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Usability Testing for the Operation of a Mobile Robotic Telepresence System by Older Adults

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Mobile robotic telepresence (MRP) systems feature a video conferencing interface on a mobile robot, enabling pilot users to remotely control the robot while communicating with a local user. For older adults in an assisted living facility, the operators are mostly caregivers or remote family members. This small-sample usability testing aimed to evaluate the use of MRP by the older adult. Participants navigated the robot to locations in the home, e.g., to check if the front-door is closed. Two levels of automation were introduced; assisted teleoperation and autonomous. Observations revealed that the older adults enjoyed the dexterity with which the robot could be teleoperated in the assisted teleoperation mode. Yet, they preferred the operation of the MRP at the autonomous mode where the robot navigated autonomously towards the locations the user indicated. Usability, preference and objective findings raise awareness regarding elder care assistive robot developmental factors. Future experimental plans are discussed.

INTRODUCTION

Typical mobile robotic telepresence (MRP) systems are characterized by a video conferencing interface on a mobile robot. This enables a pilot user to remotely control the robot while communicating with the local user (Kristoffersson, Coradeschi, & Loutfi, 2013). An important application of a MRP system is in the care of older adults for various functions such as health surveillance, social interaction and safeguarding (Beer & Takayama, 2011). Usually, a family member, health care worker, or caregiver for the older adult controls the MRP. However, there may be situations where an older adult living independently may also want to control the robot locally to perform other functions in the home such as assisting in locating items (e.g., looking for their glasses or medication), detection of hazards (e.g., to see if the gas stove or the water heater were turned off), video call someone (e.g a family member, friend or colleague), or merely to relocate the robot or navigate it to its charging station. Most studies involving MRP for older adults have mostly focused on control by secondary users and caregivers (Coradeschi et al., 2013; Orlandini et al., 2016; Shiarlis et al., 2013). User studies to evaluate the usability of MRP control by the older adults are still lacking.

This usability study examines one of the potential uses of a telepresence robot which is detection of hazards in an older adult home. Many older adults are living in potentially hazardous environments (Carter, Campbell, Sanson-Fisher, Redman, & Gillespie, 1997). Home safety can be improved if the potential hazards are detected and proactive measures taken (Mayhorn, Nichols, Rogers, & Fisk, 2010). Research has shown that older adults' understanding and experience with home hazards can provide a wealth of insight that could inform the design of hazard detection and warning systems (Mayhorn et al., 2010). We therefore explore as a test case, the detection of hazards in a home-like environment using an MRP system teleoperated by an older adult.

A major factor to consider when introducing robotic assistance for older adults at home is their preference to

maintain a certain level of autonomy as the robot assists them (Smarr et al., 2012). A strategy proposed in the literature to accomplish this balance is through levels of automation (LOA), which involves defining the degree to which the robot would carry out certain functions in its defined role of assisting the user for each specific task. In the case of caregiving, the appropriate LOA is expected to keep older adults active as one of the highlights of independent living for older adults (Olatunji et al., 2019).

A number of short-term evaluations of MRP for eldercare revealed maneuvering challenges and higher workload while manually driving the robot (Cesta, Cortellessa, Orlandini, & Tiberio, 2013; Kiselev & Loutfi, 2012). This spotlighted the driving of the robot as a critical function to apply LOA to, particularly because specific LOA designs that would be suitable, feasible and fitting to the needs of the older adults are still lacking (Vagia, Transeth, & Fjerdingen, 2016). Evaluation of some semi-autonomy features in MRPs to relieve the pilot user from the mental and physical demand of maneuvering the robot have been previously carried out by (Kiselev et al., 2015). This study builds on that by developing specific features for two LOA designs: assisted teleoperation mode and autonomous mode. In the assisted teleoperation mode, the robot supports the user in the process of tele-operating by automatically slowing down when it gets close to obstacles. In the autonomous mode, the user simply selects a target location in the home and the robot autonomously navigates towards it. We explore the usability of these two LOA designs in MRP for older adults at home.

Usability metric of these two modes of operation and user insights were collected from the older adult participants. The outcomes provide preliminary recommendations for design improvements along with detailed experimental plans for more full scale studies. The study reveals an exciting area of development where the older adults are given the opportunity to teleoperate the MRP system at different levels of autonomy.

