Human-Robot Interaction Research to Improve Quality of Life in Elder Care – An Approach and Issues

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Abstract

This paper describes a program of research that aims to develop and test healthcare robots for elder care. We describe the aims of the project, the robots developed, and studies we have performed in HRI in elder care. We highlight research design issues that have become apparent in the retirement home setting when testing robots. These issues are relevant to robotics researchers wishing to evaluate the effects of robotic care on older people's quality of life.

Description of healthcare robot project

The aims of this project are to develop robotic technologies to help older people either in assisted living facilities or in their own homes. The robotic devices should help with everyday living, with the aim to improve health outcomes and quality of life. The technology should be safe and not cause any harm.

We are motivated by the need to provide care for some older people, the growing number of older people around the world, expected difficulties in finding enough care staff, and recent advances in mobile robot technology that have the potential to help.

Our project is jointly funded by the New Zealand Ministry of Science and Innovation and by the Korean Ministry of Knowledge Economy, via the Electronics and Communications Research Institute (ETRI), with Yujin Robot. It has been running since July 2008 and current funding continues in to 2012, with other funding applications under review.

The joint project is based at the University of Auckland, New Zealand. The academic research team is multidisciplinary and includes engineers, computer scientists, psychologists and psychiatrists, gerontologists, general practitioners, physiotherapists, and healthcare informatics researchers. The project includes New Zealand and Korean technology companies with the aim of commercializing the robotic platform and software in a low-cost form.

We formed a collaboration with a non–profit retirement village (Selwyn Village in Point Chevalier, Auckland, New Zealand). The village is enthusiastic about using technologies to provide the best care to residents. The village has 165 low-level dependency beds, 150 high-level dependency beds, 16 dementia beds and 300 apartments/units for independent living. Staff and residents at the village have taken part in studies on this project, as described in the next sections.

Approach

Our approach has progressed in a series of steps, which are outlined below.

Literature review

The first step in our research was to conduct a literature review of existing healthcare robots for older people (Broadbent, Stafford, and MacDonald, 2009). This identified a number of healthcare robots that had been manufactured but were not successful because people did not want to use them. It is clear that user acceptance is a cornerstone of the project. Our review focused on several robot and human factors central to acceptance, including age, gender, and expectations of the user, as well as appearance, tasks, and behavior of the robot. The review found that for robots to be successful they should perform tasks that are matched to the needs of the user, and that the robot's appearance should match the task they perform.

Acceptance studies

In conjunction with the review, we conducted some initial experiments on a Peoplebot robot that we already had in our Robotics Laboratory by attaching a blood pressure meter (Broadbent et al., 2010). These experiments helped to establish some reactions to basic socially assistive healthcare robots and investigate the salience of some fundamental HRI variables. Positive initial attitudes and emotions towards robots predicted higher ratings of the robot interaction. We conducted another experiment where we varied the robot's synthesized voice accent (Tamagawa et al., in submission). A robot with a local New Zealand accent was rated as having a better performance than a robot with a U.S. accent (and the U.S. accent was rated more robotic-sounding). This step illustrated to us that the accent of the robot's voice and users' expectations were important considerations in the introduction of a healthcare robot.

Identifying needs

Before designing a new robot specifically for elder care, we conducted a study to establish the needs, preferences and concerns of the user group. We ran focus groups and a questionnaire study at Selwyn Village with staff, residents, and relatives of residents (Broadbent, Tamagawa, et al., 2009; Broadbent et al., in press). These studies showed that the key healthcare tasks people wanted the robot to perform in the village were detecting when someone fell over and automatically calling for help, detecting when someone who had dementia wandered away from the village, reminding people to take medications and about appointments, and measuring vital signs. Other highly rated tasks included physical assistance for lifting heavy things, cleaning, turning on and off appliances and lights. We decided to focus on the healthcare tasks that required cognitive assistance, and so did not require manipulation of objects nor a very strong robot as the available robot prototype was not structurally built to carry weight. Software development aimed to facilitate the functions of the robot according to the needs identified.

These studies found that the preferred height for the robot was about 125 centimeters, that people wanted the robot to look more machine-like than human-like, and the preferred color was silver or white.

