefits for aging-in-place in terms of helping the elderly stay engaged and more independent [14,15], there is growing evidence for its use with the ADRD population.

A recent observational study confirms that robots provide sensory enrichment, positive social engagement, and entertainment for individuals with ADRD [16]. Huschilt and Clune [6] urged health professionals to consider SARs as a viable way to assist persons with ADRD maintain their independence, enhance their quality of life, and provide relief to overburdened caregivers. Studies that evaluated interactions of individuals with ADRD and SARs found that the technology reduced their agitation and depression while improving their mood through companionship and engagement in cognitive activities [5,14]. In a randomised controlled study with a SAR named Paro, researchers found that the robot significantly improved facial expressions and social interactions of the participants in the intervention group compared to those that received standard care by staff members [17]. Another study using a quasi-experimental within-subject design in a psychogeriatric setting found that implementation of SARs using individualised care intervention had a positive effect on mood and goal attainment [13]. From the caregiver's standpoint, SARs have the potential to decrease stress by reducing the demands on care recipient supervision [18]. Caregivers have reported that having SARs to provide reminders, emergency assistance, safety monitoring and social support are essential features in a SAR [19,20]. While evidence on the potential of SARs for the ADRD population is emerging, more preliminary studies are needed to bolster their full-scale development and implementation in the community.

Currently, much of the research conducted on SARs are focussed on social companionship in long-term care and community settings [15,17]. To that end, examining the acceptance of the technology by caregivers and care recipients is a crucial precursor prior to its commercial development and implementation in the home context. Specifically, in addition to integrating essential functions and features, an in-depth examination of potential caregiving benefits, economic viability, and challenges to implementation of the technology at homes of caregiver-care recipient dyads is crucial. The purpose of this study was to beta-test and gather perspectives on a novel SAR prototype with ADRD caregivers. The SAR was developed using a programmable research robot. The novelty of the robot was its capability to be programmed with commercially available smart home Internet of things (IoT) devices to receive and convey information to the care recipient and caregiver. The specific focus of the study was to examine its feasibility with regards to facilitating and inhibiting conditions leading to its adoption at home. By integrating findings with previous research on other types of SARs, we propose a conceptual model underscoring the real-world requirements for implementing the technology at home for ADRD care.

Methods

The study protocol involved demonstration of the SAR to caregivers of individuals with ADRD in a simulated home setting followed by a focus group and a follow-up phone interview.

The SAR was set up in an occupational therapy teaching lab designed as a studio apartment comprising a full kitchen, a bathroom and a bed side. An adjacent conference room was used for the focus group discussion.

Participants

Participants for the study were recruited from the principal investigator's research network and through caregiver support programmes in the region. We included caregivers of individuals with diagnosed ADRD in the study. They needed to have ongoing or past experience as the primary caregiver in the family. The care recipient may be in any stage of the disease residing or not residing with the caregiver. Individuals aged 18 or below were excluded. The study protocol was reviewed and approved by the Institutional Review Board of the University of New Hampshire in the United States and all participants signed an informed consent form.

Caregivers who met the inclusion criteria were invited to participate through convenience sampling. Eight caregivers, two men and six women, were recruited. Four of the female caregivers cared for their husbands, and the other two were caregivers for their mother and father respectively. The two male caregivers cared for their wives. Five caregivers lived with their care recipients and three resided separately. Five of them were retired, two worked part-time and one was employed full time. The average age of the care recipients was 78.5 (ranging from 59 to 98). Seven of them were reported to have Alzheimer's disease and one had Lewy body dementia.

The average time since diagnosis for the care recipients was 6 years. Based on the last medical visit, the caregivers reported that two care recipients were in the early stages of their disease, three were in the middle stages and the remaining three were in their late stages.

Socially assistive robot

We used a pioneer 3DX (Figure 1 (L)), a programmable research robot, as the SAR platform. A Dell gaming laptop was attached

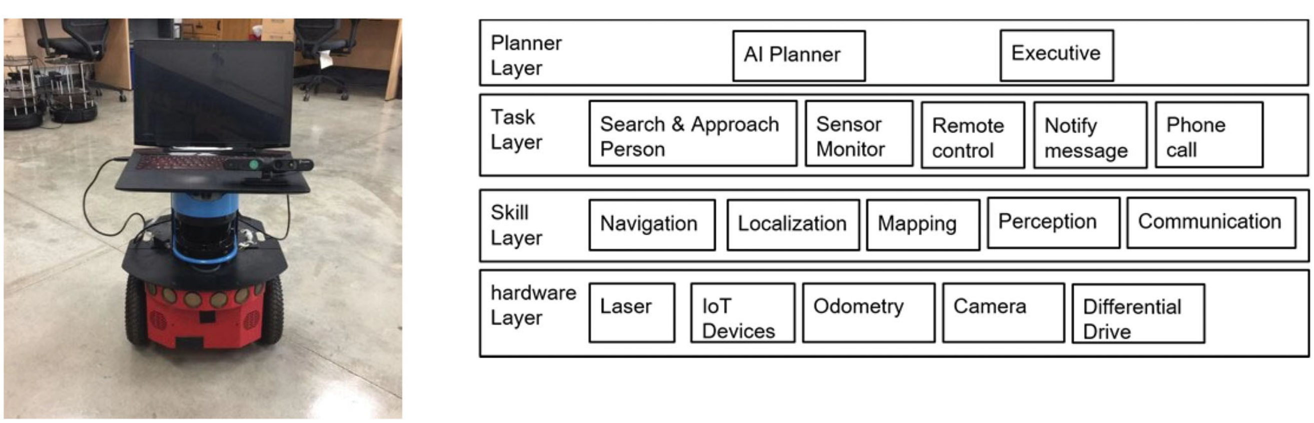

Figure 1. Pioneer 3DX platform as a SAR for dementia-care.