METHOD

Participants

Four older adult participants (1 Female, 3 Males) aged 66-71, were recruited for the study through snowball sampling. They participated voluntarily in the study. They did not receive any financial compensation for their participation. They spent about 1 hour on the average for the period of the study.

Apparatus

Experimental environment. The study took place in a home-like setup at the Applied Autonomous Sensor Systems, at Örebro University, Sweden, as shown in Figure 1. The home-like environment consisted of a kitchen, living room, bedroom, and a charging area for the robot. Every space in the environment is on a plane level ground with passages for movement as seen in Figure 1. The participant sat in the living room and controlled the robot around the house from the sofa.

Figure 1. A cross-section of the Örebro University home-like environment used for the study.

User interface. The user interface (as shown in Fig.2) was designed to run on a browser. It could be operated from multiple platforms; personal computers, tablets or mobile phones. It was more convenient for the older adults to use a device that they were already familiar with, which is why a personal computer was used in all trials as the operating platform.

The interface contains three screen sections. The left section contains the video feed of the operator of the robot and controls to adjust the output of the video (e.g. the audio volume could be muted or the image pixelated or blurred). This left section also contains the volume settings for the wide variety of the hearing differences that are common among older people. Below the volume settings are the four conventional navigation arrow-control buttons through which the user can direct the robots to go to a desired direction.

The central section of the interface consists of the video scene as depicted by the robot's camera. A flat-cylindrical shaped pointer with a tail connecting it to the end of the screen, serves as the indicator for a trackball through which the user pointed the robot in the direction they wanted the robot to advance. Clicking on this 'pointing plate' and holding on to the click moved the robot physically in the desired direction. This method of control along with the conventional arrow-control buttons on the left side of the interface described earlier constituted the assisted teleoperation LOA mode.

The right section consists of a robot-generated map of the apartment. This map is a reactive top-down view of the apartment with a dynamic position of the robot represented as it navigates in the environment. It contains some letters to indicate specific sections of the apartment for example 'K' for kitchen, 'L' for living room. The robot is represented as a green dot with an attached smaller red dot to show the direction it is facing. The map was reactive in the sense that the user could click on any part of it and the robot would respond in real time by navigating to the point on the map that was clicked.

The right side of the interface also contains 'goal buttons' which the user could click on to send the robot to a specific location in the apartment (e.g., bedroom, entrance) without the need to give direction or specify a path for the robot. These 'goal buttons' along with the map clicking mechanism served as the autonomous LOA mode.

This user interface was not specifically designed for older adult users, but rather for novice users envisioned to be caregivers who would use the system for various purposes connected with navigating the robot to perform tasks remotely.

Figure 2. User interface depicting different levels of automation.

The robot

The robot is a mobile robot with a differential drive and a screen for telepresence (shown in Fig. 3). It has with a mechanical tilt but no pan function. A Hokuyo URG-04LX-UG01 Scanning Laser Rangefinder is attached to the base of the robot for navigation. A Structure Core RGBD camera is fitted to the top of the screen for wide angle viewing. The robot runs standard ROS Melodic with an Arduino-based motor driver.

Implementation of LOA

The MRP system was programmed to operate at two levels of automation.

Assisted Teleoperation mode. In this mode, the movement of the robot is teleoperated using the mouse-controlled pointing plate as a steering on the user interface. Another teleoperation option provided in this mode was the convention direction control keys (left, right, forward, backward) was also provided. The robot was programmed to slow down when close to obstacles to ease maneuvering around obstacles.

Figure 3. The telepresence robot used for the study.

Autonomous Operation mode. In this mode, controls are provided for the user to give the robot a target location, and then the robot autonomously navigates to it. This was implemented through buttons on the bottom right part of the user interface that bore the names of the goals (such as ‘kitchen’, ‘living room’). It was also possible to click on the point of interest on the map and the robot would autonomously navigate to the point.

Experimental Design and Measures

A within-participants experimental design was used. The independent variables were the levels of automation: Assisted teleoperation mode (A) and Autonomous operation mode (B).

The dependent variable was the perceived usability of the system. Performance measures were the number of sub-tasks successfully completed, the number of hazardous objects identified, the number of correct locations of the identified items, number of errors made in form of collisions with walls or obstacles.