The robots

Based on these results we chose Cafero (an existing robot made by Yujin Robot, Korea) to be the platform. Yujin modified the design to take off the arms as this would make the robot less expensive to manufacture, and these were not critical for the tasks that the robot had to perform. We chose not to have a face on the robot's screen because earlier focus groups had said they did not want a face on the robot. Figure 1 shows a picture of the modified Cafero robot (Charlie). We have used Charlie in our studies to date at the village.

A smaller 'iRobiQ' robot from Yujin has been programmed with the same software and is currently being tested as a table-top robot (see Figure 1).

Figure 1. Charlie the modified Cafero robot (left) and iRobiQ (right)

Both robots use wheels to move around flat, indoor environments, on carpet, tiled or wooden floors. The navigation system uses specially installed ceiling markers, which are detected by an infrared illuminator and camera on top of the robot. The robot must survey the markers initially, to create a map. The robots have additional sensors (a laser range finder and sonar sensors) to detect nearby objects, and very close objects. They are able to avoid obstacles while moving. The robots each have a camera, and a touch screen for interaction. The robot interaction software runs on a single board PC using Windows XP. Applications are programmed in Flash/ActionScript 3.0 and C++, and use Yujin's proprietary robot services programming interface for controlling low-level functions. The robot interacts with the user by speaking, displaying messages/images/video/text on a touch screen, accepting user input on the touch screen and by receiving speech commands. There are also interfaces to the robot's hardware (sensors and movement system), to a face recognition service (using OpenRTM) and to web services for external data storage (for example medication data). Applications include:

- Taking vital signs measurements using connected off the shelf devices (blood pressure, pulse oxygen level, blood glucose level). The blood pressure device also measures arterial stiffness by calculating augmentation index (from Pulsecor, NZ).
- Reminding people to take medication.
- Responding to a fall that is detected by accelerometers worn by residents, and signaled through a Zigbee network. The robot response may include a telepresence link (a video stream) to staff. In

addition, locations, activity and falls are shown in a friendly GUI on an iPad device that is available to staff.

- Greeting and user authentication
- Entertainment (music videos, quotes, pictures)
- Telephone calls to phone numbers using Skype
- Brain fitness (from a commercial company)
- Rating the application and the robot interaction experience.

The user interface is carefully designed to tell the user exactly what to do at each step. For example, the user is explicitly asked to push the continue button to proceed to the next step.

HRI studies in the retirement village with the healthcare robots

In our first cross-sectional study, the robot was placed in a show-home at the back of the village, and 53 residents and staff interacted with the robot on a one to one basis for about 30 minutes. Participants completed a questionnaire before and after the interaction. Results showed that the robot was rated highly - on average 80/100. The attitudes people held towards robots before meeting the robot were important in predicting how much they enjoyed the interaction. Attitudes towards robots improved after the interaction (Stafford et al., 2010). The robot was also tested in a small study of medication management in private rooms.

The feedback people gave us about the robot was used to improve the applications. Other applications were added including making telephone calls from the robot, face recognition, voice recognition, and brain fitness software (in the form of quizes, and memory games).

Our subsequent studies have a longitudinal design. We based the robot in a lounge at a low-level dependent-living building, and in the lobby at the independent living parts of the village for two weeks in each location and monitored peoples' reactions and responses using video, questionnaires and interviews. The robot visited a small number of residents in their own rooms each day. Written informed consent from residents and residents' families and staff was obtained before engagement in completing questionnaires and interacting with the robot. Accelerometers were placed on the waist and the wrist and accelerometer data captured and initially stored, and then fed to a central iPad in real time through the Zigbee wireless network. This was in preparation for an interaction with the robot directly. Data analysis is underway.

Issues to be aware of in research in this setting

During the course of our studies at the retirement village, we have identified a number of research issues that we think are critical to successful research in this environment. Here, we discuss these issues.

Software development process

From the experience of the first trial, we significantly changed our software development process. In the first trials, we tried to gather all application requirements from the researchers in the group before starting the design and development. However, later it was found that the initial requirements were not complete and domain experts suggested several changes to the software just before the trials. Therefore, we had to go through several iterative steps, which were unexpected during the planning phase.

