Helping Elderly Users Control a Telepresence Robot With a Touch Screen

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Abstract

Few studies so far have experimented with the control of mobile robotic telepresence systems (MRP) especially with elderly people as controllers. In the few studies that had elderly people control a MRP it was shown that these people have particular difficulties with the driving such as with steering the robot or when driving while simultaneously talking to the person on the other end. How can the system be made easier for them? Could a touch screen device improve control of these systems for the elderly?

This thesis investigated this by means of an experimental approach in which we used the Giraff telepresence robot to compare two different input devices (mouse and touch screen) for control by elderly and young adults for comparison of results. We did not find statistical significance for most of the tests that compared the two interfaces and the two age groups but this could be because of the low number of participants (N = 22). However, there seems to be a positive effect of touch screen in the number of collisions and the driving times (between checkpoints) that elderly subjects had with the robot. Moreover, the number of collisions of the robot with the environment when using the mouse was significantly higher for elderly (compared to young) while with the touch screen there was no significant difference compared to young users. Statistical significance was found in the driving times (between checkpoints) with the robot for both interfaces where young participants performed the task in significantly less time than the elderly. Finally, we found significant difference in the training times of the system for the two groups where elderly needed significantly more training with the system than young users.

Apart from these results, we saw that the input device plays a role in the usability of the system but there are also other probably more important factors that are related to cognitive issues as it seemed that some participants needed a better understanding of how the system works and to better calculate distances of objects in the remote location.

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1 Introduction

Telepresence is being able to feel or appear as if one is present in a remote location through the use of computers. Mobile robotic telepresence systems (MRP) (Kristoffersson, Coradeschi, & Loutfi, 2013) are developed for enabling telepresence applications in which one can remotely operate a robot to interact with other people as if they are in the same environment.

MRP systems (definition and examples given in chapter 2) for various applications have been designed and studied so far (Desai, Tsui, Yanco, & Uhlik, 2011; Kristoffersson, Coradeschi, & Loutfi, 2013; Labonte et al., 2006), including applications for the elderly and aging in place (see **Figure 1** for an example MRP system specifically designed to be received by the elderly). MRP systems are something especially useful for elderly people, as they often live alone, and generally have more health-related problems and need someone to watch after them. Also, it can be the case that they would want to be able to visit their friends or participate in activities through a MRP. In addition, in a study by Beer & Takayama (2011), elderly participants mentioned that they preferred to pilot the system than receive a visit.

Figure 1. The Giraff robot (Giraff Technologies AB, 2015)

The problem is that so far, these systems are not designed to be controlled by the elderly (although they are fairly easy-to-use even for novice users). Very few studies so far have included elderly users in their control experiments with MRP systems. The TERESA project[1] has the goal of developing a semi-autonomous MRP system that will be controlled by the elderly. As part of this project, experiments with elderly controlling the robot have been conducted.

[1] http://www.teresaproject.eu

Based on these studies and some first-hand observations (discussed in section 2.2.2), it seems that older adults have difficulties controlling the speed and direction of the robot while simultaneously communicating with the person on the other end of the system. The question of what exactly causes these problems is still open. It also depends on the subject as they could be caused by lack-of or limited computer experience, accessibility issues, memory-related problems, general health issues related to old age, or lowered self-confidence when using new technology. Of course problems like that are not unique to the elderly people. Some younger pilot users can also have difficulties with the controls of the robot. Some of the elderly subjects mention that an alternative option for control (other than mouse) should be available to improve the system (Beer & Takayama, 2011).

As touch screens are intuitive to use and it is shown that they are easy to use in general for novice computer users and especially the elderly (Holzinger, 2002), a possible solution would be to use a touch screen as input for the control interface instead of a mouse. Touch screens are convenient because they remove the extra layer of interface abstraction and can allow users to directly interact with the robot and its behavior.

In this document we aim to investigate whether a touch screen device is a good alternative option to a mouse for controlling a telepresence robot, especially by elderly users.

