Robots in older people's homes to improve medication adherence and quality of life: A randomised cross-over trial

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Abstract. Healthcare robots are being developed to help older people maintain independence. This randomised cross-over trial aimed to investigate whether healthcare robots were acceptable and feasible and whether the robots could impact quality of life, depression and medication adherence. 29 older adults living in independent units within a retirement village were given robots in their homes for 6 weeks and had a non-robot 6-week control period, in a randomised order. The robots reminded people to take medication, provided memory games, entertainment, skype calls, and blood pressure measurement. The robots were found to be acceptable and feasible, and many participants described them as useful and as friends although not all comments were positive. There were relatively few problems with robot functions. The participants' perceptions of the robots' agency reduced over time. The robots had no significant impact on adherence, depression or quality of life. While the robots were feasible and acceptable, improvements in their reliability and functionality may increase their efficacy.

Keywords robots, quality of life, medication, adherence, blood pressure, companion, acceptance

1 Introduction

1.1 Eldercare robots

Research teams across the world are developing robots that can provide services to older people to help them cope with age-related declines in physical health and cognitive abilities [1-3]. These robots include companion type robots, such as Paro, that are designed to provide companionship and reduce agitation in patients with dementia [4]. Other robots have been designed to help people with more practical tasks, such as physical assistance [5], health-care related tasks [6] and rehabilitation [7,8].

User trials of such robots to date have often been lab-based, observational, and used wizard of oz scenarios [1]. Few studies have been conducted in real-world settings and even fewer have been randomised controlled trials. Results to date have been promising, with two RCTs showing that companion robots can reduce loneliness in a rest-home/hospital aged care facility [9, 10].

Recent advances in technology mean that service robots are reaching a stage where they too can be tested more autonomously in real-world settings. This paper reports the results of a randomised cross-over trial of two types of autonomous service robots in an aged care facility over three months.

1.2 Background to this study

This research relates to the multidisciplinary, cross-faculty, international healthcare robotics project, jointly funded by New Zealand's Science and Innovation Group within the Ministry of Business, Innovation and Employment (MBIE), and South Korea's Ministry of Knowledge Economy (MKE). The long term goal of the project was to develop an affordable healthcare robot for use in aged communities. The University of Auckland researchers come from engineering, computer science, health informatics, health psychology, general practice, gerontology nursing, integrated care, and geriatrics.

This project started with a questionnaire and focus-group study of staff, residents and relatives preferences for robots within an aged care facility [11]. This indicated several key roles for robots in the centre: falls detection and calling for help, detection of wandering, reminders for schedules & medication, and vital signs assessment. We also added an entertainment and socialization function as this was identified as a need by several senior staff. These applications were developed by Auckland UniServices Ltd and the University of Auckland. Two robots from Yujin Robot Co., Ltd were programmed with these functions (Cafero robot and iRobiQ). These robots were tested in several small studies at the retirement village, and were shown to be acceptable to trial participants [12-15].

This paper reports on a larger controlled trial held at the retirement village with several robots of each kind [16]. The aim of the trial was to investigate whether personal service type robots in the homes (independent units) of older people at the retirement village were feasible and acceptable and to provide pilot information regarding their ability to improve quality of life, reduce depression, and improve medication adherence compared to a control group. We also investigated how participants' attitudes towards the robots changed over the course of the trial using both questionnaires and open-ended interviews.

2 Method

2.1 Trial design

Repeated measures randomised controlled cross-over trial.

2.2 Setting and participants

The study was held at a large retirement village in Auckland, New Zealand, with a range of services, from independent living apartments to hospital facilities. The village has over 700 residents, who are mostly aged over 65 years. Recruitment for the study began in September 2011. One hundred and sixteen residents in the independent living apartments at the village were invited to take part in the study through letterbox flyers and advertised talks and demonstrations held at the village centre in November 2011. Thirty residents gave written informed consent to take part in the trial. Ethics Approval was obtained from the University of Auckland, and permission was gained from the CEO of the Selwyn Foundation. One person withdrew prior to randomization leaving 29 participants who were randomized..

2.3 Procedure

The study was divided into two 6-week periods with an washout period of 18 days between them. The robots were placed in the village from the 1st November 2011 until the 21st December 2011. They were removed over the Christmas holiday period. The robots were repositioned from the 8th January 2012 to the end of March 2012.

After baseline measures were taken, participants were randomized to receive the robot during the first 6 week period or the second using computer generated random numbers. Primary outcome measures were taken by blinded interviewers. Interviews about attitudes to robots were not blinded.

2.4 Interventions

During the intervention period the robots were installed into the residents' apartments by the researchers, usually in the dining room. IrobiQ (small robot) was installed on a table top to make it an appropriate height for interactions, while Cafero (taller robot) was freestanding. While both robots have navigation systems and wheels and can be mobile, they were both stationary for this project in order to reduce risks of injury. Both robots run on batteries and have a charging station.

The robot applications were idividualised to the participants needs and communicated over wireless network services to a server which held participants' profiles and measurements, medication prescriptions, and logs of robot activity. The participants were shown through all of the modules available on the robots. Each participant was also provided with a user manual, which informed him/her how to perform basic troubleshooting steps. All residents were provided with a phone number to call if they had any questions or problems.

What did the robots do? Two types of autonomous robots were used in the study, both manufactured by Yujin Robot, Korea (http://yujinrobot.com/eng/). The first robot, iRobiQ, is 45 by 32 by 32 cm and weighs 7kg. It has a 7 inch touch screen, microphone, camera, speakers, a face capable of expression through Led lights, IR obstacle sensors, and runs on windows XP (see Figure 1). It could take blood pressure and pulse oximetry, had music videos and quotes, and a medication management program. The robot's head could swivel and tilt in response to sound, its arms could raise, and its base could swivel. The robot 'danced' when it played music by raising its arms, swivelling its base and head, and showing face lights. The robot displayed a menu screen, and the user could touch the function they wanted to use at any time. Once selected, each function ran autonomously. Seven iRobiQ were used in this trial.

The medication management system was programmed by the health provider with the participants' usual medications. The robot autonomously raised it arms, sounded a bell, and said '[participant name], it is time for your medication' each time medications were due. The robot asked a series of questions which the participant answered via the touch screen, and guided the participant through taking each medication. The robot asked the participant to confirm if they had taken each medication, if they felt unwell or had any side effects. The system had been developed and successfully piloted [15]. If a resident's medication was missed, the robot sent an alert to a duty cell phone. On receiving the alert a nurse familiar with the resident's medication regime would make a clinical decision to take any action regarding the noncompliance. This action was generally taken immediately but in some circumstances contacting the resident was left until the following day. The risk assessment of non-compliance primarily related to the type of medication missed. If the alert also included a message to contact the resident as they were feeling unwell, then an immediate phone call was made to ascertain the urgency of the clinical situation and appropriate action was taken following this conversation. If the resident was unable to be contacted by phone, a research assistant made a visit to the resident's apartment.

The second robot, Cafero, is approximately four feet tall and has a touchscreen, microphone, camera, speakers, IR obstacle sensors, (see Figure 1). It also took blood pressure and pulse oximetry and had music videos and quotes, but not the medication management program. Instead Cafero had a simple Skype calling function, had a commercially available program that provides cognitive exercises, Dakim Brain Fitness (http://www.dakim.com/), a website showing information about the village, and a calendar reminder system. Cafero also had data exchange with Lifetime Health Diary™ (an online platform created by the Lifetime Health Diary Ltd, New Zealand. It integrates clinical data and background health information about the patient). The robot displayed a menu screen and the user could touch the function they wanted to use at any time. Once selected, each function ran autonomously.

Fig. 1. IrobiQ (left) and Cafero (right) robots used in the study.

2.5 Measures

Measures were taken and interviews conducted by trained interviewers using standardized techniques at baseline, after the first 6-week period, and after the second 6-week period. At baseline, information was collected about age, gender, ethnicity and education. The 10-item Abbreviated Mental Test Score was administered to assess cognitive impairment and scores below 7 indicate impairment [17].

The *primary outcomes measures* were health related quality of life, depression and adherence. Health related quality of life was measured using the SF-12 [18]. This 12-item measure contains a physical and mental health component, and has been validated by Quality Metric Incorporated. Higher scores indicate better health related quality of life. Depression was measured with the Geriatric Depression Scale (GDS-15) [19], comprising 15 yes or no items which assess depressive symptoms over the last week. Self-reported adherence was measured using the Medication Adherence Report Scale (MARS)[20], in which higher scores indicate higher levels of adherence.

To assess the *acceptability* and feasibility of the robots, a combination of open-ended interviews, questionnaires, a diary and data logs from the robots were used. The interviewers asked participants about how they felt about the robot, how often they used the robot, how the robot affected their lives, in what ways the robot was or was not useful, what they thought of its appearance, and what they would change about it, and how their visitors reacted. The questionnaires included the Robot Attitudes Scale (RAS) [10], which assesses what people think about robots on 10 items (e.g. friendly, useful, trustworthy), and the Mind Perception Questionnaire [21]. This psychometrically validated scale assesses perceptions of the robot's ability to experience things (E.g. feel pain, and pleasure) and have agency (E.g. have thought, and memory). We asked participants to keep a diary of adverse/positive events (E.g. grandchildren played with robot and had fun; robot would not turn on). The data logs recorded when the robot was used, for how long, and which applications were used, as well as the data from the applications such as blood pressure readings. For reasons of limited space, this paper reports the questionnaire and interview results only.