Our experience in the first robot trial (Jayawardena et al., 2010) included some delays in the initial stages, because we needed more onsite testing and software improvement than we expected. The process of software improvement was difficult since detailed requirements were often changed during initial on site testing, requiring software engineers to modify the software during the testing process, which led to further errors and continued testing and improvement. In addition there were difficulties communicating new requirements and we found it necessary to carefully document all variations, gain approval from the group, and only then update the software. This reduced misunderstandings, and the need for repeated changes for the same issue. In a multidisciplinary environment, the opportunity for misunderstanding is much higher; it is important to specify requirements and variations very clearly so that everyone understands exactly what the robot will be doing once specified changes are made.

From that experience we learned that in order to maximize input from the domain experts, we should add enough flexibility to the software by introducing customizability. Therefore, for the second trial, we developed a method to customize the interaction flow on-site. In this method, the interaction flow is specified in an XML file and therefore domain experts can author or change the interaction flow or the behavior of the robot on-site, without modifying the source code.

Robot testing and field customization

Robots must be thoroughly tested prior to being introduced to the participants.. Effective testing is a challenge for a number of reasons. Firstly, software developed in a research environment rarely meets production requirements. Yet the environment is a real one, not a laboratory environment, and it is important to minimize software errors so that the research study results accurately reflect the participants' interactions with working software, rather than their frustrations with software errors and crashes.

The XML based approach explained in the previous section reduced the cycle time for testing and improvement of the robot's interaction, since changes could be made on the spot, and for example a psychologist and an engineer could work together to try changes and together ensure the design was implemented as both people expected. Also there were fewer errors generated by on-the-spot changes, since changes to the XML file rarely caused other software bugs (whereas changes to software source code can often introduce minor errors, which lead to more testing and further bug fixing). Our plans are to create user-friendly robot application development tools that are usable by non-programmer researchers, for developing and modifying robot applications for trials.

Also as a result of the first trial experience, we extended the testing plans for the second trial, and included a testing period on site at the retirement village, and then returning the robot to the laboratory for further software development, then further tests at the retirement village. Unfortunately the time for testing was reduced by scheduling requirements and even after we followed the shortened testing process, there were still software errors to resolve on site. After one part of the trial was complete, we returned the robot to the laboratory for a period, and then later continued the remainder of the trial, which went well and with almost no errors to address. We feel therefore that our process for testing is adequate, but more time should be assigned. During the trials, there were a few software errors that we had to work around (including crashes from external services). It is important to extensively test the robot on site, and leave time for correcting errors.

A final challenge is to ensure that researchers take a production approach to developing the software and the trial proceedures. In the retirement village, it is important to present a professional approach, rather than the trial and error process that many researchers adopt in a laboratory, and include researchers in healthcare, psychology and engineering.

For all the reasons above it is important to provide a high level of initial detailed project planning, and day to day project management of the trial, to ensure that the trial goals are met with a high level of integrity, despite the variety of daily issues that arise, and the pressure from the field environment to change the trial process in an ad hoc fashion. The trial project plan should include all aspects of ethics application, recruitment, enrolment, staff and resident communication, robot deployment, multiple stages of testing, logging, resources and information recording. The plan should be managed during the trial to ensure it is followed, and variations are managed correctly.

Daily schedule

We found that only during part of the day are residents generally active and therefore interested in interacting with the robot. In the rest home, there were many organized activities, and our plans had to work around the daily schedule. Around meal times there was a lot of traffic in the building and the robot could receive some attention from residents. At the independent living apartment block, there was activity during the morning and early afternoon, especially near lunch time (lunch was provided in the dining room for anyone in the village), however in the evening the building was very quiet (residents provided their own dinner). Plans for robot interactions must be designed around the normal daily activity of the potential participants, and to take advantage of opportunities such as traffic to meals.