Based on the literature introduced above, which we will discuss in more detail in chapter 2, our hypotheses are the following:

H1 The usability and quality of interaction of the system will be improved for the elderly when a touch screen is used instead of a mouse for the control.

H2 The elderly users will prefer to use a touch screen device instead of a mouse for control of the system after they have tried both ways of input.

H3 The benefits of a touch screen for elderly users will be better than those for younger users.

1.1 Outline

The structure of the thesis is as follows:

Chapter 2 provides an overview of studies with MRP systems where some related studies with experiments with pilot users (not elderly) are briefly presented. The focus is on interface improvements, suggestions and findings. The few studies that had elderly people control a MRP system are presented and discussed next and finally some important findings related to the benefits of touch screens compared to mouse as input especially for the elderly are described.

Chapter 3 focuses on the experimental method that we followed to test the hypotheses including information about the procedure, the task for participants, details about how participants were recruited, the independent and dependent variables that were measured and finally the materials that we used for the experiment.

Chapter 4 presents the results of the experiment. This includes general description of the data and demographics of participants, statistical tests and graphs to test our hypotheses, tests about video games effect on results, comparison of training times that participants had with the system and finally some video observations of participants.

Chapter 5 provides a critical discussion of the findings while conclusions and recommendations for makers of MRP systems and for future work are given.

2 Related work

In this chapter, we will give a definition and analysis of MRP systems (section 2.1), followed by an overview of studies with MRP systems (subsection 2.2). Of particular interest is the kind of problems that users have with driving the robots and their suggestions for improvement of control. Moreover, it is interesting to see effects on users from alternative ways for controlling the robots or from presenting information to them in different ways. The goal is to get an overview from experiments on what works well for users, what needs improvement and what needs more studies. These findings are followed by studies that experimented with benefits of touch screens versus mouse as input devices and especially for the elderly (subsection 2.3). The reason for this is to examine whether touch screens are a good alternative to mouse for people with limited computer experience and also for elderly users so that control of the robot could potentially be improved for elderly users.

2.1 MRP definition and analysis

In their review paper on the topic of MRP systems, Kristoffersson, Coradeschi, & Loutfi (2013) define a MRP as:

"Mobile robotic telepresence (MRP) systems are characterized by a video conferencing system mounted on a mobile robotic base. The system allows a pilot user to move around in the robot's environment. The primary aim of MRP systems is to provide social interaction between humans. The system consists of both the physical robot (sensors and actuators) and the interface used to pilot the robot.

*A **Pilot user** is a person who remotely connects to the robot via a computer interface. The pilot who is embodied in the MRP system can move around in the environment where the robot is located and interact with other persons.*

*A **Local user** is the user that is being situated at the same physical location as the robot. Local users are free to move around while interacting with the pilot user who is visiting them via the robot.*

***Local environment** is the environment in which the robot and the local user are situated."*

In a MRP system there are many factors that influence the interaction between the pilot user and the local user. **Figure 2** describes the main elements of a MRP system and the roles they have in the whole interaction process.

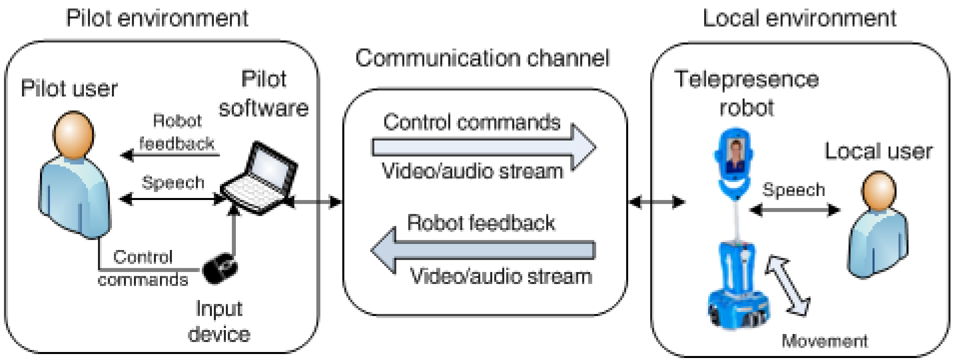

Figure 2. Interaction with a MRP system

Each one of these elements in the system can have an impact in the whole interaction process. For example, a pilot user uses an input device to send control commands to the robot via the communication channel. This process is affected by cognitive matters of pilot users, such as the pilot user's experience with computers or video games, experience and understanding of how the specific system works, perception of the robot dimensions and position in the remote location (situation awareness) that can be communicated by robot feedback on the pilot software, the sense of immersion (and feeling of presence) in the remote location which can be influenced by the quality and timing of video/audio stream from the robot. The user interface of the pilot software also affects this process as depending on its usability and accessibility level, can influence the user's understanding on how the system works and what kind of commands they can give to the robot. Also the pilot user's focus of attention (for example on the screen or on their hand) or memory impairments can affect their actions (such as forgetting which button to press).

Pilot user's dexterity, their reflexes, reaction times and experience with the specific input device also play a role in the quality of their commands. The type of input device can also cause some lag on user's actions or affect the feeling of control that users get from it. It can also affect precision, speed and usability of control movements which can translate to better movement of the robot. These are processes that happen in the pilot environment. The communication channel which sends pilot user's commands to the robot can be affected by network speed and latency which influence the time in which the robot gets the commands for movement and the time that feedback from this movement travels back to the pilot user.

2.2 MRP system studies

MRP systems are designed and used according to the intended application of use. Systems for a variety of applications have already been developed and studied, including office environments which help remote workers attend formal and informal meetings from a distance (Lee & Takayama, 2011) or health care applications that allow physicians to monitor the health of postoperative patients at home remotely (Fitzgerald, 2011). Some MRP systems developed for the elderly and aging in place (Coradeschi et al., 2011) have also been studied. Another example is for the purpose of monitoring the health of elderly people living alone or in elderly houses (Boissy, Corriveau, Michaud, Labonté, & Royer, 2007) or interacting with them from a distance (as in the case of relatives visiting them remotely) (Moyle et al., 2014). MRP systems can also be used as a safeguard system in a smart home (Coradeschi et al., 2013), school applications (Bloss, 2011) where the systems help students attend classes even when they are sick at home or recovering at a hospital or the possible use case of a teacher giving a lecture from a remote location, and finally general MRP systems for general use (Lazewatsky & Smart, 2011).

2.2.1 Control of MRP systems

The studies described here were selected out of 40 papers that were initially gathered from Google Scholar, related to the general topic of MRP systems. The final selection of 23 studies (20 without elderly, 3 with elderly people, plus one unpublished study with elderly) was made due to the fact that in all of these studies, experiments were conducted, in which subjects control a MRP system. Elderly subjects participated as pilot users only in experiments of section 2.2.2, but the rest are still relevant because of the types of problems that younger pilots can have with the control of these systems and the guidelines that the authors suggest for their interface designs.

In the human subject study by Adalgeirsson & Breazeal (2010), effects of expressivity (gestures, body pose, proxemics) from a custom built telepresence robot (MeBot) were measured. For the design of the control interface of the robot, a fully articulated 3D model of the robot was displayed to pilot users to “close the feedback loop” so that the pilot user could have a better understanding of the effects of their controls. For the navigation of the robot, a 3D mouse (Space Navigator by 3DConnexion) was used which allowed operators to translate and rotate a target location which is relative to the robot’s current location. An overhead display was used for this visualization along with sonar range data and other logistic information such as battery voltages. 48 subjects with a mean age of 23 years participated in the experiment but there are no mentions of problems controlling the robot.

Bagherzadhalimi & Di Maria (2014) studied the usability of MRP systems from a pilot’s perspective in a museum-visiting context. For the study, the Double telepresence robot was used. 12 (9 male, 3 female) adult participants with a mean age of 27.8 participated in the experiment which was about visiting a museum from a remote location. 6 participants were experienced with MRPs and 6 were inexperienced. The experienced group of participants, on average rated the system more useable for visiting a museum than the inexperienced group. All of the participants stated that the system in general was easy to learn and use, although they had some problems entering the room and driving backwards as these tasks were found to be a bit challenging to them. Especially for novice users, the majority of the problems were caused by trying to keep the appropriate distances to people and objects and to drive backwards. Another common problem mentioned especially from novice users was the difficulty in simultaneously controlling the robot and communicating with the other person. Despite these issues, the general rating of the navigation in the local environment was satisfactory.

Boissy et al. (2011) studied the controls and learnability of a MRP (TELEROBOT) used in the context of in-home telerehabilitation in an unknown-to-the-participants environment. 10 rehabilitation professionals participated in the experiment (2 male, 8 female). On the control interface, a video stream from the robot camera was presented, a mouse was used as input and the pilot user could continuously see the position of the robot in a two-dimensional map window that also illustrated main obstacles. A radar window displayed laser range finder data and a horizontal line was displayed 1 meter from the robot while 2 vertical lines on the sides of the robot helped users guide the robot through narrow spaces. Results showed that rehabilitation professionals were able to teleoperate this robot in an unknown home environment after 4 training sessions of 4 hours total duration. Their performance was less efficient than that of an expert who had more than 50 hours of training and familiarity with the environment. The authors suggested that efficiency could be improved by a better interface and increased situation awareness to the pilot user (i.e. perception of robot's location, surroundings etc.).

Gonzalez-Jimenez, Galindo, & Ruiz-Sarmiento (2012) experimented with the Giraff telepresence robot. 15 people (34 years average age) with different technological skills, teleoperated the robot and gave high marks about the impression on the driving experience, the interface appearance and learning curve, while the lowest marks were about the camera image quality and the docking difficulty. Three ways to improve the autonomy and interaction experience with the Giraff were identified by users: 1) automated docking, 2) obstacle detection and warning, 3) information about the Giraff position (localization). Based on these findings, technical improvements were made to the Giraff but they have not been tested with users.

The studies of Takayama & Go (2012) and Takayama & Harris (2013), conducted experiments with participants driving MRP systems but the goal was to explore the metaphors that people use to address these systems.

2.2.1.1 Studies exploring feeling of presence of pilot users

The studies by Kristoffersson, Coradeschi, Loutfi, & Eklundh (2011); Kristoffersson, Severinson Eklundh, & Loutfi (2013); Kristoffersson (2013); Kristoffersson, Coradeschi, Eklundh, & Loutfi (2013) conducted experiments with participants having to control the Giraff telepresence robot and were focused on the quality of interaction between the pilot user and the local user. Quality of interaction through a MRP system is not only related to social communication but it includes a spatial element as the pilot user can move around in the remote location while communicating with the local user. The tools that they used to measure both the social and spatial elements of the quality of interaction (from the pilot user's perspective) were the feeling of social and spatial presence by pilot users when being embodied in the robot (subjective measure), the spatial formations occurring between pilot and local users (subjective behavior assessment) and sociometry (objective measure).

Nakanishi, Murakami, Nogami, & Ishiguro (2008) experimented with the impact of telepresence camera control on social telepresence. They found that forward-backward movement of the camera had a significant impact to social telepresence while rotation did not. The effect disappeared when the control was automatic.

In the study by Rae, Mutlu, & Takayama (2014), 32 adults (mean age 20.9), 8 per condition, used the Double telepresence robot to collaborate in a construction task with a remote person. Effects of robot mobility on a user's feeling of presence and its potential benefits were tested. Results showed that mobility significantly increased the feeling of presence but did not increase task efficiency or accuracy in the low mobility condition. Participants had problems controlling the robot even though they were given 10 minutes to train with the system and were provided with an instruction sheet with explanation of controls. They were observed to back into walls, run into pipes on the ground and move extremely slowly to avoid collisions. One participant even tipped the system over while in the training period and crashed it so it had to be recovered from a prone position on the floor.

2.2.1.2 Studies comparing different user interfaces for control

In a series of studies by Desai, Tsui, