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# Does the Robot Have a Mind? Mind Perception and Attitudes Towards Robots Predict Use of an Eldercare Robot

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**Abstract** Robots are starting to be developed for aged care populations and some of these have been made into commercial products that have been well received. However, little is known about the psychological factors that promote acceptance or rejection of robots by older people. Finding out more about these psychological determinants of robot uptake and acceptance is the primary focus of the study described in this paper. A healthcare robot feasibility study was conducted in a retirement village. Older people ($n = 25$) were invited to use a prototype robot with healthcare functions over a two week period. Questionnaires were completed before and after the period. It was found that residents who held significantly more positive attitudes towards robots, and perceived robot minds to have less agency (ability to do things) were more likely to use the robot. It was also found that attitudes towards robots improved over time in robot-users. Our results suggest that the cognitions older people hold about robots may influence their decisions to use robots. The study results also validate participants' subjective self-reports of attitudes towards robots and perceptions of robot mind, against the objective measure of robot use. Interventions to foster adaptive cognitions could be developed and applied in the design, deployment and marketing of robots to promote their use and acceptance.

**Keywords** HRI · Older people · Robots · Health · Mind perception · Attitudes · Technology acceptance models

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## 1 Introduction

The proportion of older persons compared to the proportion of younger persons in the global population is currently increasing [1]. These trends are particularly notable in the more developed regions, and especially in Japan, Germany, and Italy. There have been predictions of shortages of workers to care for this growing ageing population [2, 3]. It has been proposed that healthcare robots may be able to supplement support for older people, their families and caregivers [4–6]. Many research organisations and companies are currently studying and/or developing eldercare robotic devices. A well-known example is Paro, a robotic seal, which has shown promising results in improving mental health [7, 8]. However, there are also unsuccessful cases where robots have not been widely adopted by aged-care populations, e.g. [9, 10].

More understanding is required of factors that minimise the rejection of eldercare robots and optimize their acceptance. There is some understanding of robot factors that promote acceptance; notably that the robot is both useful and easy to use. There is also some knowledge of human predictors of acceptance. However, known human predictors of technology acceptance tend to be fixed and/or historical demographics. For example, female gender and older age have been associated with low acceptance of novel technologies [11]. There are two issues with fixed demographic factors as acceptance predictors. One issue is fixed factors may predict non-acceptance of technology, but do not explain the underlying *causes* of non-acceptance. The second issue is that, by definition, fixed predictors are fixed. It is not possible to make older women more accepting of novel technologies by changing their gender and reducing their age. However, unlike demographics, psychological characteristics of potential technology users may be less fixed. Greater knowledge of potentially modifiable psychological factors associated with the acceptance and rejection of robots in an aged-care context may assist designers in creating acceptable eldercare robots to help meet the challenges of ageing populations.

### 1.1 Goals

The primary goal of the study described in this paper was to further knowledge of psychological factors involved in the acceptance of eldercare robots. Specifically we investigated whether the attitudes that older people hold about robots and their perceptions of the robot's mind could predict the use of a healthcare robot in a retirement village.

The study had several secondary study goals. These included testing the feasibility of deploying a prototype robot in a complex real-world eldercare environment. An additional goal was obtaining feedback from real-world older participants on the prototype robot and its healthcare functions or modules. The feedback will be used to further develop and improve the robot and its modules in an iterative fashion.

This paper's focus is on psychological factors and does not focus on the functional effectiveness of the robot. Assessing effectiveness was beyond the scope of this feasibility study, and robot functionality is an important but likely insufficient factor for acceptance.

The introduction next provides an overview of related work in eldercare robots. The issue of increasing acceptance of eldercare robots is raised. Next, the potential for technology acceptance models to assist in increasing eldercare robot acceptance is examined. The next two sections propose two psychological factors as predictors of eldercare robot acceptance: attitudes towards robots and the theory of mind. The last section of the introduction provides the study's specific aims and hypotheses.

### 1.2 Eldercare Robots

For eldercare robots to have enduring commercial success, they must perform useful tasks that will promote continued usage once any novelty effects have worn off (e.g. [9]). Past research using a variety of methodologies has identified potentially useful tasks for domestic eldercare robots. Identified tasks include chores such as vacuuming [12]; cleaning in general, polishing and cleaning windows and walls, and moving heavy items [13]. In another study, retirement village staff and residents rated detection of falls, lifting heaving objects and monitoring the location of people who wander away from the village, as the three most useful tasks for a hypothetical and unspecified eldercare robot. The study conducted focus groups with residents and staff using open ended questions to elicit preferences for robot functions and appearance in the absence of any robot. Subsequently a list of robot tasks was made from participants' responses [14]. More personal tasks such as baby-sitting, pet-minding, and food preparation have been considered less suitable for robots [13].

Another approach to determining suitable robot tasks is to first assess the needs of older people, and subsequently develop technologies to address those needs (e.g. [15–17]). Much of the research on preferred robot tasks is based on surveys administered in the absence of an embodied robot. This is a valid approach; however physical interactions with embodied robots can also provide useful information about usability, and reveal changes in preferences and attitudes about robots and robot tasks [18].

A number of robots have been developed to perform different tasks in eldercare. Socially assistive eldercare robots aim to interact with older people to improve or maintain their physical and/or mental health [19]. Companion robots include the seal robot Paro [8], the teddy-bear-like Huggable [20], and robotic cat NeCoRo [21]. The robotic dog, Aibo, has been shown to have similar benefits in reducing loneliness compared to a real dog in eldercare [22]. Other robots intended for eldercare include the mobile navigation and memory-aid robot Pearl [23]. Robot developers Fraunhofer IPA state the Care-o-bot 3 can safely navigate around humans, facilitate human-human interaction, and transport household objects to and from human users. They propose the Care-o-bot 3 may assist older people to continue living safely in their own homes [24]. This study used the robot Cafero—a multi-functional mobile robot with a touch-screen. Cafero has been adapted for eldercare by incorporating software for telephone calling, vital signs assessment, fall detection, medication management and entertainment [25]. Bandit is a mobile robot platform with a humanoid torso. Bandit has been used for cognitive stimulation and as an eldercare exercise instructor [26, 27]. However most eldercare robots are either not yet commercially available, or are not widely deployed.

There is initial evidence for the effectiveness of robots in improving health outcomes in older people. A systematic review of the effects of robots in eldercare found 41 relevant studies—most of which focused on companion-type robots and Paro in particular [4]. The review concluded that while the effects on psychosocial and physiological outcomes are promising, larger randomised controlled trials are required to test efficacy. There is some limited evidence that robots are preferred to non-robotic devices in eldercare. For example Kidd, Taggart, and Turkle's [28] study indicated that nursing home residents preferred the activated Paro compared with the turned-off Paro. Tapus and Mataric [27] showed that Bandit was preferred to a non-robotic interface.