Informed consent

Informed consent is a key principle of ethical research. Typically, ethics committees (or Institutional Review Boards) require written information sheets be given to potential participants and consent forms must be signed. This can be problematic in research in elder care, due to cognitive decline. Enduring power of attorney (POA) for personal care can be given when a person is judged as not being able to care for himself/herself. Here someone else can be given the power to make decision for a person who has lost the ability to make decisions for themselves. In this situation informed consent must be gained from the person with the power of attorney, who is often a relative.

When there is insufficient cognitive capacity to make decision and an enduring POA has not been appointed a statement can be made by a close family member/whanau member as to the view that the person would have wished to participate and that the research is in their best interests. The ethical processes around informed consent for vulnerable elders need to be thoroughly understood and debated with the ethics governance bodies prior to embarking.

Even when an older person in elder care can make their own decisions to take part, cognitive decline and physical fragility mean that reading long information sheets takes a long time, people may become too tired in one session to complete the consent and other set up requirements for the study, and people may wish to talk with their relatives to get their opinion before agreeing to take part.

Working with older people in research takes extra time and explanations are more successful in person rather then by written communication only. Discussion with families and caregivers should be expected. Another option is to do research in a public setting where people are normally 'on show' where an ethics committee may grant researchers permission to do observations without getting written informed consent from each individual participant. Examples from other areas of research include conducting observations in a shopping centre or in the street. Anonymous research can also sometimes have more relaxed requirements where choosing to complete the assessments constitutes consent. Researchers are advised to consult their local IRBs or ethics committees for advice for their locality.

Confidentiality

Confidentiality is another key component of ethical research. Researchers should be aware that data collected must be kept confidential and no reports should be published that include participants' identifying information unless the participant has given his or her written consent for this information to be released.

It is important to ensure that confidential information used by the robot is not shown during a public or media demonstration. For example, old data should be erased or not used when showing options for a recognized participant during a public demo.

It is also important to carefully record and backup data that is removed when results are anonymized, and then ensure that backups of all data are securely stored.

Informing staff and residents

Research conducted in a retirement home setting needs to consider the viewpoints of the staff. Consulting and informing the management and staff (including nurses and caregivers) is critical to gaining support for studies.

We have learned it takes time to inform all the residents and staff about the robots and what the research is about. Although some residents and staff were wary to begin with, this changed over time with information and experience. Researchers should be aware that it can take time for the momentum of studies to build.

Senior management agreement is essential, so that staff receive encouragement for the study from their supervisors.

Qualitative and Quantitative designs

Researchers need to decide what kind of research they wish to conduct based on their research questions. Generally there are two approaches – qualitative and quantitative designs. Qualitative designs often approach research with a more flexible view of reality: reality can be seen as constructed by people rather than there being one objective reality. It aims to understand phenomena in a natural setting and includes methods such as ethnographic studies, focus groups, open-ended interviews and data analysis techniques such as grounded theory, where data is explored for meaning and understanding. Qualitative studies are most useful for answering questions that you know little about, such as, "how will people with dementia react to this robot?". Typically qualitative research has a low number of participants. Quantitative designs assume there is an objective reality to which we can gain access via precise measurement and observation. Quantitative designs include experiments and surveys, and measurements are made. Typically statistical analysis is performed to assess whether the findings are statistically significant (i.e. not due to chance). Questions suited to quantitative designs in HRI can include counts, such as "how many people decide to interact with a robot?, how long for?, and how does altering the face on the robot change the number of people who approach the robot?", as well as questions like "Can falls be reliably detected with use of an accelerometer?".

The choice of design depends on the research question. The remainder of this paper focuses primarily on quantitative designs, as they are suited to the question "Can a robot improve quality of life in elder care?" By measuring quality of life before and after the introduction of a robot to one group, and comparing this to a control group who do not get a robot, we can see whether the robot can improve quality of life.

Inclusion and exclusion criteria

Researchers should carefully describe the criteria that describe eligibility for study participation. These criteria include geographic location and demographic details. Exclusion criteria may include things that will make the data hard to interpret. For example, in an HRI study in elder care a researcher may choose to exclude people who are unable to complete a written questionnaire. While this will limit the generalisability of the results to only people who can do this, it may be a practical requirement for the study. Researchers must carefully decide inclusion and exclusion criteria before starting. The criteria should be chosen after a clear analysis is undertaken of the trial environment and population. In an older care study, this includes analyzing the extent of dementia and the physical and cognitive stamina and abilities of the pool of potential participants.