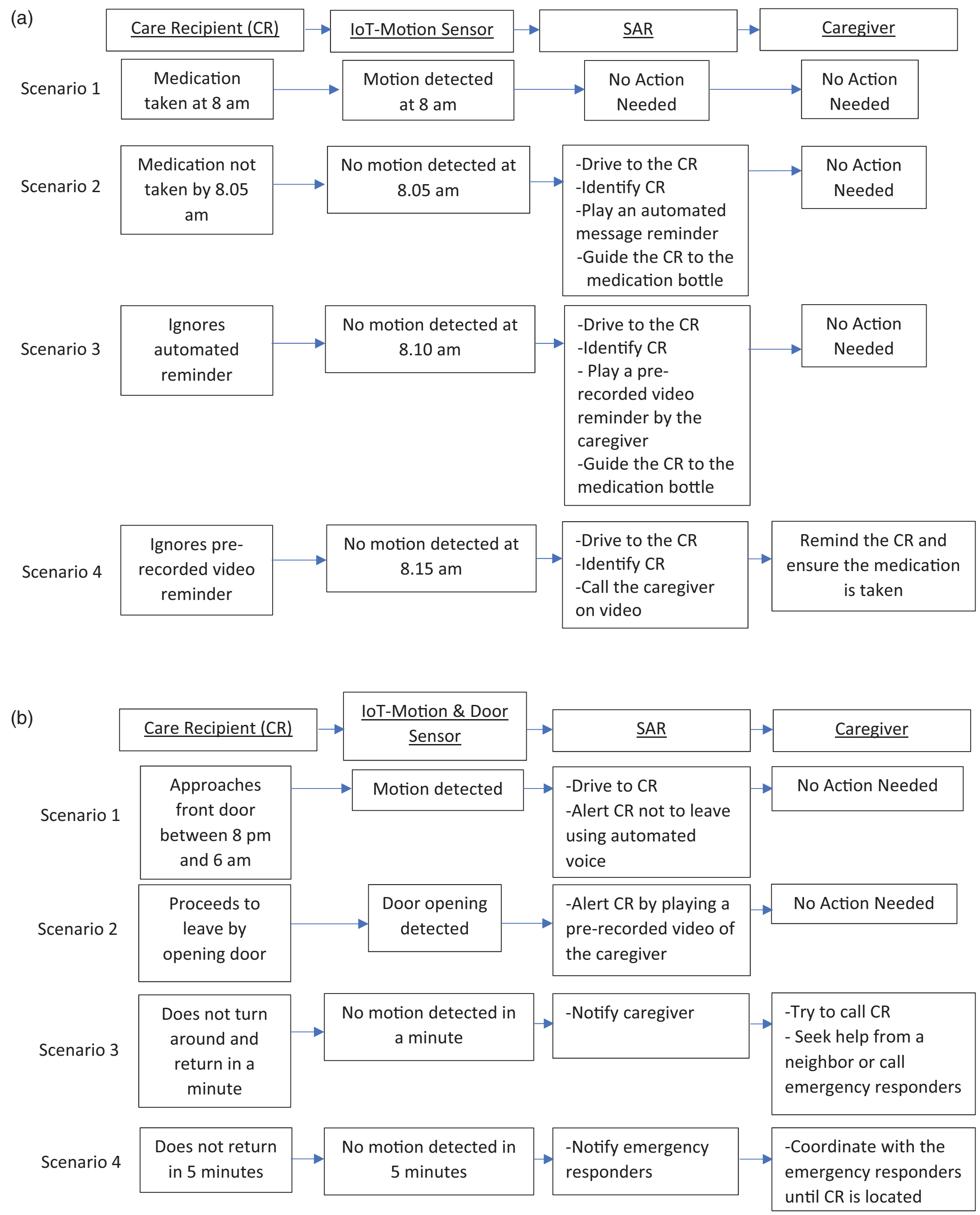

Figure 2. Flowchart of the SAR Protocols. (a) Reminder- Medication intake at 8 am. (b) Alerting- Prevent wandering at night.

with robot for all high-end computations. Figure 1 (R) shows the Robot Operating System (ROS)-based software framework we designed to deliver the two protocols. We organised all the software components in a layered system architecture. There were four layers in this framework: *Planner Layer* was the command centre of the robot. It connected with and synchronised all sensor information, processed and executed the plan; *Task Layer* implemented all tasks that the robot can accomplish. These tasks were stored in an artificially intelligent (AI) planner to generate the plan. The tasks are more complex control logic that make use of the robot's basic functions implemented in the "Skill layer;" *Skill Layer* hosted all basic algorithms for navigation, mapping, localisation, communication and perception including face and speech recognition; *Hardware Layer* hosted all hardware used by the robot.

IoT devices and security

The IoT component of this project was implemented using the Samsung SmartThings ecosystem, which provided a comprehensive framework for smart home and IoT devices. The innovative aspect of the robot was its ability to link with these commercially available IoT sensors to detect events in the environment related to the two caregiving protocols. We implemented the project workflow and integrated it with SmartThings Cloud, IoT devices, and a local server. More specifically, the IoT component included three types of IoT devices: (1) Motion sensors to detect the care recipient's motion; (2) Multipurpose door sensor to detect the door's status to alert the caregiver in case the care recipient wandered out; (3) A smart hub for connections between sensors and *SmartThings* cloud. SmartThings cloud is a remote cloud service used as a data transition centre. The cloud platform was used to collect status information from every sensor and send status information to our local server. Our *Local Server* processed various requests from the robot and responded accordingly. It communicated with SmartThings cloud to collect information about the IoT devices. All IoT devices were based on Zigbee communication protocol and were programmable by using the Groovy language through developer workspace.