For eldercare robots to be effective they must not only be functional, but older people must be comfortable with their use. Acceptance in this context has been defined as the robot being willingly incorporated into the person's life [5]. Consequently longitudinal human-robot interaction (HRI) studies are required to assess true human-robot acceptability. There are insufficient longitudinal eldercare HRI studies in a real world environment [4, 6], and despite the first electronic autonomous robot being created in 1948 [29], little is known about the variables that increase or decrease human acceptance of robots. This lack of knowledge of predictors of acceptance of eldercare robots is likely a barrier to their successful design, deployment and commercialisation; and a motivation for our study to explore psychological factors.

### 1.3 Technology Acceptance Models

Technology acceptance models have previously been applied in robotics research to study factors related to acceptance [30]. Fred Davis [31] is the author of the original Technology Acceptance Model (TAM). While anticipating the discovery of other technology acceptance predictors; Davis proposed perceived 'ease of use' and 'usefulness' of the technology as the major predictors. The much cited Unified Theory of Acceptance and Use of Technology model (UTAUT) [11] has built on Davis' parsimonious model by adding a variety of demographic and situational factors, such as age, gender, computer experience, and 'voluntariness' of technology use. Voluntariness was added in an attempt to address participant self-selection confounds.

Many studies have since shown technology acceptance models (including Davis' original TAM) to be predictive of technology acceptance [11, 32]. However the addition of many variables to UTAUT has been criticised for increasing the complexity of technology acceptance models without advancing understanding of *how* these variables contribute to technology acceptance. A deeper understanding of technology acceptance predictors is proposed to create truly acceptable technologies [32].

A further issue is technology acceptance models may be limited in their ability to generalise to acceptance of eldercare robots. Potential limitations include technology acceptance studies being typically conducted with simpler technologies such as cell phones and computers, and rarely involving embodied agents such as robots. The studies rarely assess longer-term acceptance in a real-world setting [6], and usually involve younger participants. Younger people may differ substantially from older people in terms of technology acceptance. Older people are less likely than younger people to have knowledge of similar technologies, such as computers, that they can generalise to robots. Indeed older people have been found to be more reluctant to adopt novel technologies than younger people [33].

Eldercare robots that can provide users with easy to use and useful functionalities are more likely to be acceptable compared with robots that do not provide these things [11, 31]. However, as identified by technology acceptance models, predictors of acceptance are *perceptions* of ease of use and usefulness, not objective measures of these factors. This suggests it is of limited use having a highly functional robot if it is not perceived as such by potential users. If people think a robot is worthless, they may be reluctant to even try using it. Hong et al. [34] discuss how *pre-use* technology expectations are more likely to originate from manufacturers or mass media sources, whereas *post-use* technology expectations are more likely to originate from actual experience of the technology itself. If people are not willing to try using a technology then they cannot experience its functionality. Therefore uptake or initial use may be considered a critical if insufficient precursor to acceptance.

Fortunately, in exploring predictors of robot use, there are alternatives to adding more fixed demographic predictors to acceptance models. It may be helpful to investigate more explanatory and potentially modifiable predictors such as psychological variables. The general public view of robots might be characterised as having special status as artefacts with physical and/or cognitive humanlike qualities and this seems to trigger a range of preconceptions, which may be based on science fiction, movies, and television [35, 36]. Media images and messages may interact with a human predilection to anthropomorphise. Consequently people may perceive something different about robots, over and above other non-robot technologies such as computers or cell phones, which may affect robot uptake and subsequent acceptance.

Therefore to help identify predictors of eldercare robot acceptance we propose to explore two potential psychological factors in eldercare robot use—attitudes towards robots and perceptions of robots' minds.

### 1.4 Attitudes Towards Robots

For the purpose of this study we take our definition of 'attitude' from social psychology. Attitudes are positive or negative evaluations of objects of thought. Attitudes can be composed of affect (feelings towards the object), behaviours (predispositions to act in a certain way towards an object), and/or cognitions (the thoughts people hold about the object) [37]. In this paper, we are mostly interested in the cognition component. This is motivated by our interest in peoples' decisions to use a robot or not.

Robot-specific attitudes, possibly in addition to generic technology attitudes, may predict robot acceptance. Heerink et al. [19] adapted the UTAUT to fit the context of an iCat robot within an elderly residence. Attitudes towards the robot were included in the model. The robot attitude items were; 'I think it's a good idea to use the robot'; 'The robot would make life more interesting'; and 'It's good to make use of the robot'. Results showed actual usage of the iCat by the 65–94 year old participants was predicted by the intention to use; and the intention to use was, in turn, predicted by perceived ease of use and attitudes to robots.

Generalisability of Heerink et al.'s results [19] to the wider resident population may be impaired by some methodological limitations. One possible limitation is there was only a single administration of the questionnaire to participants (after they had used the robot in the introductory session). Therefore baseline robot attitudes and any changes in these attitudes over the week-long trial were unable to be assessed. A self-selection bias is also likely (and difficult to avoid) with participants having more favourable attitudes towards robots than non-participants. However, Heerink et al.'s results are supported by other studies that have also found attitudes towards robots are likely important for robot acceptance (e.g. [36, 38–42]).

This study employs the Robot Attitudes Scale, which focuses on general positive or negative thoughts about robots [14]. Previous work with this scale has shown that attitudes towards robots predict ratings of the robot, and attitudes improve after meeting the robot [25].

### 1.5 Theory of Mind

A new area of investigation in HRI is peoples' perceptions of whether the robot has a mind. These perceptions may also affect acceptance of robots. Gray et al. [43] examined the extent to which people agree that various characters, such as a baby, a dog, and a robot have a mind. The research found that people perceive the attributes of mind along two dimensions: mind experience and mind agency. The dimension of mind experience can be summarised as a character's perceived ability for 'feeling'; the capacity to feel hunger, fear, pain, pleasure, rage, desire, personality, consciousness, pride, embarrassment, and joy. Conversely, mind agency can be summarised as a character's perceived ability for 'doing'; the capacity for self-control, morality, memory, emotion recognition, planning, communication, and thought. The robot character in Gray et al.'s study received a moderate score for agency (higher than the dog and some other characters) but lowest equal with God for capacity for experience. Recent research has suggested that higher perceptions of a robot's capacity for experience are tied to feelings of unease [44].

The theory of mind perception is related to anthropomorphism, in that people attribute capacities of mind to non-human characters. Humans readily anthropomorphise non-human creatures, and even non-living objects, such as computers [45]. Anthropomorphism in humans is easily generated with even primitive social cues [46]. The greater the number and intensity of these cues; the stronger the impression the human may receive that their robot partner is a social actor and higher in agency. Features common to robots such as embodiment, movement and speech may promote a sense of perceived agency in robots [47–49].

However different individuals in different contexts can perceive different levels of anthropomorphism for identical non-human agents. Epley et al. [50] addresses contextual and psychological predictors of anthropomorphism within the Three Factor Theory of Anthropomorphism. Psychological components of the theory include the cognitive motivational mechanism of *effectance*. This describes the need to interact effectively with the environment. Ascribing familiar human characteristics to unfamiliar non-human agents may assist in both explaining and predicting the agent's behaviour. This strategy may serve to reduce anxiety about how the agent may behave in the future. An extension of this work showed people expecting to interact with an unpredictable robot were more likely to anthropomorphise it than people who were expecting to interact with a predictable robot [51]. In contrast, the cognitive motivational mechanism of *sociality* describes the human need for social connectedness. For example, the more lonely people are—the more motivated they may be to anthropomorphise non-human agents.

Similarly to Epley et al. [50]; Takayama [52] discusses how perceptions of robot agency may assist in understanding human-robot interactions. Whether agency is perceived as a positive or negative attribute may depend on context. A person who perceives little agency in a robot may have their *own* sense of agency enhanced by the use of a non-agentic 'robot-as-tool'. Whereas a person who perceives more agency in a robot may be more able to interact with it more easily via natural social behaviours. However, there is some evidence that higher levels of perceived agency in robots is not all positive. Heerink et al. [19] conducted a study where older people watched videos of a robot programmed to be more or less responsive, or adaptive, to the needs of the human user. The older participants reported more anxiety in relation to a more adaptive robot than the robot that was programmed to be less adaptive. In a different study, preconceptions of a robot as more humanlike have been shown to negatively impact reactions amongst middle-aged and older people [53]. These findings suggest people may be more reluctant to use a robot if they perceive it as having a mind.

Therefore it appears possible that psychological factors related to attitudes toward robots and theory of mind are important in eldercare robot acceptance. This paper further explores these factors, and how they relate to eldercare robot use.

### 1.6 Aims and Hypotheses

This paper reports the results of a two week study of a healthcare robot in a retirement village. As technology uptake, or initial use, is a critical precursor to longer term acceptance; the main outcome is use of the robot. Therefore the aims were to test if the psychological factors; attitudes towards robots and the theory of mind; predicted robot uptake. Specifically our aims were to assess if:

1. Retirement village residents' initial attitudes towards robots could predict their use of the robot.
2. Retirement village residents' preconceptions of the robot's mind could predict their use of the robot.

We hypothesised that residents would be more likely to use the robot if they:

3. Had more positive attitudes towards robots.
4. Perceived the robot as having less mind.

Other observational results and participant ratings of the prototype robot and robot functions are reported elsewhere [54, 55].

## 2 Method

### 2.1 Participants

The study was conducted at Selwyn Village: a non-profit retirement complex in Point Chevalier, Auckland, New Zealand. The 26 acre village has approximately 650 residents, and provides progressive care from independent living units through to hospital and dementia care. This paper reports on the study in Lichfield Towers (Fig. 1), a five story independent-living apartment complex within the retirement village. This building was chosen to recruit from because the independent-living residents were relatively mobile and capable of taking part in the study and providing feedback. Lichfield Tower's ground floor comprises a range of shared areas, including the foyer, dining room, pool room, television room and lounge. The foyer receives a high level of traffic from both residents and visitors from other village buildings, as well as visitors from outside the facility.

Information about the study was placed in the village newsletter and in the letterboxes of residents who lived in Lichfield Towers. The researcher knocked on each of the 48 apartment doors in Lichfield Towers with the aim of inviting all residents in the building to participate. As shown in the participant flow diagram (Fig. 2), 25 residents consented to take part in the study. Residents were informed that the aim of the two week study was to have older people help test and give feedback on newly developed functions on a prototype robot. This feedback would assist the researchers develop and improve the robot and its functions.

Residents were told that the robot could take vital signs (e.g. blood pressure), remind about medication, make telephone calls, play some songs, and play memory games. Participants were invited to use the robot as much as they liked over the next two weeks, but were told they were not required to use it if they did not want to. Residents could choose to use the robot in their own apartment for half an hour a day and/or they could visit the robot in the public foyer of the building. An inclusion criterion for participants wanting the robot to visit their apartments was that they be taking medication daily. The purpose of this was to obtain feedback on the robot's medication management module.

The mean age of the 25 resident participants was 86.12 years, $SD = 4.35$, ranging from 78 to 95 years. Eighteen of the 25 participants were female. Four participants completed their formal education at age 12–13, twelve completed secondary school up to 15–18 years, two completed a technical or trade certificate, and six completed a polytechnic diploma or university degree (one had missing data). For the computer experience item, participants rated their experience at

