

The adoption of socially assistive robots for long-term care: During COVID-19 and in a post-pandemic society

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Abstract

The rapid spread of COVID-19 has prompted a surge in the adoption of technology, highlighting a number of potential applications for Socially Assistive Robots (SARs). Our entire healthcare system has been under unprecedented strain, and going forward, we must consider how robotic technology could help improve the quality of care and day-to-day functionality of our care facilities. Herein, we present our human-robot interaction study in a local long-term care centre during the pandemic and the lessons learned from deploying a SAR to screen staff members. We investigate staff acceptance and the influence of demographics on perceptions of the SAR. Results show that overall, staff were positive about the screening robot, and that autonomous screening with a social robot is a potential application in long-term care homes. We further detail the challenges and future opportunities to develop SARs, including recommendations to successfully implement and adopt these robots in a post-pandemic society.

Introduction

Long-Term Care (LTC) staff and residents have been especially vulnerable and disproportionately impacted during the COVID-19 pandemic. In Canada, those in LTC accounted for 43% of COVID-19 deaths, while only for 3% of all COVID-19 cases.¹ While staffing shortages in LTC homes and hospitals were a concern pre-pandemic,² the pandemic has escalated these shortages to a critical level.³ Staffing shortages have impacted not only vulnerable residents but also staff members and caregivers.^{4,5} Health facilities have also had to ensure staff implement strict requirements and measures in addition to their existing duties.

Socially Assistive Robots (SARs) are robots that interact with people using natural verbal and non-verbal communication modes.⁶ They can be easily disinfected and are well-suited for contactless and repetitive tasks. SARs can help keep residents and staff safe by reducing the transmission of viruses by minimizing person-to-person contact.⁷

In this paper, we discuss SARs that have helped healthcare staff during the pandemic. We present the first exploratory Human-Robot Interaction (HRI) study in a LTC home with a SAR for autonomous health screening and investigate staff overall experiences with the robot, cognitive and affective attitudes, perceived safety, efficiency, and intent to use the robot. We also explore demographic effects (age, gender, and occupation) as well as previous robot experience to help explain staff behaviour in the context of technology adoption.⁸ Results of our HRI study are presented and discussed, along with our observations. Furthermore, challenges and future opportunities for the development and deployment of SARs in LTC homes are explored.

Overview of the literature

Herein, we discuss the adoption of technology in organizations, along with how SARs have been helping healthcare facilities during the COVID-19 pandemic.

Adoption and acceptance of robots in healthcare organizations

Due to the pandemic imposing significant health risks, the health industry has been experiencing a technology-driven transformation.⁹ SARs are becoming increasingly more integrated into healthcare settings, including hospitals, private clinics, and LTC homes, where they are helping to limit the spread of the COVID-19 virus.¹⁰ Social robots are also promoting safety measures, and providing companionship to isolated individuals.¹¹ Some important considerations when introducing such a new technology are as follows¹²: 1) what are the goals and interests of different groups within a healthcare organization, and how are they affected by the technology? and 2) what are the stress levels of staff members, and how are these affecting their emotional responses to robots?

One study with healthcare providers in hospitals in Columbia presented a description of three types of robots (telepresence robots, cleaning/disinfection robots, and assistance/logistics robots) to these individuals.¹³ A virtual questionnaire was completed which assessed users' knowledge, attitude towards, and practical use of the three robot types. Participants had an overall positive attitude about the usefulness of robots in helping with managing the pandemic. However, while people might view robots as a potential tool to assist them with their work, most participants had a low level of knowledge and experience with

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these robots, indicating that healthcare professionals may not have sufficient awareness, exposure, or training with respect to the adoption of robots.¹³

Social robots helping healthcare staff during COVID-19

Social robots have helped healthcare staff during the pandemic in hospitals and LTC homes, by performing different repetitive tasks, such as checking for face masks, enforcing social distancing rules, or spraying disinfectants,^{14,15} as well as keeping residents connected to family members through telepresence.^{16,17} In one study, it was found that residents, relatives, and care staff all had positive feedback on the Temi robot used for virtual calls between nursing home or hospital residents and their families.¹⁶ Temi, which can be operated by voice command, was easy to use, and staff found it beneficial since it was autonomous (no supervision necessary). The robot could drive into quarantined rooms, could be easily disinfected, and was easier to use than a tablet. Other robots, such as the quadruped robot Spot from Boston Dynamics, have been used to monitor and triage incoming patients in a contactless way.¹⁸ The mobile robot Lio from F&P Robotics was used to disinfect surfaces, monitor for temperature, and deliver small items in a hospital setting.¹⁹