SAR protocols

Our prototype performed two caregiving protocols that involved reminding and alerting the care recipient (as displayed in the Figure 2(a,b)). As seen in the flowchart, each protocol was demonstrated with multiple scenarios one possibly leading to another. Each scenario was driven by the behaviour of care recipient which was monitored by the IoT sensors and then conveyed to the SAR. The SAR's role in the initial scenarios was to assist the care recipient autonomously, however it notified and sought the help of the caregiver as needed to fulfil the goal. Two graduate students role played the protocols as caregiver and care recipient.

For the reminder protocol, we demonstrated the robot assisting the care recipient to take a medicine at a specific time. When the motion sensor, placed adjacent to the medication box by the kitchen counter was not activated at that time, the robot sought out the care recipient and reminded her that it is time to take that specific medicine. When the care recipient did not follow through within five minutes, the robot played a pre-recorded video of the caregiver on its display screen giving the same reminder. If the care recipient still did not respond, the robot notified the caregiver and invited her on the screen in real time to offer the reminder.

For the alerting protocol, we role played the care recipient attempting to wander out of the house at night. The motion sensor placed by the living room door triggered the robot to drive to the care recipient and alerted her that it was midnight and not to leave the house. When the individual did not respond, the robot played a pre-recorded audio of the caregiver alerting her. In the event the individual opened the door and stepped out at night, the door sensor triggered the SAR to notify the caregiver. If the caregiver was unreachable and the care recipient failed to return within a minute (as recorded by the motion sensor), the robot was programmed to call emergency responders using a recorded voice message with information on the care recipient.

Study design

This study was conducted using a grounded theory qualitative approach. The application of grounded theory using a constant comparison of data is ideal to conceptualise novel and complex interventions [21]. The Unified Theory of Acceptance and Use of Technology (UTAUT) served as the framework to investigate caregivers' perspectives on the SAR technology. The UTAUT, adapted from the Technology Acceptance Model [22], facilitates our understanding of why someone intents to use a technology or information system [23]. The framework posits that the following constructs are precursors to technology adoption; Effort expectancy (ease of use), Performance expectancy (perceived benefit of use), Facilitating conditions (organizational and technological supports for users), Technology anxiety (apprehension about use), Social influence (positive opinions of others about technology), Perceived trust (security of data), and Perceived cost [23,24]. The UTAUT constructs, in the model's initial evaluation, accounted for 70% of the variance with consumer technology adoption [23]. The model has since been extensively used to examine consumer adoption of technology in various sectors and contexts with 174 cited studies by 2015 [25]. In a relevant study on smart homes and IoTs for the elderly, the model explained 81.4% of the consumer's behavioural intention to adopt the technology [24].

Data collection

The principal investigator moderated the focus group assisted by the co-investigators. Five graduate students assisted the session through note taking. They were seated next to the participants and provided one-on-one instructions on the protocol and discussion questionnaires. Following introductions, the discussion began with the caregiver's current knowledge of assistive robotics. The SAR was then demonstrated to the caregivers including the two protocols described above. A discussion agenda along with a handout demonstrating how the robot could be programmed in the future and guiding questions for discussion were provided to the participants. The guiding questions were derived from the UTAUT.

Questions on performance expectancy focussed on the perceived benefits and needs with the robot in the context of caregiving. To that end, the caregivers filled out and discussed a checklist indicating their desirable functions and actions that needed to be performed by the SAR. For effort expectancy, questions pertaining to ease of use and challenges were included. Discussion on technology anxiety and trust were addressed by questions on privacy, security and reliability. Under facilitating conditions, we included questions on the set up of the robot in accordance to the physical layout of the home, driveability of the robot, technical support and training needs. Support of the family members towards adoption of the SAR was the focus of discussion under social influence. Finally, the cost expectancy of the SAR was discussed at length in relation to value and affordability. Importantly, the researchers introduced multiple probing questions for each of these guiding questions.

The focus group including the demonstration lasted for 3-h with a refreshment break in between. Within a week from the focus group, a 30-min follow-up phone interview was conducted with the caregivers. The purpose of this interview was to provide them the opportunity to reiterate and clarify their focus group responses as well as to probe for any additional thoughts following the session. The focus group and interview conversation were audio recorded for transcription.

Data analysis

Content analysis of the focus group and interview data was conducted using grounded theory constant comparative method. Grounded theory analytical guidelines involve flexibility based on the nature and purpose of the study [26]. The analytical process was employed in an earlier study by the principal investigator [27]. The principal investigator and five graduate students independently analysed the data first using line-by-line open coding. Each member of the team used a chart to label the code and compile the corresponding extract and quote from the data. Subsequently, they met four times in two separate working

Figure 3. Top priority SAR functions and caregiving needs.

groups to systematically debrief on the focus group data and each interview. Identified codes were discussed and overlapping codes were consolidated. Axial coding was employed to identify categories and subsequent themes. Each member of the investigative team identified a set of themes from the categories in writing and the themes that maximally encompassed the categories were chosen through triangulation. For the eight interviews, categories from each preceding interview were compared to the next to verify saturation. As the analysis progressed, newly identified categories were tagged for comparison with the next interview data. Frequency analysis of responses from the SAR function checklist was also conducted. As member check, the caregivers were sent a list of the analysed categories with a summary on each. They were requested to verify the categories and add any missing perspectives that they felt strongly needed to be included in the study findings.