**Fig. 1** Lichfield Towers building, showing entrance and interior of its foyer

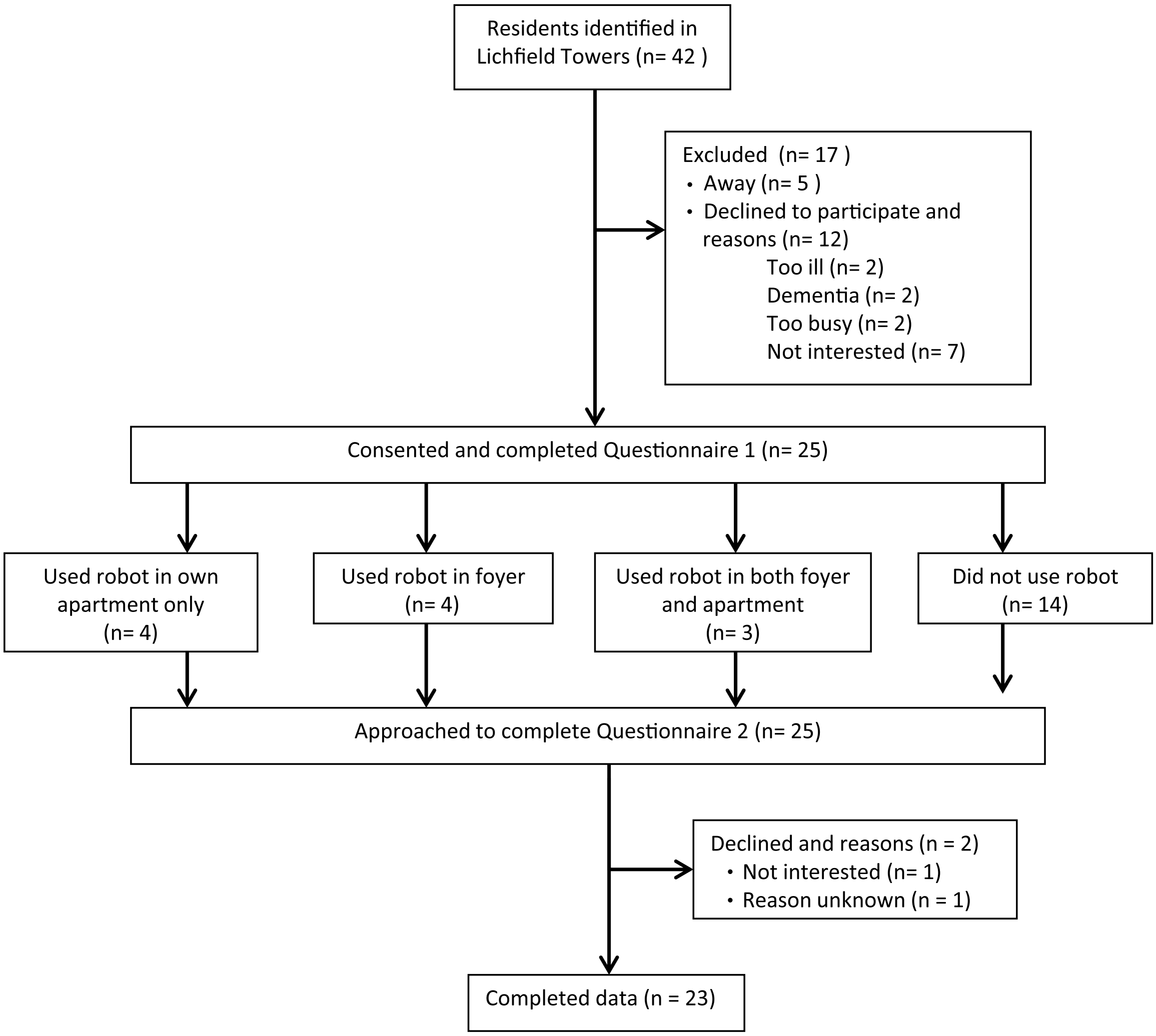


**Fig. 2** Participant flow diagram

basic computer tasks such as email and Internet searches on a numeric scale. The possible responses ranged from 1 (not at all experienced) to 8 (extremely experienced). Residents' average level of computer experience was low at 2.29, $SD = 2.24$.

### 2.2 Procedure

Approval for the study was obtained from the University of Auckland Human Participants Ethics Committee. After obtaining residents' informed consent, baseline questionnaires were administered to participants before meeting the robot. The robot was then introduced to the building. During the study, the robot was taken to the apartments of residents who chose this option for 14 consecutive days for approximately 30 minutes between the hours of 7.30 am and 9 am. Morning visits were chosen as this was when residents typically took their regular medications. This meant participant could test the robot's medication management module, as well as using all the other robot functions. In the first visit, researchers showed participants how to use the robot. The robot also photographed these residents to program the robot's face-recognition software.

Between 11 am and 2 pm for the same 14 days, the robot was situated in a corner of the foyer on the ground floor of the building. These times were selected as outside these hours the public foyer had little foot traffic. During the trial the robot was attended by a researcher who demonstrated how to use the robot or offered assistance as required. Anyone who entered the foyer during this time was free to interact with the robot. People who used the robot in the foyer had the option of having the robot photograph them. The robot would then invite participants to type their name on the touch-screen keyboard. This participant input allowed the robot to register their faces. The robot could then recognise and greet participants by name via both speech and on-screen text.

As part of study procedures, video was taken of the interactions. The results of the video analysis are reported elsewhere [56]. Follow-up questionnaires were administered after the robot was removed from the building at the end of the trial.

## 2.3 The Robot

The robot used in this study was the second version produced by the HealthBots project, which is a joint project between the University of Auckland, Electronics and Telecommunications Research Institute (ETRI), and Yujin Robot. The overall goal of the HealthBots project is to develop healthcare robots that are acceptable to older people, their families, and staff. The HealthBots project is an interdisciplinary collaboration of psychologists, engineers, computer scientists, and medical professionals [57].

### *2.3.1 Software and Hardware*

The HealthBots robot (see Figs. 3 and 4) is a differential drive mobile robot, powered by a 24 V Lithium-Polymer battery. It consists of a rotatable touch-screen, microphones, ultrasonic sensors, bumper sensors, and a laser range finder. The commercial robot was provided by Yujin Robot together with our partners at ETRI in South Korea.

The first version of the robot was deployed and tested through November–December 2009 [25, 58]. Building on results of the earlier study, our researchers designed and developed improvements and extensions to the robot's eldercare software functions. Software tools were developed to enhance the ability of roboticists, psychologists and healthcare experts to work together in iteratively refining the robot's interactive behaviour. A number of external services were developed for integration with web resources and to provide others a view of medications and vital signs data on a PC. The software version used for this study is an improved version of software used in the first HealthBots trial [58]. The front-end of the application was developed using Flash/Action Script 3.0 and the back-end was developed using C++. The robot software communicated with several web-services for information retrieval and update. Additional robot functionality was achieved via integration with third-party applications.

Several lessons related to the software development approach were learned during the field trials with the first version of the robot. Lessons included the importance of flexibility to meet individual preferences and usability needs (e.g. users may prefer a different screen colour, a larger font, layouts, images, videos, certain dialogues, voice accent, screen flows or application modules etc.), customisability,