Questionnaires. A demographic questionnaire and an abridged version of the Negative Attitude toward Robots Scale (NARS) questionnaire (Syrdal, Dautenhahn, Koay, & Walters, 2009) were administered at the beginning of the experiment. A simple usability evaluation (as described by the Nielsen-Norman Group for a sample population, (Laubheimer, 2018)) was carried out using Likert scale questions to assess perceived usability in terms of learnability, comfortability, utility, enjoyment and perceived safety of interaction was administered at the end of each trial. A Single ease questionnaire (SEQ) (Sauro, 2012) as a subjective assessment of the ease of use was also administered to the participants at the end of the session.

Task

The task was to navigate the robot from the living room to different parts of the home to carry out five subtasks: 1) if the charging station of the robot is in the bedroom; 2) if the front door is closed; 3) if there were any fall-risk items lying on the floor along the way (e.g., a loose hanging cable on the floor); 4) if the cooker was turned off, and 5) if the tap is running in the kitchen. The order of the sub-tasks varied among the participants and between conditions.

Procedure

Participants participated one at a time during the study. An overview of the experiment was explained to them before they signed the consent form. Background information such as age,

gender and occupation of the user was collected. The initial attitude of participants towards technology was collected using NARS. A short training was conducted for the participants to help them understand how to operate the robot through the interface in each of the LOA modes. The task, (described above) was explained to the participants.

The participants carried out the task while sitting in the living room of the model home described in the *experimental environment* section. They operated the robot through the user interface of the system. Upon completion they were asked to navigate the robot back to the charging area. The participants were asked to verbally note their observations and the hazards they detected (e.g., the cooker is turned off, there an item that can cause a fall in the bedroom), while the experimenter took notes. Participants performed this set of tasks twice, once in each LOA mode. The target potential hazard items were changed within trials for the participants without the knowledge of the participant. At the end of each task they filled the post-task questionnaire which was the usability assessment. After completion of the entire session, they filled a post-test questionnaire where they indicated their experience while controlling the robot. At the end of the experiment, they were debriefed regarding the objective of the research and the conditions being tested.

RESULTS

The results present the perception, responses and preference of the users in terms of usability, learnability, ease of use of the system as a whole, particularly for older adult users. The first section of the result presents the demographics of the participants and their predisposition towards the robot as revealed by the outcome of the shortened NARS questionnaire. Further discussion with the participants and their opinion regarding the potential use of the system are also presented.

Participants’ Demographic Characteristics

The participants were from varying professional backgrounds (2 in teaching, 1 in medicine and 1 in computer systems development). Their predisposition towards the interaction with the robot as revealed by the outcome of the abridged NARS assessment is presented on a scale of 1 to 5 depicting strongly disagree to strongly agree respectively: Anxiety towards the use of the robot (Mdn = 2.5), tension while communicating with a robot (Mdn = 2), shyness if given a job to use robots (Mdn = 3), emotional vulnerability with robots (Mdn = 3), dependability on robots (Mdn = 2).

Objective Performance

Performance measures taken to obtain objective performance of the participants were the number of sub-tasks successfully completed (5 in total), the number of hazardous objects identified (3 in total), the number of correct locations of the identified items, number of collisions of the robot while being teleoperated (this was assessed only in the assisted teleoperated mode where the users had the responsibility of navigating the robot manually without the robot’s autonomous navigation).

Three out of the 4 participants successfully completed their tasks without collisions. Only one of the participants collided with the wall in one occasion while tele-operating the robot in

the assisted teleoperated mode. Most of the participants spotted the hazardous objects around the home correctly while tele-operating in both modes. The result based on the objective performance of the participants in both LOA modes are presented in Fig.4.

NSTC: number of sub-tasks successfully completed
NHOI: number of hazardous objects identified
NCLI: number of correct locations of identified items
NC: number of collisions

Figure 4. Results for the objective performance of the participants in the Assisted teleoperation (A) and Autonomous operation (B) modes.

Perceived Usability

The outcome of the subjective measures taken to assess specific components of perceived usability: ease of use, learnability, comfortability, utility and enjoyment as presented in Fig.5.