Results

To begin, none of the caregivers had experience with the concept of SAR for caregiving. Some, however, stated that they were aware of robotics and artificial intelligence in household technologies such as smart vacuum cleaners, thermostats, and voice activated assistants. One caregiver remarked about animal embodied robots (*"dogs and parrots")* meant to interact with the care recipient. A few others spoke of their experience with home automation technology and IoTs such as cameras and smart watches to monitor and track the care recipient. On the whole, the participants agreed that they relied on their younger generation family members to assist them with complex information communication technology needs. The results from the core focus group discussion following demonstration of the SAR and the follow up phone interview are outlined below in accordance to the UTAUT constructs.

Performance expectancy

The top caregiving needs as prioritised by the focus group members to be fulfilled by the SAR are depicted in Figure 3. The needs were verified along seven potential functional capabilities of the SAR worded as the following verbs or actions: Drive (i.e., places the SAR should have access in the house); Call/Notify (i.e., the people the SAR should contact); Assist (i.e., the activities the SAR can assist through step-by-step instructions); Alert (i.e., the instances the SAR should alert designated people); Find (i.e., locate any misplaced items); and Engage (i.e., encouraging the care recipient to engage in an activity). During discussion, the actions or tasks that were most prioritised by the caregivers pertained to *alerting* when safety was compromised- *"This time of the year and in the spring there's various changes in weather, so maybe reminders you know 'it's cold now, but it's going to be really warm this afternoon, you know, take a jacket or don't take a jacket;" "Wish the robot can sense and alert if there is an abnormal heart rate or drop in blood pressure;" "Sound a siren or alarm first if the person tries to leave* *the house."* The SAR *needing to remind* the care recipient to complete various tasks were also high on the list- "*My husband has 13 different pills and if you could get a medication dispenser to program with the robot;" Prioritise things (to remind) for health, water and food;" "Maybe something with exercise I think that would be useful if there were some sort of an exercise program that he could take part in."*

During discussion the caregivers also expressed keen interest in other functional capabilities of the SAR with specific references to *engaging the care recipient*. They pointed out the notion that the SAR should not be a passive device that only gets activated or triggered by the care recipient's behaviour. Instead, they stressed that the SAR stimulate and engage the individual by displaying photos of family and friends and encouraging various meaningful leisure pursuits- *"Maybe it (the SAR) could play a game. Cards, trivia questions; "Staying connected with their old life. They get very bored, they get lonely. Something interactive. That's vital;""I think loneliness is the big issue, so I had suggested if it could interact like an interactive game with the person, or you know, have a short conversation maybe play some music." Navigability* was also identified as a category when the caregivers discussed driving capability of the SAR. Although it was clear to the caregivers that the SAR could not traverse stairs, they were concerned about day-to-day barriers and random obstacles in its way – *Make sure that it can drive around chairs and plants; there will be clutter; "Have you tried it with a pet? Is a dog going to chase it?;" it needs to drive on thick carpeting; what if carpets are not nailed down."*

While the caregivers saw the multimodal potential of the SAR to assist with caregiving, there was no clear consensus among them on the right *time window* to introduce the technology. Some believed the SAR was not useful during the early stages of their care recipient's ADRD, while others stressed that introducing it at the earliest is most beneficial. There was however clarity that the technology will have limited scope during the very late or very severe stage of the disease. Some of the key comments within this category were-"*Her early memory is kind of fading. But that's where she's at so I don't see having a robot on hand would be a benefit to myself or her:" "I would say earlier the better since it does the same thing at the same time everyday, that consistency is important for the person; "My dad only needs reminders right now so it will work, not sure of later stages as it can't help with mobility and walking*"

Effort expectancy

Caregivers at the outset acknowledged the prevailing *digital divide* as a barrier and the need for basic domain knowledge as a precursor to adopting the SAR: *Learn how to use a computer-otherwise you are at a severe disadvantage; It took me 8 months to learn a smart phone.* When it came to usability requirements, the caregivers shared the notion of a "*central headquarter*", a user-friendly interface, from which to link the robot to all the environmental sensors and to programme its daily behaviour*: Synthesise everything from one headquarter; I don't have to run around for small details … .Can all the programming be done from my laptop or tablet?* On that note, the caregivers desired *adaptability* of the SAR with the progressive nature of ADRD and changes to their caregiving role. To achieve this, it was suggested that the robot be made available as a complete package with multiple sensors and programming capability by the caregiver and family- *Could you programme it for certain people for certain situations – there are some who need very little attention and some a lot more; Include a Chinese menu of everything that's out in the market that could be packaged with the robot- so here are 15 things you can assist someone with for stages x, y or z.* Another important concern that was brought up with regards to effort was the possibility of *dual burden of care*. Caregivers mentioned that day-to-day operational complexity and technical flaws with the SAR will be counter-intuitive to its integration in their home in that it becomes an additional burden- *I don't have time for extra things that take time if it gets too complicated; Are we going to spend more time playing with it to try and make it run? Then we are caretaking it too."* On that note, all caregivers agreed that the SAR as well as the interface should provide *multimodal feedback* on the operational status and that the system is functioning optimally- *If the robot can tell us there is a problem with it or some bugs that needed to be fixed; if we can go into a database and see what the robot has done throughout the day …*

Technology anxiety

While caregivers did not express concerns explicitly, anxiety surrounding the SAR emerged during conversation on installation, set up, and daily programming. The core categories with the anxiety pertained to *technological complexity* and the possibility of *system failures*. Addressing these anxieties also align with other constructs of the UTAUT constructs including performance expectancy, effort and facilitating conditions. A resonating need throughout the focus group and interviews was the need to have professional installation followed by timely and ongoing technical support- *"I'm confident it will work the same way every time once it is set up right; the only anxiety is if it stops working; if it had a good technical crew, I will have less anxiety;" a designated tech company has to help with set up and support.*