Social robots have the potential to help residents as well as healthcare staff in high-risk environments such as LTC homes. Pre-pandemic, one study showed the efficacy of using a robot over a tablet in promoting healthcare behaviours.²⁰ Participants were randomly allocated to either a robot group or a tablet group. Those interacting with the robot had higher participation in relaxation exercises, and rated the robot higher on trust, enjoyment, and intent for future use than the tablet group. Another study that compared Finnish and Japanese care workers' attitudes on the usefulness of robots found that culture was an influence, namely, Japanese care workers found robots more useful than did their Finnish counterparts.²¹ A pilot study with the Pepper robot found that staff had more positive views of robots that provided practical assistance.²² However, there have not been any HRI studies to-date focused on healthcare staff real-world interaction perceptions of SARs during the pandemic.

Implementation of a screening social robot in long-term care

We conducted a robot screening study over the course of two months in the Fall of 2021 at a LTC home in Toronto, Canada, with the robot Pepper from Softbank Robotics. Prior to starting the study, Pepper was stationed in the lobby for several days, where it greeted everyone walking by, and described how it would help with health screening at the home. Staff were encouraged to interact with the robot and ask questions of the research team. The robot was then moved from the lobby to the front entrance of the home in front of the reception area. This study was approved by the University of Toronto's ethics board.

Participants

Eighty-four participants were recruited from approximately 200 staff members working at the home. We obtained 56 pre-study and 34 post-study completed questionnaires from them. Flyers with information about the study were placed at the front reception area and in the elevators. A short introductory video with Pepper was also e-mailed by management to all staff members. Prior to the start of the study, participants provided written consent. Each participant was given a unique QR code to use for the screening task during the study.

Study procedure

Staff members participated in the robot screening at the start of two different shifts, at 6:30 a.m. and at 2:30 p.m. As staff entered the front door, they would be screened by Pepper; there was a human receptionist at the front desk to make final screening decisions when staff did not pass Pepper's screening. The steps of the robot screening are shown in Figure 1 and a video of Pepper conducting the overall screening procedure is provided on our lab's YouTube channel: <https://www.youtube.com/watch?v=X6EKXENu9bY>. The average time for the screening task was eighty seconds.

Design

Pepper was stationed at the front entrance of the LTC home, Figure 1. Pepper records each screening event in a file that contains the date and time, along with temperature reading, face mask confirmation, QR code, and screening answers. This file is e-mailed to administrative staff at the LTC home, including after each failed screening.

- Step 1: Staff approach Pepper at the front entrance. There is a box of masks on the table, and a contactless thermometer next to the robot (labelled in the figure).
- Step 2: Pepper greets staff by waving and saying "Hello! I'm Pepper, the health screening robot."
- Step 3: Pepper asks staff to take their temperature, by pointing toward the contactless thermometer, and confirms if their body temperature falls within normal range (<37.8°C). If no fever is detected, Pepper confirms by saying "Great, no fever!" and displays this text on the tablet. If an elevated temperature above 37.8°C is detected, Pepper will say "Please check with reception," and displays the corresponding text on its tablet.
- Step 4: Pepper asks staff to put on a new mask and confirms it is on correctly by displaying an image of the person wearing the mask on its tablet, saying "Thanks!" If the mask is not on properly, Pepper prompts the person again, saying "Is your mask on properly? I can't tell yet."
- Step 5: Pepper will ask for and scan the unique QR code (using its forehead camera) for each staff member. A confirmation screen with the QR code will appear on

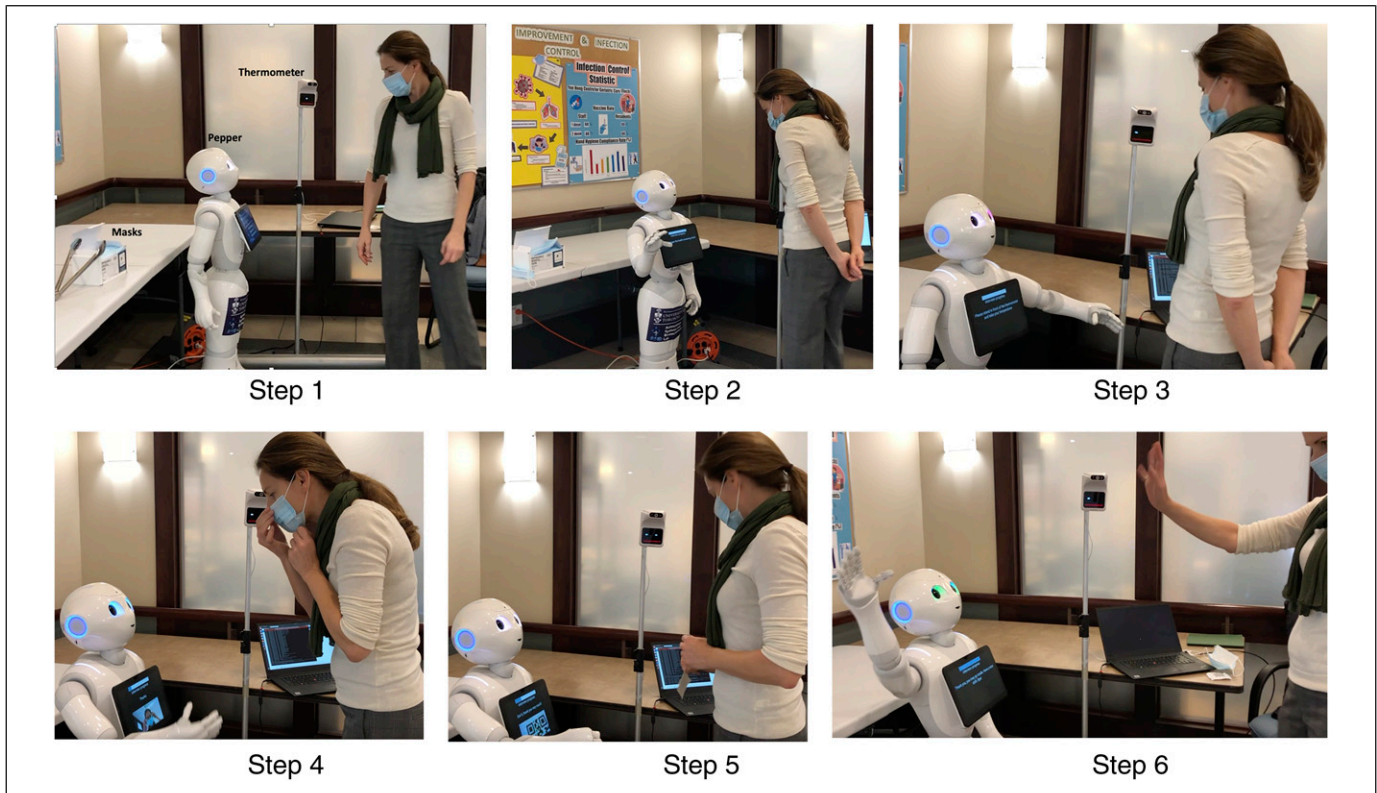


Figure 1. Health screening steps with Pepper.

the tablet, and Pepper will say “Got it, thank you very much!” while displaying the corresponding text on its tablet.

Step 6: Pepper asks health screening questions provided by the Ontario Ministry of Health, to which the staff member verbally responds Yes or No. If screening questions are completed successfully (all answers are No), Pepper waves and says “Thank you, you may go inside. Have a nice shift, bye!” If the process is unsuccessful (the staff answers Yes to one or more questions), Pepper provides a beeping sound as an alert and says, “Please go see reception,” while displaying the corresponding text on its screen.

Study questionnaires

Pre- and post-study questionnaires were handed out to participants, which included 5-point Likert questions. The questions, Table 1, focused on 7 attributes: screening experience, perceived efficiency, cognitive attitude, freeing up staff, perceived safety, affective attitude, and intent to use the robot for the screening task. Participants also provided demographic information: age range, gender, occupation, as well as previous robot experience.

Results

Overall, we found that staff rated all 7 attributes high pre- and post-study, as seen in the box and whisker plot in Figure 2. Herein, we discuss notable differences we identified with respect to these attributes.

Safety

We observed an increase in perceived safety (Q5) after participants interacted with Pepper compared to prior to robot interaction, Figure 2, although this was not determined to be statistically significant by a Wilcoxon Signed Rank (WSR) test. Namely, when asked if “a robot would make the health screening process safe,” a positive difference was found when comparing the median and Interquartile Range (IQR) after interaction with Pepper ($\bar{x} = 4.5$, $IQR = 1$) compared to prior to interacting with the robot ($\bar{x} = 4$, $IQR = 1$).

Previous studies show that perceived safety, which is important for long-term HRI, is associated with comfort, predictability, sense of control, and trust.²³ In our study, staff already believed the robot would make the screening process safe prior to interacting with the robot. This was further validated after interacting with Pepper when they responded even more positively that they believed the robot made the screening process safe. It has been previously shown that direct interaction with a social robot elicits more positive feelings toward robots, as compared to indirect contact,²⁴ and becoming familiar with robots may improve HRI.²⁵

Gender and age

Thirty-one women and 8 men filled out the pre-study questionnaire, while 21 women and 12 men completed the post-study questionnaire. No statistically significant differences were found for women when comparing the questionnaire results before and after interaction with Pepper; their

Table 1. Pre- (Post-) study questions with the 7 attributes.