Ease of Use and Learnability

Participants considered both modes easy to use in terms of the amount of effort they had to put in to get the system to perform the specified goal. Though, most of the participants noted that the Autonomous operation mode (Mdn=4.5) was easier to use compared to Assisted teleoperation mode (Mdn=4). Participants expressed pleasure and satisfaction at the ease of tele-operating the system with comments such as “I’m pleased that I can easily control the robot”, “it’s fun to use”.

Most of the participants reported that the Autonomous operation mode (Mdn=3) was easier for them to learn compared to the Assisted teleoperation mode (Mdn=1).

Utility and Satisfaction

Participants considered the robot useful in both LOA modes but felt the Autonomous mode (Mdn=4.5) would offer higher utility than the Assisted teleoperation mode (Mdn=4) particularly when they had other concurrent tasks to perform.

Participants indicated that they were more comfortable using Autonomous mode (Mdn=4.5) compared to Assisted

teleoperation mode (Mdn=4). There were no differences in the perception of safety of the participants while controlling the robot in both modes. They considered the robot equally safe to use in assisted teleoperation mode (Mdn=4.5) and autonomous mode (Mdn=4.5) though they seemed to enjoy using autonomous mode (Mdn=4.5) to assisted teleoperation (Mdn=4.).

Figure 5. Perceived usability measures by mode of operation.

GENERAL DISCUSSION

This is a small sample usability test study to present the potential of older adults utilizing an MRP system to carry out hazard detection related functions in their home. It provides some insight into the possibility of extending the use and users of such MRP systems to meet the needs of older adult users (Kristofferson et al., 2013). It forecasts the desired concept of active and successful aging for older adults which involves maintaining mental and physical capacities that facilitate productive and social engagement in society (Rowe & Kahn, 1987).

The developed MRP tested in this study is expected to serve as a tool to aid older adult users perform some needed functions in the home, independently and successfully. It fulfills one of the aims of technology designed for older adult users to aid active aging in terms of engagement in meaningful pursuits for individual wellbeing (Foster & Walker, 2015). Alongside the main use of safety monitoring emphasized in this study, the process of using the system demands a certain level of mental and physical effort from the older adult users that helps them maintain an active and healthy lifestyle threshold. This agrees with the vision of engaging the capabilities of older adults in a way that would contribute to their mental, physical and social wellbeing and improve their quality of life (Alan & Foster, 2013).

Specific levels of autonomy of the robot utilized in the form of LOA modes in the study were employed to explore the effect of such modes on the perceived usability of the system and experience of the older adult users. Results, based on the sample studied, indicate that the older adults were able to effectively accomplish the defined task in both LOA modes. Even though, further discussions with the participants seem to reveal that they can attend to more tasks concurrently if the robot is operating in the autonomous mode. This agrees with literature on the possibility of increasing levels of autonomy to extend users’

capabilities (Endsley, 2017). But it is noteworthy that the older adults were able to use the system successfully even in the non-autonomous mode (i.e., assisted teleoperation mode) as revealed by their objective performance and the results from subjective assessment. This highlights the merits of learnability and ease of use of the system in the lower LOA. It also reveals the potential of the older adult users utilizing the system in alternative LOA modes to accomplish specific tasks or subtasks which is one of the objectives of introducing alternative robot autonomy levels (Kaber & Endsley, 1997).

In terms of the resources required to accomplish the task such as time and effort, the system can be described as efficient in both modes for this study. Though, this claim cannot be asserted until further study is carried with more participants and more assessment measures. Duration of the task in this study, for instance was not taken because there were breaks in between the sub-tasks when users discussed their opinion about specific aspect of the system. We would recommend to further assess the efficiency of the system in terms of the resources demanded of the user in relation to extent of task accomplishment using the system (ISO, 2018).

In terms of satisfaction, the results from variables assessed such as comfortability, perception of safety and enjoyment indicate positive responses from the participants. This points to the potential of achieving positive physical, cognitive and emotional responses from the users while using the system in both modes. This is particularly striking, considering the initial disposition of the participants towards the robot that was not clearly positive as indicated by the NARS result.

We acknowledge the limitation of drawing inferences based on the convenience sample of participants, but the study has served to highlight the need for further exploration of the use of MRP systems by older adults to improve their quality of life. It calls for an extended usability study in test environments and also in real homes of older adults. This would better establish the potential of the MRP system to be used by older adults to meet relevant needs and support their independence.

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