Perceived trust

The study participants did not express any notable concerns with privacy and security of data transmitted to and from the robot. Although this issue cannot be discounted, a unique category relating to caregiver's trust had to do with the *care recipient-SAR bonding* or the lack thereof. While some caregivers viewed the bonding optimistically- *The relationship has to be built from the early stage for comfort and dependability,* others had misgivings about their loved one's reliance on the technology- "*I'm free to go out when I have an aide at home, but I'm not sure if I can leave him (care recipient) with the robot all alone;" I'm confident that it will do what it is supposed to do, but I'm not sure if my husband will follow through."*

Facilitating conditions

The caregivers provided valuable input on factors to help facilitate the integration of the SAR at home. *Personalised training* was identified as a major need- "*If the university could offer a course or a workshop on this for caregivers … ;" demonstrate the technology to my family; someone needs to show me the protocols"*; Another factor to consider with the set up of the SAR was the *home layout* of the care recipient. In addition to the navigability and driving capabilities of the SAR, caregivers mentioned that the structure and design of the home may facilitate or hinder the robot's interaction with the care recipient-"*We live in an old farmhouse, so there is nothing much we can do to create additional space*; *two level home is a concern and the robot will need information from places it can't drive to; make sure there is WIFI connectivity across*

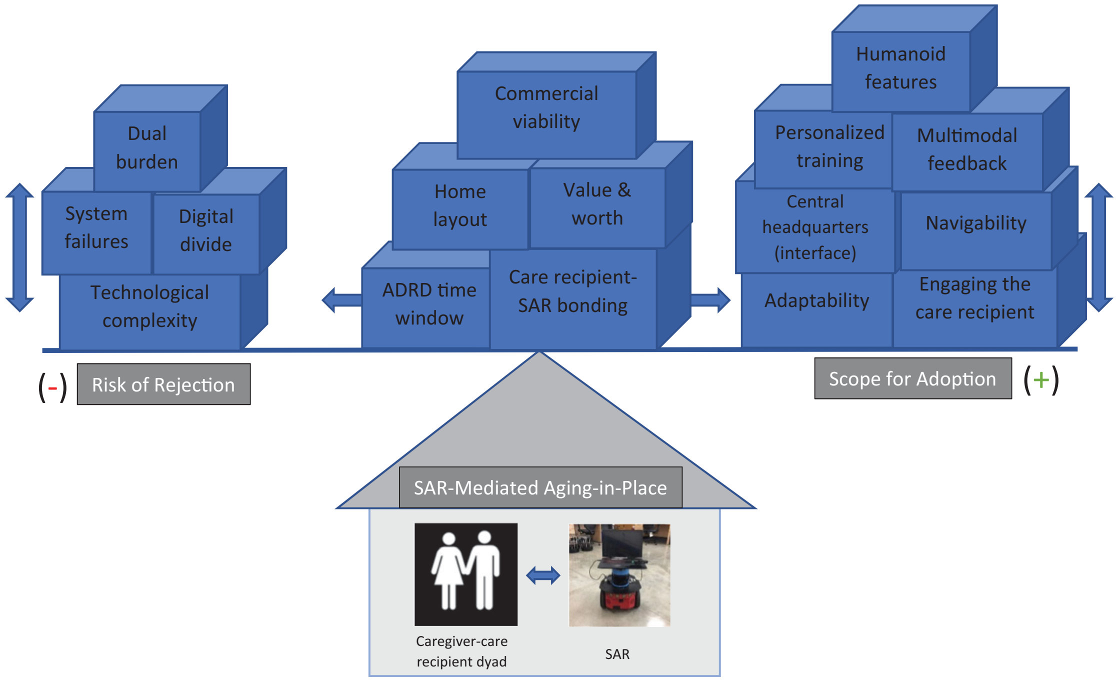

Figure 4. Conceptual model on socially assistive robot adoption by caregiver-care recipient dyads.

the house; my husband spends most of his day downstairs and the robot can drive to him in the living room and kitchen. To facilitate acceptance and bonding, the caregivers recommended the SAR have more *humanoid features* including physical embodiment and natural sounding voice- *"More friendly or familiar face on the screen is needed; I think its important that it is tall enough; Maybe use pre-recorded messages by family members."*

Social influence

The caregivers unanimously felt that their family members will be supportive of having the SAR at home- *"Everyone across generations in my family will be supportive; "I think they would think it's a good idea ... they would be very favourable of having anything that makes things easier for me"* They remarked that involving their significant others in the process of set up and programming will be crucial for sustainable use- *"Involve the grandkids; They are thirty something and grown up with technology."* At the same time, the caregivers acknowledged that the SARs will be most amenable for the *next generation of caregivers* due to the digital divide and the time it takes for diffusion of a full-fledged commercial SAR for ADRD- *"This won't be of much use to us older group, but it will for the next generation coming along; This sort of technology needs to be developed now, so the next generation of caregivers can readily take advantage of it."*