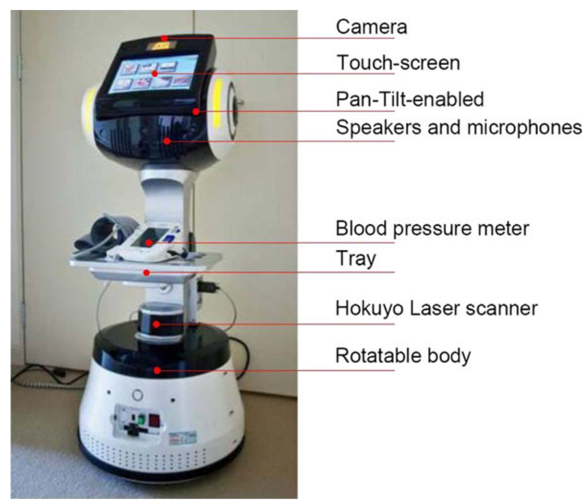


**Fig. 3** Charlie—the HealthBots robot

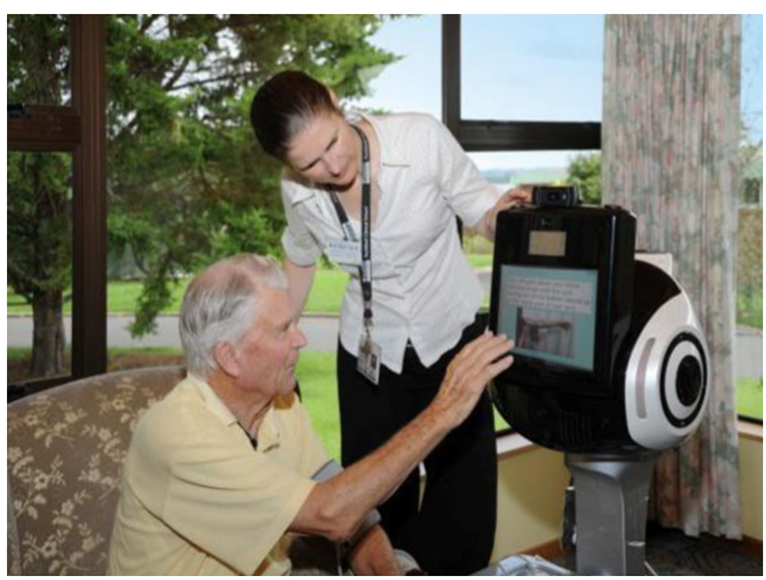

**Fig. 4** A researcher demonstrating the robot to a retirement village resident

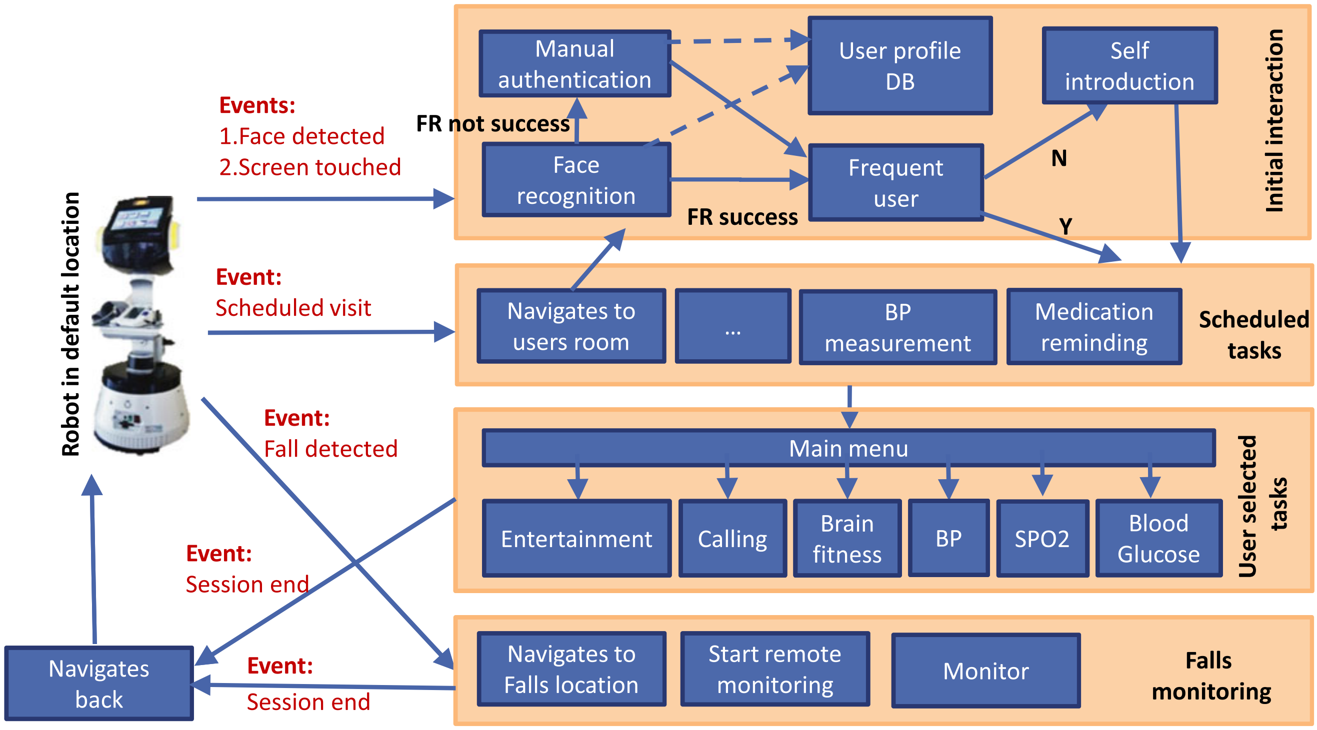


**Fig. 5** Scenarios employed on the robot. Key: FR = face recognition, DB = database, BP = blood pressure, SPO2 = blood oxygen levels

faster prototyping, accommodating changing requirements, integrating information rich applications and web services, more development involvement of subject matter experts (SMEs), and development of effective tools for robot behaviour authoring and customisation. The software architecture was re-designed considering these requirements for this second version of the robot.

A key consideration in the software architecture design was rapid customisability. This provided the flexibility to respond to user preferences and usability needs. To improve the software continuously, an iterative approach was used throughout the software development cycle. This enabled the inclusion of real-time feedback from the SMEs, pilot groups, end-users, and other stakeholders. The software architecture was sufficiently flexible to accommodate new findings, suggestions, new requirements, etc. even during testing and deployment phases.

### 2.3.2 *Robot Behaviour/Interactivity*

The robot had three main response behaviours:

1. Public foyer setting: Respond to face recognition or touch-screen press to interact with users in the building foyer. Perform user-selected tasks on a touch-screen main menu. Participants in the public foyer were free to choose from any of the robot's service modules with the exception of medication management. The face recognition system is described in detail in Kuo et al. [59].
2. Apartment setting: Respond to face recognition or touch-screen press to interact with users in their apartments. In the apartment setting the robot initially performed scheduled tasks (blood pressure measurement and medication reminding), and then offered the user the choice of other services.
3. Respond to fall events. This functionality was not used for this study. A subsequent study has been conducted on this aspect (unpublished).

Figure 5 illustrates the robot in the default position, the events that trigger the different behaviours, and the robot behaviours in each scenario. All three scenarios are embedded in the robot behaviour implemented by the robot software.

By default, the robot was kept docked at its charging station in the foyer. If someone approached or touched the robot, either a 'Face Detected' or a 'Screen Touched' event was triggered. This starts the initial interaction phase, which includes face recognition, authentication, and self-introduction. At the end of the initial interaction phase, the robot displays the 'main menu'. At this junction users could select any available service (vital signs measurement, calling, entertainment, and brain fitness). The interaction session ends when the user finishes the session or no interaction is detected after a certain time period.

For the scheduled apartment visits within the multi-level Lichfield building, researchers transported the robot in the elevators between floors on a trolley. The robot then navigated down the corridor to the resident's apartment. The apartment door would be opened by the resident or a researcher. The robot next navigated inside the apartment and positioned itself in a pre-programmed location in front of the seated participant. It was beyond the scope of this feasibility study to have the robot navigate each apartment and locate the participant. However, the researchers or participant could use the robot's remote control to move it from the pre-programmed location as desired. Apartment HRI sessions were initiated as previously described in 'robot behaviour/interactivity 2'. At the end of the session, the robot would navigate outside the apartment and be returned by researchers to the default location in the public foyer.

#### 2.3.3 *Robot Functions: Service Modules*

Seven prototype service application modules were developed; vital signs measurement, medication reminding, falls detection, entertainment, and telephone calling. Brain fitness games were also available on the robot. The modules were designed to be sufficiently intuitive so an older person who had never used a computer before could easily use them; yet adaptive enough so experienced users would not get frustrated. An example of the latter is that experienced users could bypass module introductions and instructions. Participants responded to the robot via the robot's touchscreen, and the robot responded to participants via synthesised speech and on-screen text.

The vital signs measurement module assessed blood pressure, arterial stiffness, pulse rate, blood oxygen saturation, and blood glucose levels. Vital signs devices were attached to the robot via a USB hub, with a Bluetooth link for blood glucose monitoring. Participants could measure their own vital signs using the robot without assistance from the researchers. The robot provided optional instructions via speech, on-screen text, and/or demonstration video. Vital signs results were delivered via speech and displayed on the robot's screen.

The medication management module reminded users of their medication schedules and consisted of a sophisticated dialogue system connected to a back-end web service. The medication module was only conducted in apartments and not in the public foyer setting (Details of the development and testing of the medication management module are published in [60]). As required by the University of Auckland Human Participants Ethics Committee, an MD researcher attended the robot in the apartments for the medication management sessions for this trial. A third-party software, BrainFitness from Dakim [61], provided games designed to be an enjoyable way for older people to practice their cognition and memory. Entertainment sub-modules provided music videos, pictures, and quotes. The robot's calling module—developed using the Skype API—enabled participants to make telephone calls to friends and family.