2.6 Data analysis

Descriptive statistics are used to summarize the characteristics of the sample. Primary outcomes were compared between the period with the robot and the period without for all participants. To analyse the effects of the robot on depression, QOL, and adherence, three mixed ANOVA were conducted (with the repeated measures variable being the scores at each timepoint, and the group factor the order of the robot or no robot phases). We were looking for a significant group by time interaction to indicate that the robot made a difference to outcomes. Attitudes towards the robots and perceptions of mind were analysed using repeated measures t-tests.

3 Results

The mean age of the sample was 85.23 years (SD 5.14, range 72 to 94). There were 14 males and 15 females. Fourteen participants had three years of secondary school education or less, 3 had four or five years of secondary education and 12 had higher education (technical, trade or university degrees). Their self-rated computer experience averaged 3.17 (SD 2.17) of a maximum of 8. The mean score on the Abbreviated Mental Test was 9.24 (SD 0.99). One participant scored 6, which is suggestive of cognitive impairment; this person was married to and living with another participant.

There were no significant differences between groups at baseline in depression, cognition, adherence, or physical QOL scores. There was a baseline difference in mental QOL scores, $t(23) = 3.64$, $p=.001$). Table 1 shows these scores.

To analyse the effects of the robot on depression, QOL, and adherence, mixed ANOVA were conducted (with the repeated measures variable the time-point (Dec/Feb) and the group factor the order of the robot or no robot phases). A significant group by time interaction would indicate that the robot made a difference to outcomes. There were no significant group by time effects ($p>.05$). Analysing the data by paired samples t-tests for robot versus no robot periods showed the same results.

Table 1. Residents' depression, physical quality of life, mental quality of life, and adherence scores between groups and across time.

	Baseline Robot 1st	*Dec Robot 1st*	*Feb Robot 1st*	*Baseline Robot 2nd*	*Dec Robot 2nd*	*Feb Robot 2nd*
Depression	1.32(1.13)	1.82(2.04)	1.82(2.48)	2.44(2.34)	2.10(1.74)	2.33(1.82)
SF12 PCS	36.68(11.59)	36.85(10.88)	40.79(12.37)	42.71(10.72)	40.28(10.57)	39.80(13.23)
SF12 MCS	59.21(5.07)	54.76(1.90)	52.55(2.34)	49.54(8.86)	56.71(1.81)	55.86(2.23)
MARS	23.16 (2.13)	23.00 (3.03)	22.17 (5.53)	24.33 (0.82)	24.83 (0.41)	24.67 (0.52)

Note - SF12 PCS SF-12 physical health component summary score, SF12 MCS SF-12 mental health component summary score, MARS – Medication Adherence Report Scale. MARS is only analysed for those with the medication management robot (iRobiQ). Follow up means (SE) are controlling for baseline for SF12 MCS.

Residents' attitudes towards robots and mind perception scores at baseline and after using the robot are displayed in Table 2. There was a significant decrease in how much agency people perceived the robot to have after using it for the trial.

There were 75 calls made to the phone line, of which 68 pertained to errors on the robots (such as a frozen screen). The majority of these problems could be fixed by the research assistant rebooting/restarting the robot. Seven calls concerned medication management: a set-up issue (1), not reminding (2), missed medication (2), medication reminding at 4am (1), medication change possibly coming up (1). Medication issues were discussed with the nurse on the research team on three occasions, and the participant was called and reminded on one occasion, the medication reminding program was checked on three occasions.

Table 2. Attitudes towards robots and robot mind perception scores at baseline and after using the robot.

	Baseline	*Follow-up*	*t*	*p*
Robot Attitude Scale	56.62 (8.43)	53.60 (9.02)	1.67	.10
Robot agency	21.22 (10.42)	16.87 (8.62)	2.95	.007
Robot experience	12.27 (7.22)	12.08 (7.81)	3.27	.90

3.1 Interviews about the robots (N=26)

When asked how they felt about the robot, 17 responses were positive and included: being a friend e.g. "I felt like I had a friend in it…"; feeling "OK" or "comfortable" with it; and finding it interesting. There were three negative responses, e.g. "It was a chore. It would be less of a chore if it worked properly", and one mixed response "Quite comfortable except 3-4 times in the night when it woke us up".

They were asked how people reacted to the robots: 22 described positive reactions, e.g. "Amazed and delighted". There were two mixed responses. Five people said that no-one else used it, 8 said 1 or 2 people, 5 said 3-5 and 3 said more than 7 others.

There was a range of how often people reported using the robots. 17 people reported using it at least once a day everyday primarily for medication reminders, 2 people said every second day, and 6 people reported not using it much, and one not at all.