Cost expectancy

The caregivers were inquisitive about the cost of the SAR. As the displayed technology was a prototype, we appraised the *affordability* that most families would be willing to spent for a fully developed SAR with the desired functionalities and features. Most of the caregivers stated initially that a cost of more than $10,000 will be unaffordable not only for them, but also for most families. All caregivers agreed that a cost of $3000–$5000 was reasonable. However, the most significant part of the conversation was not about affordability, but *value and worth* in relation to their formal caregiving expenses and possible relocation costs- *Home care costs $7000 a month- Let's start right there itself; "When I look at the cost over time, five to six thousand is not unreasonable at all;" I'm paying 28$an hour, five days a week, to my aide. It (the SAR) is not going to replace him, but I may be able to cut down on the hours; If you get an extra year or two at home, the cost is paid for.* To alleviate out-of-pocket expense, the caregivers also proposed some important financing options to facilitate *commercial viability* of the SAR including government assistance, and low interest loans- *"Hoping the government kicks in some money ... .;If there is possibility down the road to subsidise this technology."* A key option that interested the group was the possibility of the SAR being leased from a large home health technology provider. Not only was this option considered as affordable, some stressed on it as logistically viable especially after the care recipient's long term care relocation or lifespan- *"If a big company wanted to rent them or lease them out, that would be alright;" If there was a trial period to see if the robot was actually successful, you won't have to put all your money out and then if it didn't work, you just lost $20,000;" "I would think that the ability for it to be used and passed on and used elsewhere and resell it would be important."*

Discussion

The objective of the study was to demonstrate a uniquely developed SAR to ADRD caregivers and gather their perspectives on critical needs and strategies to facilitate its ongoing development and effective implementation at home. Eight family members who have been providing more than six years of informal caregiving on average collectively contributed nearly seven hours of qualitative data. Based on the aforementioned categories, we conceptualised three inter-related themes that dictate the potential of SARs to be an effective tool to support aging-in-place of individuals with ADRD. The conceptual model depicting these themes is presented in Figure 4. Relevant literature on SARs are integrated to compliment these themes.

SAR-mediated aging-in-place

From having observed the SAR, it was clear from the data that the caregivers appreciated the role and potential of the technology to assist their care recipients age-in-place. Conversations regarding expected needs, cost and affordability, and above all, perceived usefulness confirmed their acceptance and motivation to see the technology developed for ADRD caregiving. The technology was not only viewed as a tool for peace of mind or safety, but also as an active companion of the care recipient. Earlier studies have already validated and examined this stated role of the robot in long term care and community settings [5,13,17].

Acceptance of the technology was evident based on its articulated implications for relieving care burden and enhancing autonomy, health, and quality of life. Studies have corroborated that an individual's attitude, positive or negative, towards SARs are shaped by their prior experience with the technology and expectations on what the robot can and cannot do in accordance with human attributes [28–30]. Even though the caregivers had no first-hand experience with SARs prior to this study, they clearly articulated not just the need, but the future trajectory of the technology for the upcoming generation of caregivers. When asked about their concluding thoughts on the SAR, they stated- "*Technology has to play a role. It is not ready to meet the needs now, so I know this is the next big thing coming; I have heard that caregiving takes away about 8 years of your life. We need to get out and have outlets for our stress to prolong our life; Dad hasn't gotten up, hasn't taken medication, why is he not back from the bathroom-these may sound simple, but offloading these small worries from us takes out that day-to-day stress*. These assertions are well supported by similar studies that involved caregivers to test and provide input on prototype SARs. Researchers concluded that engaging the robots in caregiving scenarios could result in decreased frustration, stress, and relationship strain, and increased social interaction [31,32]. However, as depicted in the model above, the potential and future of SAR technology to promote aging-in-place of individuals with ADRD delicately hinges on addressing the facilitators and barriers described as categories in the findings. Two dichotomous themes as outcomes were evident based on how well technology developers, information communication technology providers, home health professionals, and policy makers addressed these facilitators and barriers.

Scope for adoption

From the findings, it was clear that several functions and design features dictated future adoption of SARs among caregiver-care recipient dyads. As reflected by previous research on the social role of SARs [5,13,17], SARs need to be customisable to engage the care recipient through the day to be an effective tool for ADRD. Providing safety, emergency assistance, and basic reminders were viewed as integral functions of the SAR as reported in previous research [18]. As mentioned, we used a programmable research robot to demonstrate the feasibility of creating the SAR by linking it with smart home IoT devices. When developed commercially, the robot should be comprehensively "packaged" with the necessary IoTs to adapt to the progression of the disease and caregiving needs. A central interface or portal that offers easy programmability as well as real-time and summative feedback of the robot's status was stated as a requirement. Recommended driving capabilities sought were designated path, random obstacle avoidance, navigation in tight spaces, and mobility on various floor surfaces. Interestingly, these findings coincide with design recommendations and architectural modifications for robots in the home environment [33]. As far as appeal, the technology needs to be relatable in appearance with a digitised voice or capability for storing and conveying pre-recorded messages. Coincidently, many studies have outlined relevant aesthetic recommendations for SARs including the need for realistic anthropomorphic features, a prominent appearance, and varying naturalistic speech output [34,35]. In fact, in a study of a human-like SAR, a group of older adults who interacted with the robot reported positive attitudes towards its social features and intended applications [19]. Another study on interactions of the care recipients and SARs showed that individuals with ADRD are very likely to ignore the robot in 40% of verbally driven behaviours due to poor speech intelligibility [7]. A critical pre-requisite to adoption was also found to be the need for one-on-one personalised training for set-up, programming and trouble shooting. While these design requirements were categorically evident, there were notable practical complexities that may support or undermine adoption of the SAR.

From an ADRD standpoint, an ideal time window needs to be established for introduction of the SAR at home. Many caregivers conceivably view the SAR as an early intervention technology for ADRD. Integrating the technology into the individual's daily routines and establishing consistency prior to the manifestation of cognitive declines were logical reasons to consider here. On the other hand, to feel inherently motivated based on perceived need, some caregivers may prefer delayed implementation after functional declines and consequent care burden are realised. For the time being, studies have validated that acceptability of the SARs improve when their expected capabilities are in sync with the purpose and context for which they are installed [29].

Caregivers in the study also questioned their care recipient's skills and openness to relate and follow through with the SAR even when the technology works reliably. Researchers argue that end users (i.e., caregivers in this context) need to gradually view the robot as trustworthy provided the technology is robust and autonomous to make decisions [29,36]. Best practices and guidelines to promote compliance and bonding of the care recipient with SAR remains a priority. Value and worthiness of the SAR as perceived by the caregiver-care recipient dyad will be reliant on multiple factors such as their socio-economic status, current caregiving effort and costs. Finally, for the SAR to be economically viable in the long term, several policy-based and commercially driven measures need to be in place to offset the cost of the technology as also noted in a previous study [32]. In particular, caregivers will vastly benefit from reimbursements and subsidies for the technology through public funding systems. Alternately, they also value a large and well-established provider network to possibly lease out the technology, offer a trial period and a sustainable programme to refurbish and transfer the technology to other families.

Risk of rejection

The study also revealed potential pitfalls that may lead to rejection of the SAR. Rejection here may be broadly defined as abandonment (the technology being removed or returned), non-use (the technology being turned off completely), under-used (the technology's functionality being underutilized), or misused (the technology being operated incorrectly or inappropriately). Risk factors to be cognisant are the underlying complexity with the technology compounded by the limited domain knowledge and skills of potential end-users. To this end, prior computer experience, age and gender were found to correlate with and predispose comfort or anxiety with the SAR [29,37]. To accommodate such disparities, the need for personalised training needs to be reiterated here as well. Moreover, frequent failures of the system possibly due to programming error, connectivity issues, and hardware breakdown will prove detrimental to adoption of the technology. Taken together, one or more of these factors may seemingly *tip the scale* for caregivers to reject the technology as discussed through the notion of dual burden. Nonetheless, on a positive note, studies conducted in general with potential end users with cognitive impairments show that with continued direct interactions with SARs, their reluctance decreases while increasing their intention to use the technology [13,29,38].

Limitations

There are limitations to consider in this study. Both sources of data, the focus group and follow-up interviews, were derived from a single cohort of caregivers. Data from a second cohort of caregivers would have been helpful to corroborate the findings. That said, the identified categories did resonate with much of the existing literature on SARs tailored for chronic health conditions as well as ADRD. Participants were recruited through self-selected sampling as opposed to being chosen purposively on specific demographic or caregiving characteristics. Nonetheless, the participants did have adequate diversity in terms of their experience, care recipient's disease stage, relation to the care recipient, and demographics.

Conclusion

The SAR was viewed by caregivers as a promising technology with clearly outlined scope and benefits for individuals with ADRD. However, the eagerness for the technology was also dampened by a cautious optimism that several design and implementation requirements ought to be addressed first. The implication is that while the SARs are foreseen as a next generation technology, the groundwork to develop and commercialise the technology specific to ADRD and aging-in-place must begin now. Research and development efforts should strive to transfer ongoing advancements in mainstream robotics, artificial intelligence, and smart home automation to fulfil the outlined design requirements. From the implementation standpoint, major information communication technology corporations need to take note of the market potential in advanced home health technology for aging and consider SARs in their purview. At the systems level, public programmes need to fund or provide subsidies for advanced home health technology such as SARs as a vital resource for aging-in-place and to minimise premature nursing home relocation and long-term care costs. Findings from this study seem generalisable across many types of SARs that are undergoing development for ADRD care. Future SAR research should focus on examining its implementation in the real world, and most importantly verify its home-based usability and the long-term impact on caregivers.

Acknowledgements

The researchers would like to thank the following graduate occupational therapy students for their engagement and contribution to this research: Ellen Ross, Casey Buckley, Juliana Vendola, Chelsy Moody and Janine Holder.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Funding for the study was provided by a University of New Hampshire Collaborative Research Excellence (CoRE) grant. Initial support was provided by the England Faculty fund at the College of Health and Human Resources at the University of New Hampshire.

References

[1] Alzheimer's Association: Alzheimer's facts and figures [Internet]. Chicago (IL): Alzheimer's Association; c2020. Available from: https://alz.org/alzheimers-dementia/facts-figures

[2] Gallagher D, Ni Mhaolain A, Crosby L, et al. Dependence and caregiver burden in Alzheimer's disease and mild cognitive impairment. Am J Alzheimers Dis Other Demen. 2011;26(2):110–114.

[3] Genworth: cost of care survey 2019 [Internet]. New York (NY): Genworth Financial Inc; c2020. Available from: https://www.genworth.com/aging-and-you/finances/cost-of-care.html

[4] Astell AJ, Bouranis N, Hoey J, et al. Technology and dementia: the future is now. Dement Geriatr Cogn Disord. 2019;47(3):131–139.

[5] Bemelmans R, Gelderblom GJ, Jonker P, et al. Socially assistive robots in elderly care: a systematic review into effects and effectiveness. J Am Med Dir Assoc. 2012;13(2):114–120.e1.

[6] Huschilt J, Clune L. The use of socially assistive robots for dementia care. J Gerontol Nurs. 2012;38(10):15–19.

[7] Rudzicz F, Wang R, Begum M, et al. Speech interaction with personal assistive robots supporting aging at home for individuals with Alzheimer's disease. ACM Trans Access Comput. 2015;7(2):1–22.

[8] Begum M, Serna RW, Yanco HA. Are robots ready to deliver autism interventions? A comprehensive review. Int J of Soc Robotics. 2016;8(2):157–181.

[9] Huijnen C, Lexis M, Jansens R, et al. How to implement robots in interventions for children with autism? A co-creation study involving people with autism, parents and professionals. J Autism Dev Disord. 2017;47(10):3079–3096.

[10] Pennisi P, Tonacci A, Tartarisco G, et al. Autism and social robotics: a systematic review. Autism Res. 2016;9(2):165–183.

[11] Malik NA, Hanapiah FA, Rahman RA, et al. Emergence of socially assistive robotics in rehabilitation for children with cerebral palsy: a review. Int J Adv Rob Syst. 2016;13(3):135.

[12] Johnson MJ, Loureiro RCV, Harwin WS. Collaborative tele-rehabilitation and robot-mediated therapy for stroke rehabilitation at home or clinic. Intel Serv Robotics. 2008;1(2):109–121.

[13] Bemelmans R, Gelderblom GJ, Jonker P, et al. Effectiveness of robot paro in intramural psychogeriatric care: a multicenter quasi-experimental study. J Am Med Dir Assoc. 2015;16(11):946–950.

[14] Broekens J, Heerink M, Rosendal H. Assistive social robots in elderly care: a review. Gerontechnology. 2009;8(2): 94–103.
[15] Kachouie R, Sedighadeli S, Khosla R, et al. Socially assistive robots in elderly care: a mixed-method systematic literature review. Int J Hum-Comput Interact. 2014;30(5):369–393.
[16] Chu MT, Khosla R, Khaksar SM, et al. Service innovation through social robot engagement to improve dementia care quality. Assistive Technol. 2017;29(1):8–18.
[17] Liang A, Piroth I, Robinson H, et al. A pilot randomized trial of a companion robot for people with dementia living in the community. J Am Med Dir Assoc. 2017;18(10):871–878.
[18] Salichs MA, Encinar IP, Salichs E, et al. Study of scenarios and technical requirements of a social assistive robot for Alzheimer's disease patients and their caregivers. Int J of Soc Robotics. 2016;8(1):85–102.
[19] Louie WY, McColl D, Nejat G. Acceptance and attitudes toward a human-like socially assistive robot by older adults. Assistive Technol. 2014;26(3):140–150.
[20] Pino M, Boulay M, Rigaud AS. Acceptance of social assistive robots to support older adults with cognitive impairment and their caregivers. Alzheimers Dement J Alzheimers Assoc. 2013;9(4):P342–P342.
[21] Creswell JW, Poth CN. Qualitative inquiry and research design: choosing among five approaches. Thousand Oaks (CA): Sage publications; 2016.
[22] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 1989; 13(3):319–340.
[23] Venkatesh V, Morris MG, Davis GB, et al. User acceptance of information technology: toward a unified view. MIS Q. 2003; 27(3):425–478.
[24] Pal D, Funilkul S, Charoenkitkarn N, et al. Internet-of-things and smart homes for elderly healthcare: an end user perspective. IEEE Access. 2018;6:10483–10496.
[25] Williams MD, Rana NP, Dwivedi YK. The unified theory of acceptance and use of technology (UTAUT): a literature review. J Enterprise Info Manag. 2015;28(3):443–488.
[26] Glaser BG, Strauss AL. Discovery of grounded theory: strategies for qualitative research. New York (NY): Routledge; 2017.
[27] Arthanat S, Vroman KG, Lysack C, et al. Multi-stakeholder perspectives on information communication technology training for older adults: implications for teaching and learning. Disabil Rehabil Assist Technol. 2019;14(5):453–461.
[28] Takayama L. Perspectives on agency interacting with and through personal robots. In: Zacarias M, Oliveira JV, editors. Human-computer interaction: the agency perspective. Berlin, Heidelberg: Springer; 2012. p. 195–214.
[29] Whelan S, Murphy K, Barrett E, et al. Factors affecting the acceptability of social robots by older adults including people with dementia or cognitive impairment: a literature review. Int J Soc Robotics. 2018;10(5):643–668.
[30] Lehoux P, Grimard D. When robots care: public deliberations on how technology and humans may support independent living for older adults. Soc Sci Med. 2018;211: 330–337.
[31] Begum M, Huq R, Wang R, et al. Collaboration of an assistive robot and older adults with dementia. Gerontechnology. 2015;13(4):405–419.
[32] Wang RH, Sudhama A, Begum M, et al. Robots to assist daily activities: views of older adults with Alzheimer's disease and their caregivers. Int Psychogeriatr. 2017; 29(1): 67–79.
[33] Mitzner TL, Chen TL, Kemp CC, et al. Identifying the potential for robotics to assist older adults in different living environments. Int J Soc Robotics. 2014;6(2):213–227.
[34] Pino M, Boulay M, Jouen F, et al. "Are we ready for robots that care for us?" Attitudes and opinions of older adults toward socially assistive robots. Front Aging Neurosci. 2015;7:141.
[35] Begum M, Wang R, Huq R, et al. Performance of daily activities by older adults with dementia: the role of an assistive robot. In: 2013 IEEE 13th International Conference on Rehabilitation Robotics (ICORR); 2013 Jun 24; Seattle, (WA): IEEE; 2013. p. 1–8.
[36] Young JE, Hawkins R, Sharlin E, et al. Toward acceptable domestic robots: applying insights from social psychology. Int J Soc Robotics. 2009;1(1):95–108.
[37] Heerink M. Exploring the influence of age, gender, education and computer experience on robot acceptance by older adults. Proceedings of the 6th international conference on Human-robot interaction; 2011 Mar 6; Lausanne, Switzerland: ACM. p. 147–148.
[38] Gross HM, Schroeter C, Mueller S, et al. Further progress towards a home robot companion for people with mild cognitive impairment. In: 2012 IEEE International Conference on Systems, Man, and Cybernetics (SMC); 2012 Oct 14; Seoul, Korea: IEEE. p. 637–644.