Questions pre-study (post-study)	
Strongly disagree	Strongly agree
1	5
Q1 (screening experience)	I have had a good experience with the way the health screening (<i>the robot health screening</i>) is being conducted at Yee Hong
Q2 (efficiency)	It would be (<i>it is</i>) more efficient if the screening was done (<i>is done</i>) automatically with the robot
Q3 (cognitive attitude)	I think having a robot ask COVID-19 health screening questions would be (<i>is</i>) a good idea
Q4 (freeing up staff)	Using a robot would (<i>did</i>) free up staff that need to do the screening
Q5 (safety)	I think a robot would make (<i>makes</i>) the health screening process safe
Q6 (affective attitude)	I think a robot will make (<i>makes</i>) the screening process enjoyable
Q7 (intent to use)	I would (<i>would continue to</i>) use a robot to do the COVID-19 screening at Yee Hong

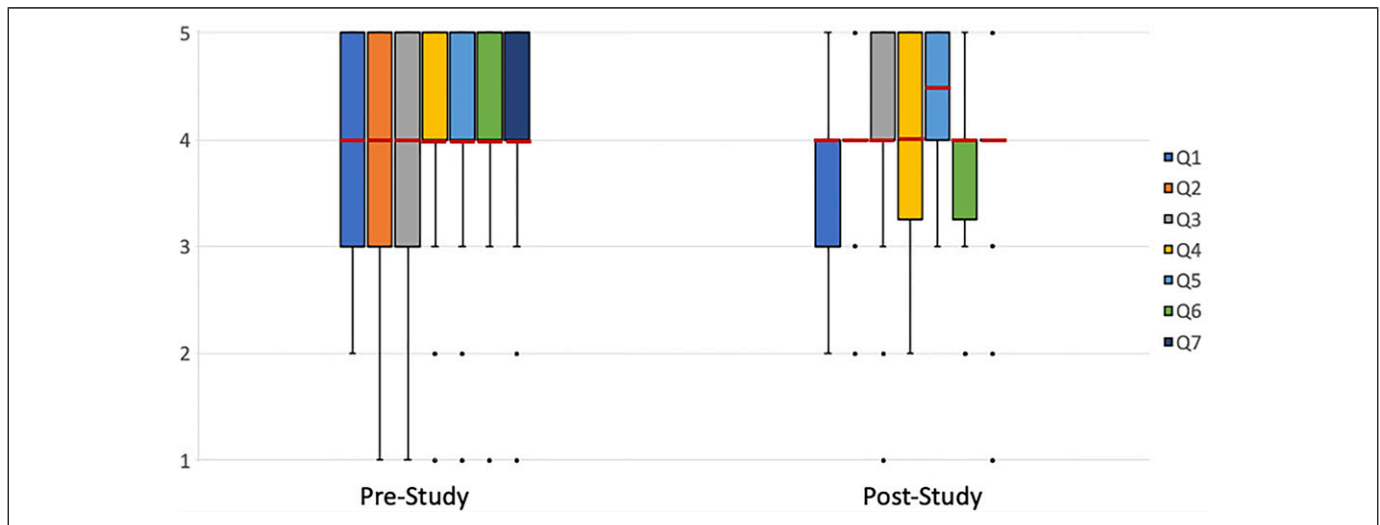


Figure 2. Box and whisker plot of pre- and post-study results for all participants. Median is represented by bold (red) lines, quartiles by the boxes, and minimum/maximum by the whiskers.

responses were consistent across all the seven attributes. However, we did find that men had a greater positive change in cognitive attitude (Q3) after interacting with Pepper, Figure 3. Cognitive attitudes reflect people’s thoughts, such as if they think a robot is useful.²⁴ Namely, when asked if “Having a robot ask COVID-19 health screening questions would be a good idea,” a statistically significant positive difference was found using a WSR test ($Z = 2.000, p = .046$) when comparing results between men after they interacted with Pepper ($\bar{x} = 5, IQR = 1$) compared to prior to interacting with the robot ($\bar{x} = 4, IQR = .25$).