Ten reported that the robot had no effect on their lives. Seven reported positive effects, 3 neutral and 4 negative. The positive effects included companionship (2), relief from going to the medical centre (1), photos bringing back memories (1), adding interest (1), entertainment increasing happiness (1), and reminders (1). Negative effects included: "boring and frustrating", "the camera… was an invasion of privacy…it was quite disturbing when it got the medications wrong".

Participants reported the comments that other people made about the robot. 14 reported positive comments, 5 reported negative comments and 3 reported mixed comments. Positive comments included interest, cuteness, amusement, privilege, "wow that's great", "quite amazed", "good for keeping brain alert, they wanted to take their BP and the brain test". Negative comments included "it was a pain in the backside", "husband does not like it", "grandson was disappointed". Mixed comments included

"Good idea but needs more developing", and "some people passed it off as something to learn about and enjoy. Some people ignored it. Some thought it was stupid."

Seven people reported that the robot was not useful. Seven reported that the medication reminding was useful, 6 reported entertainment was useful (2 entertainment, 1 athletic pictures, 3 music, 1 brain fitness), one reported the reminders, 2 reported the Skype function, 3 blood pressure, one the date and time, one that it was useful as a night light, "keeping wife happy", "Felt like someone was taking care of me".

Suggested changes were: continuous music (2), relaxation music (1), better music (1), more music (1), do the washing up (2), vacuuming (2), make easier to turn off (4), fewer leads (1), able to pick up emotions (1), hold a conversation (2), more internet (1), exercise program (1), turn down noise/brightness (1), program it myself (1), make voice less condescending (1), did not like the metallic squeaky voice (1), did not like how it said "have a nice day", increase its memory; 7 said no changes.

The participants were asked how they would feel about having a similar robot all the time. Nineteen said that they would not want it – reasons included: being out (1), don't need it (1), not enough room (4), don't need medication reminder as can remember (3), does not do anything for me (1), needs to be built up (1), not enough time to use it (1), hard to move/switch off/needs more programs. Three people said they would like to have one, and two that they wouldn't mind, and one that it would be like a television or radio that they would switch on/off.

Sixteen people reported that the size/shape/appearance were OK or good, two said the robot was too big, two wanted the screen bigger/clearer. One liked the robot because it looked like a teletubby. Three said it was cute and one that it was attractive; one liked the eyes and grin. One said it was unusual, and one that it looked like a robot. One wanted to be able to turn it off and put it away.

Other comments included: would like it to have an event reminder, video Skype, radio stations, the robot was friendly and comfortable, too many researchers and forms to fill out, the robot would be useful for others but not for me, it should show the medications, if it worked properly it would be useful, not good for someone who is really sick because not interested, blood pressure was unreliable; marvellous bit of technology, enjoyed the study, the study was fun, useful and interesting.

4 Discussion

This report describes a trial of healthcare assistant robots that were deployed at a retirement village for a three month period. The robots provided a number of services and communicated with a server over wireless links. The trial shows that it is possible to deploy robots in such an environment, and that people can use the robots. There were no benefits or harms to QOL, depression or adherence with medications.

Together with our previous studies the results of this larger deployment of robots show that some older people are able to interact with robots and may accept robots, and that it is feasible to deploy robots in a retirement village setting. There were many positive and some negative reactions expressed about robots. No other studies, to our knowledge, show improvement in QOL, medication adherence or depression due to robots in homes. It may be that a much larger trial would show significance; quality of life changes are difficult to show and require large numbers of interactions.

There were a number of challenges conducting this trial. First, while the number of robots was larger than previous trials, the power of the study to find significant effects was small. Second, care had to be taken that the robots did not cause participants to make mistakes in adherence. For safety, we chose participants who usually managed their own medications, and a nurse and physician remotely monitored responses.

There was a significant decrease in perceived agency of the robots by older people in independent living after interacting with the robot. This may reflect an adjustment from unrealistic expectations about robots to a more realistic position, an effect we have previously observed [13].

People's comments about the robots were mixed. Many negative comments were of a relatively minor nature, and might be addressed by improving the robots' software, providing more customization of services to the particular needs of the users, and more business work flow focus on the purpose of robots in particular scenarios.

Overall in the participant responses there is a background theme that reflects the lack of a clear value proposition for the robots' activities in the trial, including direct comments about what the eventual purpose of the robots would be, and indirectly some ambivalence to the robots. The robots were deployed doing various tasks and people were asked to respond about how they considered the robots. However the robots were not deployed in the operational activities of the retirement village, and there was no articulation or expectation that robots were required to achieve any operational objectives; the main goal was to see whether adding robots to the environment would alter quality of life or have any risks. Operational deployment is the next phase for the Healthbots project, where the efficacy, costs and benefits of the robots and applications will be evaluated for specifically designed activities in an operational scenario where the robots are filling a clear operational role in healthcare.

5 References

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