### 2.4 Robot Speech

The robot's synthetic speech was generated through diphone concatenation type synthesis implemented with Festival speech synthesis system [62] and used a New Zealand accented diphone voice developed at the University of Auckland [63]. Expression was added to the synthetic speech through an intonation modelling technique described in Igic et al. [64] called 'Say Emotional'.

### 2.5 Navigation

For map building and navigation, the robot used the StarGazer robot localisation system [65]. StarGazer is a robust, easy to use, and accurate commercial navigation system. The system requires small passive white dot landmarks. The unobtrusive landmarks are installed with approximately one meter separation on the ceiling of the robot work-space. A map of the area was built using the built-in map building module of the robot. The robot could then autonomously navigate to designated places (such as the charging station, participants' apartments etc.) and avoid obstacles using the pre-built map and landmarks. Landmarks were installed on the ceiling of all locations the robot traversed in the course of the study; public areas, corridors and apartments. Resetting the robot position was not required due to the robot being installed with the complete pre-built map.

### 2.6 Measures

#### 2.6.1 *Baseline Questionnaire*

*Demographics* Participants were asked their age, gender, level of education, and computer experience.

*Robot Attitudes Scale (RAS)* [14] This 11 item scale was used to measure residents' attitudes towards robots. This scale was chosen as it had been developed in an earlier study at the same retirement village, and been shown to predict the quality of the residents' interaction with the robot [25]. The primary purpose of using the RAS was to assess the strength of positive or negative attitudes toward robots; and to assess whether or not these attitudes were different between different groups, and if they changed as a result of interactions. A reduced eight item version of this scale was used for this study to minimise participant burden. The eight items chosen had the highest factor loadings (friendly: unfriendly, useful: useless, trustworthy: untrustworthy, easy to use: hard to use, reliable: unreliable, safe: dangerous, helpful: unhelpful, and interesting: boring). As per the original instructions,

**Table 1** Instructions and wording of the Robot Attitudes Scale and Dimensions of Mind Perception Questionnaire

| Measure | Scale instructions | Example items |
|---|---|---|
| Robot attitudes scale [12] | Please circle the number that best corresponds to how you feel towards the healthcare robot you are about to interact with. I think the robot will be… | 1 2 3 4 5 6 7 8<br>Unfriendly Friendly<br>1 2 3 4 5 6 7 8<br>Useless Useful |
| Dimensions of mind perception [39] | This survey asks you to make estimates of the abilities of the robot. Please rate the robot on each of the following scales. Try to indicate the degree to which you believe the robot has each of these capacities by using the numbers from 1 to 7 as a yardstick on which to measure the robot. | [Agency]<br>How much is the robot capable of remembering things?<br>1 2 3 4 5 6 7<br>Has no memory Has memory<br>[Experience]<br>How much is the robot capable of experiencing physical or emotional pleasure?<br>1 2 3 4 5 6 7<br>Cannot feel pleasure Can feel pleasure |

participants rated robots on each of the eight attributes using an eight point scale. The attribute opposites served as semantic anchors. RAS items are summed to create an overall score between eight and 64 where higher scores equate to more favourable robot attitudes. Cronbach's $\alpha$ was 0.90. The instructions and example items are shown in Table 1.

*Dimensions of Mind Perception* [43] Eleven items were used from this 18 item scale to minimise participant burden. The scale is composed of two subscales: mind *agency* (six items were chosen; perceived capacity of the robot to recognise emotions, have thought, memory, self-control, plan and be moral) and mind *experience* (five items were chosen; perceived capacity of the robot to feel pleasure, hunger, pain, and have personality and consciousness). We used the original response options, which are on a seven point scale with semantic anchors. The possible range of scores was from 6 to 42 for agency, and from 5 to 35 for experience. Instructions and example items are shown in Table 1.

#### 2.6.2 *Follow-up Questionnaire*

This included a second administration of the Robot Attitudes Scale and Dimensions of Mind Perception scale. It also included a question on whether the resident had used the robot or not. Participants who used the robot were asked to write a number indicating the quality of their overall experience of the robot interaction using a scale from 0 (poor) to 100 (excellent). They were also asked how much they would like to use the robot again using a scale from 0 (not at all) to 100 (very much). These two items had been used in a previous study and found to be acceptable to older users [25]. Robot-users were asked to rate how easy or hard they found the robot to use on a five point semantic scale. The response options were; very hard, hard, neither hard or easy, easy, and very easy. Participants were asked to rate the robot's usefulness for themselves on a four-point semantic scale. The usefulness response options were; not at all useful, a little useful, useful, and very useful. There was a fifth option of 'not useful for me but useful for others'. The latter item was included due to comments made during a previous study by the relatively high-functioning independent-living residents. A common comment was while residents could not see the robot currently being useful for themselves—they could see it being useful for their future selves, or for other less independent residents.

### 2.7 Statistical Analyses

Statistical analyses were conducted with PASW Statistics Data Editor. Three mixed ANOVAs were performed. The within-groups variable was the two time points (baseline and follow-up) and the between groups variable was whether or not the participants used the robot. Non-significant Kolmogorov-Smirnov tests ($p > 0.05$) indicate the distribution of scores for robot attitudes, and robot mind agency and experience, between the two groups (who used and did not use the robot) were sufficiently normal to justify parametric analyses. The first ANOVA used the Robot Attitudes Scale as the dependent variable, the second used perceived mind agency and the third used perceived mind experience. These analyses tested whether participants who used the robot differed from those who did not use the robot, on attitudes and mind perceptions, and if there was a time by group effect. To increase statistical power for analyses of the two items; robot rating and intentions to use the robot again, two residents who completed all the measures and used the robot but lived in the rest-home part of the village were included.

## 3 Results

### 3.1 Use of Robot

Of the 25 residents who completed the baseline questionnaire; 11 did use the robot over the two week trial period and 14 did not. Of those who used the robot ($n = 11$), their use varied from once to 16 times (*mean* 5.5 times). Within this robot-user group, people who used the robot more often reported better attitudes towards the robot at follow-up ($r = 0.68$, $p < 0.01$), but there were no other significant correlations with other outcomes.

Neither age, gender, nor education ($p < 0.05$) were related to residents' choice to use the robot. However, a Mann Whitney $U$ test revealed those who did use the robot had significantly higher computer experience ($Md = 2$, $mean = 3.40$, $n = 10$) than those who did not use it ($Md = 1$, $mean = 1.50$, $n = 14$), $U = 39.50$, $z = -2.06$, $p = 0.04$, and a medium-large effect size $r = 0.42$.

There was a significant group effect for robot attitudes. Residents who chose to use the robot had better attitudes towards robots than residents who did not use the robot, $F(1, 16) = 6.70$, $p = 0.02$ (*Mean* 'did not use robot' 41.67 CI: 35.63 to 47.71; *Mean* 'used' 52.10 CI: 46.06 to 58.13); Partial Eta Squared = 0.30. There was also a significant time effect for attitudes. Overall there was a significant improvement in participants' attitudes towards robots from before to after the trial, $F(1, 16) = 9.99$, $p = 0.006$. (*Mean* before trial 44.44, CI: 39.77 to 49.11; *Mean* after trial 49.33, CI: 44.85 to 53.80), Partial Eta squared = 0.38. Lastly, there was a significant group by time interaction for attitudes, with greater increases in positive robot attitudes in the robot-use group (see Fig. 6), $F(1, 16) = 5.21$, $p = 0.04$, Partial Eta Squared = 0.25.

A significant group effect was found for perceived robot agency. There was a significant difference between residents who did and did not use the robot in perceived robot agency $F(1, 9) = 5.49$, $p = 0.04$. *Mean* 'did not use robot' 22.33 (CI: 17.23 to 27.44); *Mean* 'did use robot' 14.50, (CI: 8.90 to 20.10), with a large effect size of Partial Eta Squared = 0.38. Non-robot users perceived the robot as having higher agency than people who did use the robot (see Fig. 7), but there were no significant time ($p = 0.88$) or interaction effects ($p = 0.24$) for agency.

For perceptions of robot mind experience, there were no significant differences detected between groups: robot using and non-robot using residents ($p = 0.28$), or over time ($p = 0.33$), or interaction effects ($p = 0.58$).

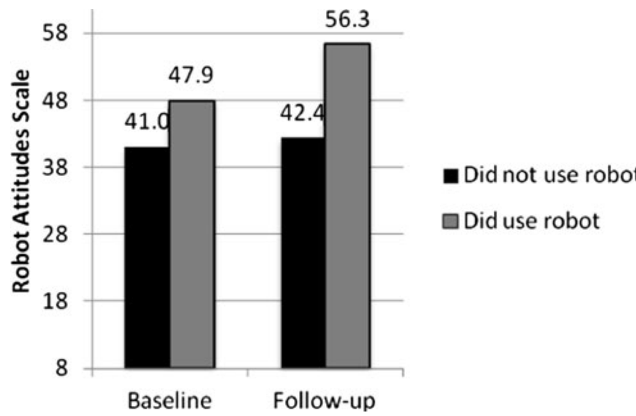


**Fig. 6** Attitudes towards robots were more favourable amongst people who used the robot compared to those who did not use the robot, and attitudes improved more in those who did use the robot. *Mean* 'did not use robot': baseline 40.99 (CI 34.39 to 47.59), follow-up 42.35 (CI: 36.02 to 48.68). *Mean* 'did use robot' baseline 47.89 (CI: 41.29 to 54.49), follow-up 56.30 (CI: 49.97 to 62.63)

### 3.2 Overall Rating, Intentions to Use Again, Ease of Use and Usefulness

Participants gave the robot interaction overall a mean rating of 78.50, $SD = 15.47$, CI: 67.44 to 89.56, $Md = 80.00$. The mean of 'intention to use the robot again' was 65.00, $SD = 39.02$, CI: 37.09 to 92.91, $Md = 80.00$. Of the nine respondents to the 'ease of robot use' question; four answered 'easy to use' and five answered 'very easy to use'. Of the 18 respondents who rated the robot's usefulness; four answered 'not at all useful', one 'a little useful', five 'useful', two 'very useful' and six 'not useful for me but useful for others'.

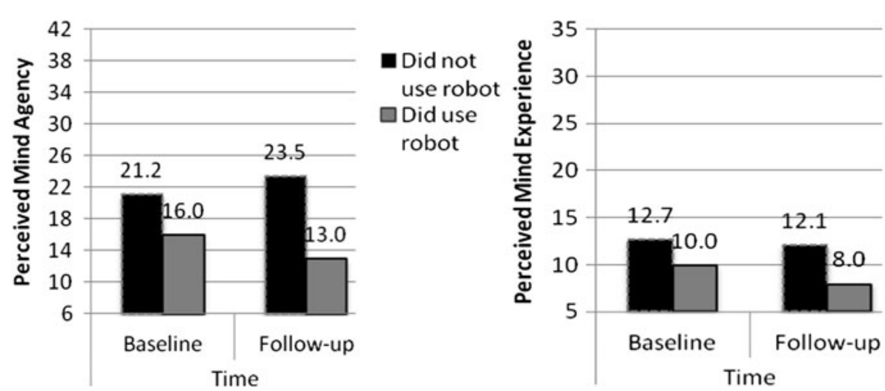


**Fig. 7** Participants who used the robot had lower perceptions of the robot's agency than those who did not use the robot. There were no differences in perceptions of the robot's ability to experience things. Mean scores are presented at each time point

To investigate predictors of the HRI rating and intentions to use the robot again amongst the small sample of users ($n = 11$), Pearson correlations and chi-square analyses were conducted. There were no significant associations between participants' age, gender, computer knowledge, and reported ease of robot use or usefulness, or with overall interaction rating or intentions to use the robot again ($p > 0.05$). There were however significant associations between perceived robot mind agency and robot mind experience (separately) with intention to use the robot again ($r = 0.68$, and $r = 0.62$ respectively, $p < 0.05$), but no significant associations with robot interaction rating.

## 4 Discussion

This study examined predictors of robot use in a small cohort of residents in a retirement village over a two week period. As predicted, people who chose to use the robot had more computer knowledge, held more positive attitudes towards robots, and attributed less mind agency to robots. The amount of mind agency and mind experience the residents perceived in robots also predicted how much robot-users intended to use the robot again.

The study's secondary goals were met. Resident feedback was obtained on the robot and its functions that can be used to improve the robot. Results provide initial support for the feasibility of deploying robots in complex eldercare settings.

There are several possible reasons why people who attributed more agency to robots may have been less likely to use the robot in this study. One reason is that thinking a robot has more agency makes older people more wary of it and afraid to try it. Another possible reason is that they were disappointed when they saw the robot and therefore did not want to use it. However, inspection of Fig. 7 suggests a trend that perceived agency decreased in those who did use the robot, and remained high in those who did not use it. This trend does not support the argument that non-users were disappointed that it did not appear have as much mind as they initially thought. The results suggest that people have preconceived ideas that robots have higher capacities to think and remember and be conscious than they actually do—an illusion that is dispelled when they actually use one. These ideas may originate from exposure to robots in the media, including books, television, film, and news reports, which often exaggerate the capabilities and dangers of robots.

Overall, participants in this study thought that robots had a higher capacity for agency than capacity for experience. This was similar to the mind dimension profile that participants ascribed to the social robot Kismet when given a written description and photo [43]. In Gray et al.'s study, characters high in either dimension of mind experience or agency were more valued. In contrast, while all participants in this study perceived the robot to be low in the mind dimension of experience, those residents who expected the robot to be higher in agency were less likely to use it. It may be that a robot perceived as possessing this type of high agency:low experience mind profile appears as an autonomous creature that has no sense of compassion or empathy. People may avoid such a robot as they fear that, at best, the robot may be indifferent to their welfare, and at worst actively inflict harm. This is in line with Mori's [68] suggestion that self-preservation is the function of uneasiness in relation to uncanny characters.

That higher ratings in this study of both robot mind experience and agency (separately) predicted intentions of using the robot again, concurs with Gray et al.'s [43] results of both dimensions being valued; but are somewhat contrary to this study's finding that higher perceptions of robot agency were associated with non-use. It may be that if a robot is perceived to have an 'unbalanced mind' i.e. the capacity for agency but not for empathy, it is perceived to be missing the checks and balances that promote both predictable and desirable behaviour. That robot-users were more likely to be those residents who perceived the robot as having both low agency and low experience, is congruent with previous reports from residents and staff (in the same retirement village as this study) that their preference was for a healthcare robot that did not look too humanlike as it was just a machine [14].

Like many previous technology acceptance studies, higher computer experience was associated with acceptance; but in contrast higher formal education was not. Many of this older generation of participants had their formal education terminated prematurely due to poverty and/or war. For older people the assessment of formal education may poorly reflect life experience. That all respondents rated the robot as easy, or very easy to use, suggests the goal of designing an 'older -user-friendly' robot was at least partially met.

The study results also contribute to knowledge about models of human acceptance of robots. The results replicate and strengthen previous findings that attitudes toward robots are important to acceptance and add a new predictor to the model—perceived robot mind. The study methodology has a number of strengths that support the application of the results to the development of individually and commercially acceptable eldercare robots. Healthcare human-robot interactions are often complex; involving variable environments and multiple stakeholders [66, 67]. While laboratory robot studies are often necessary and valuable, studying HRI in real-world environments is likely key to an in-depth understanding of real-world robot acceptability. For a variety of technical, legal, ethical, practical, and resident health reasons, studying acceptance of eldercare robots in a retirement village is extremely challenging [25, 69, 70]. This two week study was conducted in a real-world setting and used real-world retirement village residents as participants. Further, this study utilised a semi-autonomous robot with its attendant technical issues, rather than the Wizard of Oz scenario.

Further methodological strengths of this study include comparing subjective measures with objective measures. Psychological measures of robot attitudes were compared with an objective behavioural measure of whether participants chose to use the robot or not. This approach also enabled assessment of baseline differences between robot-users and non-users. Additionally this is the first time the theory of mind perception has been used to assess acceptance of healthcare robots in older people.

The study also had some limitations. Older participants often have limited capacity to complete lengthy questionnaires, so the number of measures needs to be restricted. Although a reasonable size by HRI standards, the sample size meant small effect sizes could not be detected. For this reason, longer-term trials with larger sample sizes are required to corroborate these results.

It is possible researcher presence acted as a confound. There was at least one researcher nearby when the robot was available for participant use. Researchers had to build rapport with some residents before they would consent to participate in the study. However the recruiting researcher was mindful of minimising socially desirable responding. This was achieved by emphasising that participants were being helpful whether they used the robot or not, and in order to best improve the robot we needed their honest, not polite, opinion when completing questionnaires. Given that 14/25 of participants did not use the robot it seems plausible this strategy to build rapport while simultaneously minimizing socially desirable responding was at least somewhat successful.

Further possible limitations for assessing robot acceptance include the robot being only available to all Lichfield Tower residents for three hours per day. Future research could include longer-term trials where the robot is permanently left in situ to assess how 24/7 availability impacts on acceptance. Future work could investigate why older users give high ratings to robots even if errors occur. It may be that residents blame themselves on these occasions rather than the robot.

That this feasibility study was not controlled is another limitation. Some of the robot's functions such as Skype, entertainment and medication management could have been delivered via computer or tablet. While further research is needed, there is limited preliminary evidence that socially interactive robots may provide a 'robot advantage' over non-robot methodologies for motivating health behaviours. For example, in a six week [71] study, participants were allocated to one of three weight loss methodologies; a socially interactive robot, a computer, and a pen and paper log. There was no significant difference in weight loss between the three groups but participants in the robot group adhered to the programme for longer than the other two groups, and reported a closer relationship with the robot. A further advantage for some robots is mobility. Such robots may be able to visit older people with compromised mobility, as well as transporting objects between people.

It is useful to consider what influence the robot's form and function may have had on robot use. In our previous focus groups and questionnaires with this population [14], participants reported a preference for a non-humanlike robot and had high ratings of many of the functions we developed for the robot. In fact, that was why we chose this particular form and the functions for this robot. In this study we only had one robot at the village so could not test whether people would have used a different robot more or less often. This may be an area for future research to investigate. An understanding of specific design features that promote or decrease perceptions of robot agency could be used to formulate the appropriate robot design for a particular context. However Roomba owners vary greatly in how much agency or social relationships they perceive in their robotic vacuum cleaners of identical design [72]. This suggests that subjective individual perceptions of robot agency, or intentionality [73], may be as important as the objective physical design and behaviours of the robot.

This study's rapport building strategies used to promote recruitment may be of interest to HRI researchers. During the recruiting interviews it was noted that despite efforts to inform Selwyn Village residents about the study, some potential participants held misconceptions that were a barrier to participation. Misconceptions typically related to the study purpose and methodology, and the 'nature' of the study robot. A key strategy was to elicit these misconceptions and address them where possible. For example some residents believed that as they were "no good with computers", they would also be "no good" with the study robot. Such people were usually reassured by explaining that the robot's simple touch screen operation had been designed to be easily used by someone who had never used a computer before. Another common misconception was the time and effort required by participation. Consequently the costs and benefits of participation were outlined in detail to potential participants, along with a reminder that even if they agreed to participate they could still withdraw from the study at any time.

Since the initial requirement for robot acceptance is for people to choose to interact with the robot, it is important to maximise initial human-robot engagement. This may be achieved by encouraging positive attitudes and appropriate perceptions of robot mind among potential older users. While this is likely to be context dependent, it may be beneficial to design and promote robots as having balanced mind profiles of either high agency and high experience, or low agency and low experience, and avoiding the high agency:low experience mind profile.

The cognitions older people hold about robots influence their decisions to use robots and therefore have implications for (a) how robot designers and programmers design and integrate the robot components to present an overall interaction with the user, and (b) how robots are distributed and deployed to people. This includes the marketing and information about the robot's appearance and abilities. As the service robot market develops, it will be important for robot manufacturers and distributors to develop early generations of robots that people will engage with. These will need to be followed with new generations of robots that are sensitive to the changing trends in peoples' attitudes, and perceptions of robot mind experience and agency, that will likely arise from increased exposure to the robots.

Future longitudinal studies could both assess the effectiveness and efficiency of robotic eldercare, and assess it against non-robot eldercare such as human care or computers. Longer-term trials are required to assess continued usage of eldercare robots. While the RAS appears to both predict robot use and be sensitive to changes in robot attitudes, it is beyond the scope of the RAS to determine the causes of participants' robot attitudes. Future research could explore the origins of attitudes towards robots. Further research is also required on how to encourage positive attitudes prior to the introduction of robots to eldercare. Interventions could be developed in the distribution and marketing of robots to modify attitudes and mind perceptions to encourage use and promote acceptance of eldercare robots.

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