Measurement of outcomes

In HRI there are several means by which data can be collected. These include:

- Oral interviews
- Physiological measures e.g. blood pressure
- Self-report written questionnaires
- Questions asked by the robot
- Video recording of behavior
- Observer ratings e.g. by caregivers or researchers
- Movement and falls data

It is possible to collect all these kinds of data in an elder care setting. However researchers need to be aware of participant burden and the impact of age on the ability of participants to complete long questionnaires and assessments. Older people tire more easily than younger people and it takes longer for them to complete assessments. Where possible, researchers should aim to minimize participant burden by using short measures. It is recommended that researchers are available to assist older people in questionnaire completion where required. The greater likelihood of vision and cognitive deficits in older people can make mistakes in unaided questionnaire completion more likely, compared with younger participants.

We found the study design, and practical management of the overall trial process, were constrained by the stamina of many older people for sustained periods of interaction:

- With a researcher, during enrolment in the study and for completing questionnaires,
- With a researcher, for collection of speech and face image samples, and
- With the robot.

It is important to minimize the first two requirements, and maximize the opportunity for the third, so that people interact more with the robot. We are considering automatic and indirect methods for collecting results and information, in order to reduce the cognitive demands of the first two methods.

Researchers also need to be aware of the reliability and validity of measures. Reliability refers to the extent to which a measure assesses the same thing each time without error. Validity refers to whether the measure is assessing what is intended. Questionnaire authors usually publish reliability and validity information that researchers should consult.

The benefit of video recordings is that the interactions can be watched repeatedly in order to code behaviors and speech. Using more than one kind of measure can help assess your outcomes in a more comprehensive way. We feel that multiple measures are particularly important in robot studies since HRI is still a developing area.

We next turn to some key constructs that researchers in this area may wish to assess and describe ways in which these may be assessed.

Risks and benefits

Studies should include an assessment of risks of the robot as well as benefits. Risks may include injuries to residents resulting from the robot, or increased confusion or agitation. Risks should be monitored during studies and will be a carefully thought through component of large trials involving greater numbers of people and robots.

Quality of Life (QoL)

Providing good quality of life should be an aim of long term care institutions for older people (Cotter, Savage, Meyer, & Bridges, 1998). QoL is a broad construct and generally is agreed to encompass mental and physical health, perceptions of wellbeing, physical functioning, and social functioning. Other domains in elder care may include privacy, choice, dignity, meaningful activity, and enjoyment (Kane, 2001). Measured physical function is inherently related to overall function and QOL and can be objectively measured even in very frail people. (Guralnik &Kaplan, 1989; Guralnik et al., 1995). A large number of QoL measures exist and the researcher needs to carefully choose a measure by taking into account the physical and mental capabilities of the people in the study, as well as the domains that the researchers aim to improve. There are some questionnaires especially developed for people with dementia, and others especially for people with chronic diseases. There are also generic measures that allow you to compare across different populations. It is often advised that researchers include more than one QoL measure – a specific measure designed for the type of population you are studying, and a more general commonly-used measure designed for the wider population. This allows your research to be sensitive to the specific needs of the study sample, and to allow your results to be compared with research in other areas. A widely-used general measure of Quality of Life is the SF-36, for which population age-based norms exist (Ware & Sherbourne, 1992).

Acceptance

For robots to be successful, it is critical that people use them. The Technology Acceptance Model (Davis, 1989), proposes that ease of use and perceived usefulness predict use. The Unified Theory of Acceptance and Use of Technology (UTAUT) adds social influence and facilitating conditions to the equation (Venkatesh, Morris, Davis & Davis, 2003). More recently, the Almere model has adapted the UTAUT specifically for the acceptance of socially assistive robots in elder care, which adds anxiety and attitudes towards the robot (Heerink, Krose, Evers, & Wielinga, 2010). These models can help make researchers aware of the factors that may influence use. The primary outcome of interest in acceptance models is use of the robot and it is important that use is measured carefully. Researchers can measure how often the robot is used by an individual, which applications are used most often, how long they are used for, how many people use the robot, and how patterns of use change over time.