When we investigated the responses between women and men, we found statistical differences in responses after they interacted with Pepper for screening experience (Q1), perceived safety (Q5), and affective attitude (Q6), Figure 4. Namely, when using a Mann-Whitney U test (Q1: $U = 178.5, Z = 2.115, p = .048$; Q5: $U = 186.0, Z = 2.455, p = .024$; Q6: $U = 186.0, Z = 2.439, p = .024$), men were found to have higher ratings for these attributes (Q1: $\bar{x} = 4, IQR = .25, min = 4, max = 5$; Q5: $\bar{x} = 5,$

$IQR = .25, min = 4, max = 5$; Q6: $\bar{x} = 4, IQR = 1, min = 4, max = 5$) compared to women (Q1: $\bar{x} = 4, IQR = 1, min = 2, max = 5$; Q5: $\bar{x} = 4, IQR = 1, min = 2, max = 5$; Q6: $\bar{x} = 4, IQR = 1, min = 2, max = 5$).

Staff age groups were as follows: 1) pre-study: (20-29) $n = 3,$ (30-39) $n = 5,$ (40-49) $n = 18,$ (50-59) $n = 19,$ (60+) $n = 2$; and 2) post-study: (30-39) $n = 4,$ (40-49) $n = 7,$ (50-59) $n = 17,$ (60+) $n = 5$. There were no statistical differences found within the age groups pre- and post-study nor between age groups.

Previous studies have found that men are more technology-ready⁸ and attitudes among men are more positive toward the use of robots.²⁶ Age, however, has not been found to be a barrier to user acceptance of robots in healthcare.²⁶

Occupation

Occupations with similar roles were grouped together, Figure 5, as: 1) Administrators (Admin), which included those working in human resources, reception, information technology, and office

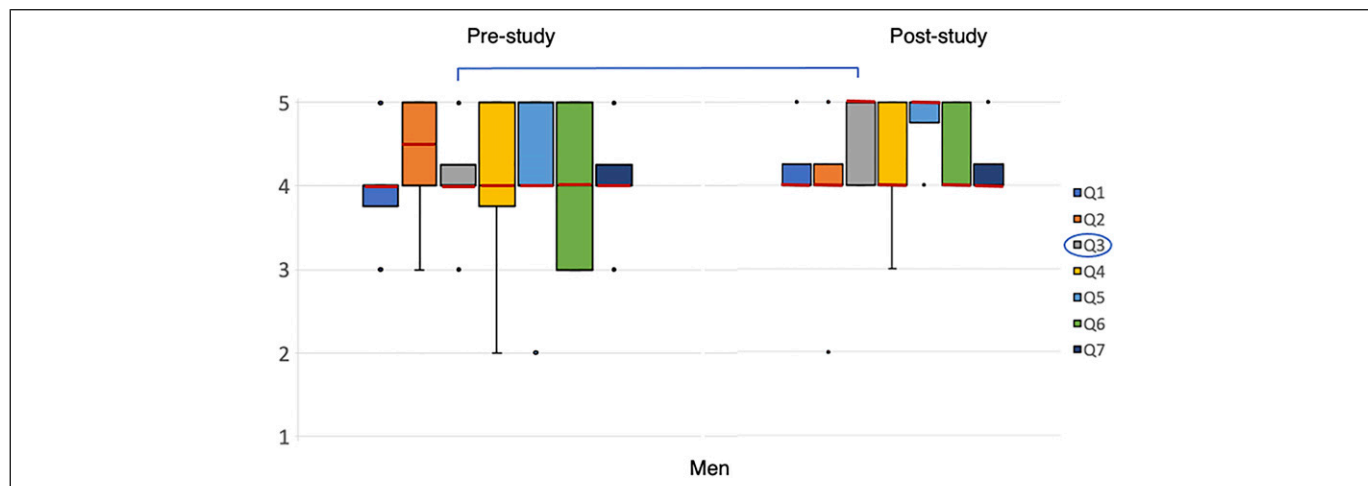


Figure 3. Box and whisker plots of within-subjects comparison (pre- and post-study) for gender. There is a statistically significant increase in Q3 for men post-study compared to pre-study.

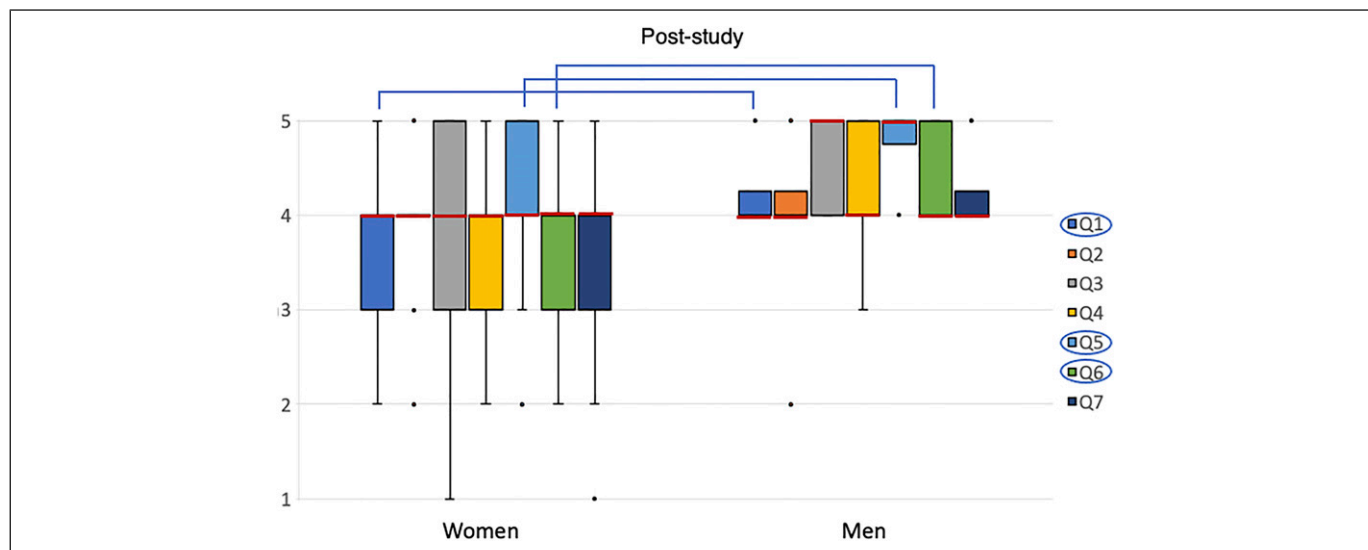


Figure 4. Box and whisker plot of between-subjects comparison post-study for gender. There is a statistically significant increase for men for Q1, Q5, and Q6 compared to women.

management roles; 2) Nurses, which included nurse practitioners, registered nurses, and registered practical nurses; 3) Personal Support Workers (PSWs); and 4) Rehabilitation and Social Care (RSC), which included social workers, recreational and activation coordinators, physiotherapists, occupational therapists, and registered dietitians.

When investigating occupational influence, our results showed that the Admin, Nurse, and PSW groups all had consistently high ratings across all 7 attributes. We found the RSC group showed a slight decrease in response ratings for efficiency (Q2) and freeing up staff (Q4) after interacting with Pepper compared to before interacting with the robot. Namely, a statistically significant difference was found (WSR: $Z = -2.000$, $P = .046$ for Q2 and Q4) when comparing results between the RSC group after they interacted (Q2: $\tilde{x} = 3.5$, $IQR = 1$; Q4:

$\tilde{x} = 4$, $IQR = .25$) versus prior to interacting (Q2: $\tilde{x} = 4$, $IQR = 1$; Q4: $\tilde{x} = 4.5$, $IQR = 1$) with the robot. This could be the discrepancy between the lower number of RSCs who filled out the post-study questionnaire (12%) and those who filled out the pre-study questionnaire (20%), as seen in Figure 5. Post-study participant numbers could have been impacted by staff shortages, and additional lockdowns due to the Omicron variant of the virus.

Previous robot experience

We explored if previous robot experience would influence participants’ expectations of the screening robot. We categorized participants into three experience groups: 1) no experience (n = 12), 2) beginner (n = 12), seeing robots on TV or at museums, 3) moderate-advanced experience (n = 10),

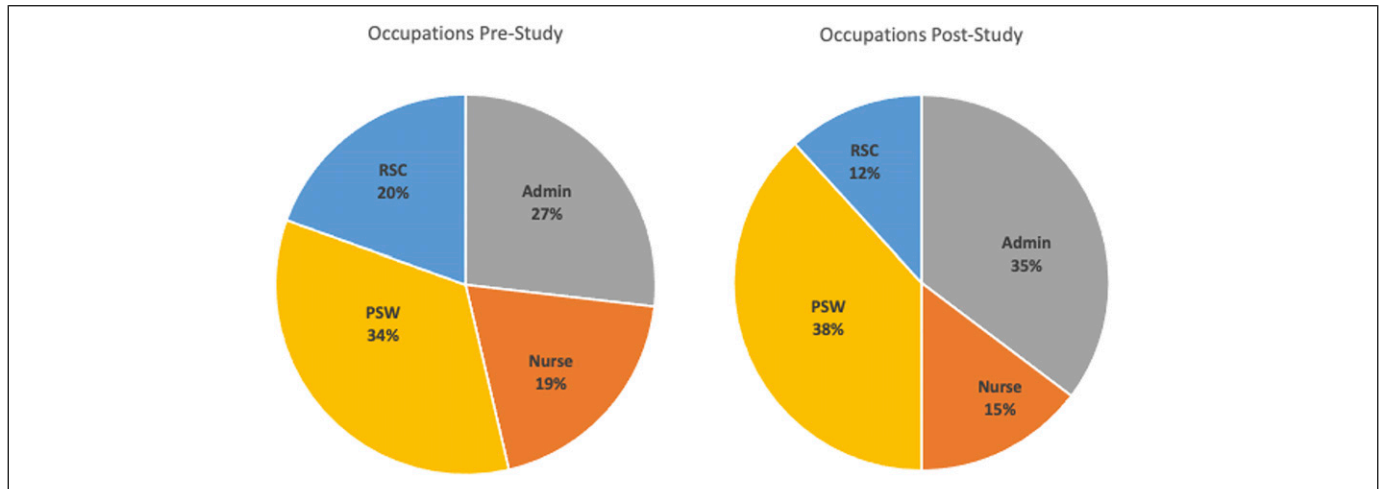


Figure 5. Percentage of participants in pre- and post-study occupational roles.

seeing robots used at their workplace, delivering packages, interacting with residents, as well as hands-on experience using a robot at work. We did not find any significant statistical differences between these groups in their ratings of the 7 attributes as the robot was easy to use and there was no prior training needed to interact with it for the screening task regardless of previous experience with this type of technology.

Discussions and conclusions

Insights and observations

Staff were engaged and complied with the robot during the entire screening task. They followed all the robot's instructions and completed the screening. They would approach the robot, ask it its name, and greet it verbally ("Hi Pepper, so nice to see you!"). Staff ending their shift would also stop to wave and say goodbye to Pepper when leaving and would smile when Pepper waved back at them. In particular, we observed the Nurse occupation group would drop by the most at the end of their shift to talk to Pepper and inquire about how it works. We found that engaged staff became great champions for the robot; a lot of the administrative staff, who saw Pepper more often during the day (and not just at the beginning or end of their shifts), would talk to other staff members about the robot and its potential benefits.

The front desk screening staff, some who were PSWs taking on extra shifts during the pandemic, were eager to learn about the robot's capabilities. They encouraged other staff members to screen with Pepper and recognized how a robot could help (or supplement) their own tasks. This was particularly evident when there were large groups of people, including visitors and staff, entering the home at the same time and the front entrance was crowded. These groups were better managed when there were two separate lines for screening, one for the human screener and one for the Pepper robot. Furthermore, front desk staff started training on setting up the robot for screening, which helped familiarize them with Pepper. The research team put together a

training manual with instructions on how to set up Pepper at the start of the day, do some minor troubleshooting, and to end the screening and put the robot away at the end of the day. The LTC home found that using a robot to automate the screening process for staff was efficient for tracking purposes, since the robot kept a log of everyone it screened with the date and time.

Several demonstration sessions of the screening robot were held at the LTC home prior to the start of the study so that staff could meet the robot and ask questions regarding the technology and the study. During this time, a number of visitors, such as family members, visiting physicians, and even delivery people showed interest in Pepper and would stop and interact with the robot on their way in or out of the home; quite a few visitors took pictures with Pepper, and the robot became a topic of conversation amongst family members and visitors. They treated Pepper as a social agent.

Lessons learned

Integrating a social robot into the workflow of a long-term care home can provide a collective benefit¹² (such as automated tracking of health screening). It is important to assess how staff directly perceive the benefits the robot brings to their work. To successfully develop and deploy SARs, we need to consider the stakeholders, and in LTC homes, the initial primary users are staff members. Understanding the intent and purpose of the robot is necessary for its successful implementation.²⁷ Based on our study findings, successful implementation requires: 1) staff having a positive experience: this can be achieved through introducing the technology, and becoming familiar with its capabilities; 2) increasing efficiency with technology: is it saving time, money, improving on an existing workflow?; 3) improving knowledge of the technology: do staff think it is a good idea, and how can this perception be improved?; 4) workload: do staff feel that the technology is helping reduce their workload over the long-term; this involves training on the technology for the short-term, and enlisting 'champions' among staff members who can promote the technology for the

long-term; 5) perceived safety: in the case of a screening robot, staff can see how the robot increases screening safety through repeated interaction with the robot for this task; 6) enjoyability of using the technology; and 7) intent to use the technology: would staff continue to use the robot for screening?

Technology alone is not enough for the successful adoption of SARs; people from within all levels of the organization should be involved in its implementation. On-site pilot and validation studies of the robotic technology are important, as is collecting real-world interaction data so as to monitor the safety and effectiveness of the robotic technology.²⁸ Moreover, training and familiarity with the robot are key to its successful implementation, so healthcare workers can quickly engage the robot to perform specific tasks or give effective guidance on how to use the robot to others who need it.²⁹

Challenges

Some of the challenges of implementing social robots in healthcare from a staff perspective include user acceptance (setting user expectations), familiarity with the robot, and training. Technical challenges include speech recognition, navigation, and autonomy. Ethical challenges include data privacy. Policies can be put in place to help safeguard and regulate data collection and data sharing.³⁰

A main technical challenge to implementing social robots in a healthcare environment, as we have seen in our study and which is an area of ongoing research, is speech recognition.³¹ Noisy environments, such as a lobby or front entrance of a healthcare facility, make it difficult for robots to detect speech, particularly if there are multiple people talking at once. Multimodal inputs for the robot (speech, touchscreen, and gestures) are essential for HRI as users have different needs and expectations, and environment conditions can vary.³²

Cost and deployment considerations

The autonomous robot screener would assist the front desk personnel with the screening task to minimize the need for additional staff to be relocated for screening purposes. The robot could screen staff during the start of all staff shifts during the day, as well as visitors throughout the day, which would be a potential cost savings of approximately \$99,000 CAD/year for staff reassignment at the home based on average wages during the pandemic. As this is a research platform and initial trial project, the screening robot is not yet a commercial product, and the overall design and manufacturing costs cannot be fully considered at this time. Taking just the hardware cost of the robot into account (approximately \$28,000 CAD), this would result in an approximate total cost savings of \$71,000 CAD. It is important to note that the screening software is not dependent on a specific robot platform and can be implemented on other robot platforms as needed.

The robot screener is especially useful during times when a surge of staff and visitors arrive to start their shifts or visit residents. This would alleviate the screening burden for the front desk staff. Additionally, the social robot can be used to perform

multiple tasks at the front lobby, including greeting visitors, answering questions, and providing directions. The robot has been designed to be easy to use, and staff only required a one-hour hands-on training session on the robot's functionality. They were also provided with a manual and short video of the robot screening task.

If there are multiple entrances to the home, a screening robot can be positioned at every entrance or even each floor to assist with screening and safety measures. Alternatively, it can be easily relocated to high traffic places, including across multiple facilities within an organization (long-term care, retirement, and hospice). Our previous social robots have also assisted residents with a number of activities of daily living^{33,34} and facilitated cognitive interventions (card games, Bingo, and Trivia).³⁵⁻³⁷ This screening robot can be used to help residents as well during off-times.

Future post-pandemic considerations

COVID-19 has prompted a re-evaluation of automation in healthcare, and it is predicted that a shift to automation and telemedicine, which can increase efficiency and help minimize person-to-person contact, will continue post-pandemic.³⁸ There has been an increase in intelligent automation following the onset of the COVID-19 pandemic; as people are becoming more familiar with different technologies, it is likely their trust in technology will increase, creating a receptive environment for their long-term adoption.³⁹

We had the unique opportunity to investigate staff members' intent to use socially assistive technology during the pandemic, and to look at factors that could influence the future uptake of robotic technology in a LTC home. An autonomous robot can help reduce the workload of healthcare staff, by being able to navigate and interact on its own with different individuals including staff, visitors, and residents.¹⁶ In the long-term, SARs should be multi-tasking robots, so they can assist staff and residents with different everyday tasks, from facilitating leisure activities,^{35,36,40} to activities of daily living,^{33,41,42} and robots could prioritize the order in which to fulfill the tasks, taking on different roles as needed. To make interactions more natural and intuitive, social robots should adapt their behaviour to different users.⁴³ Additionally, staff acceptance can be an important determinant of whether a technology is adopted over the long-term, and local champions of the technology play a key role in persuading their peers.⁴⁴

Creating a technology-positive culture within an organization is a long-term process.²² In situations where human contact is restricted or prohibited, such as during a pandemic, SARs can help minimize the health risks for healthcare staff and vulnerable older adults.^{45,46} Post-pandemic, the adoption of SARs can continue to help support staff and residents with specific repetitive tasks in a multimodal interactive way. SARs have a significant potential to help with repetitive tasks if we design them to meet the specific needs of users, both during COVID-19 and post-pandemic.

Looking forward, it is important to assess how and where SARs can best provide assistance in long-term care settings, as well as the human factors involved in deploying, interacting with, and the acceptance of SARs.

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