Summary

This paper has described our program of research, which aims to develop and test healthcare robots for older people. We have developed a healthcare robot specifically for older people based on the results of focus groups and questionnaires, and tested it in a retirement village. One of the strengths of our research is the multidisciplinary expertise that we are able to combine in one team, including partners from a robotics company and a retirement village. Another strength is that the research is in an applied setting rather than in a laboratory and we have obtained relatively large sample sizes for this type of research. Little research has tested healthcare robots in elder care settings and we feel the lessons we have learned are valuable for making others aware about research in this setting. In particular, researchers need to be aware of potential issues about integrating software and other technology for a trial setting, gaining informed consent, making sure participant burden is not excessive for older people, taking care to inform staff and residents fully, and that research may take extra time in this setting. Choosing the right outcome measures, including observational and self-report, is important in this research. Careful choice of measure of Quality of Life and use is required. Considerations of these issues will help researchers perform research into how robots can improve quality of life in elder care.

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References

Broadbent, E., Kuo, I., Lee, Y. I., Rabindran, J., Kerse, N., Stafford, R., et al. 2010. Attitudes and reactions to a healthcare robot. *Telemedicine and e-Health* 16: 608-613.

Broadbent, E., Stafford, R., & MacDonald, B. 2009. Acceptance of Healthcare Robots for the Older Population: Review and Future Directions. *International Journal of Social Robotics* 1: 319-330.

Broadbent, E., Tamagawa, R., Kerse, N. M., Knock, B. W., Patience, A. A., & MacDonald, B. A. 2009. Retirement home staff and residents' preferences for healthcare robots. In Proceedings of the The 18th IEEE International Symposium on Robot and Human Interactive Communication, 645-650. Toyama, Japan.

Broadbent, E., Tamagawa, R., Patience, A., Knock, B., Kerse, N., Day, K., & MacDonald, B. in press. Attitudes towards healthcare robots in a retirement village. *Australasian Journal of Ageing.*

Cotter, A., Savage, A., Meyer, J., & Bridges, J. 1998. Measuring outcomes of long-term care for older people. *Reviews in Clinical Gerontology* 8: 257-368.

Davis, F. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology *MIS Quarterly* 13: 319-400.

Guralnik, J., L. Ferrucci, et al. 1995. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *New England Journal of Medicine* 332: 566-561.

Guralnik, J. & G. Kaplan. 1989. Predictors of healthy aging: prospective evidence from the Alameda County Study. *American Journal of Public Health* 79: 703-708.

Heerink, M., Kröse, B., Evers, V., & Wielinga, B. 2010. Assessing Acceptance of Assistive Social Agent Technology by Older Adults: the Almere Model. *International Journal of Social Robotics* 2: 361-375.

Jayawardena, C., Kuo, I. H., Unger, U., Igic, A., Wong, R., Watson, C., Stafford, R., Broadbent, E., Tiwari, P., Warren, J., Sohn, J. and MacDonald, B. 2010. Deployment of a service robot to help older people. In Proc. Of 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 5990 – 5995, Taiwan.

Kane, R. 2001. Long-term care and a good quality of life: Bringing them closer together. *The Gerontologist* 41: 293-304.

Stafford, R. Q., Broadbent, E., Jayawardena, C., Unger, U., Kuo, I. H., Igic, A., et al. 2010. *Improved robot attitudes and emotions at a retirement home after meeting a robot.* In Proceedings of The 19th IEEE International Symposium on Robot and Human Interactive Communication, 82-87, Viareggio, Italy.

Tamagawa, R., Watson, C., Kuo, I. H., MacDonald, B. A., & Broadbent, E. in submission. The effects of synthesised voice accents on user perceptions of robots. *International Journal of Social Robotics.*

Venkatesh, V., Morris, M., Davis, G., & Davis, F. 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly,* 27: 425-478.

Ware, J. H., & Sherbourne, C. D. 1992. The MOS 36-Item-Short-Form Health Survey (SF-36), 1: Conceptual framework and item selection. *Medical Care* 30: 473-483.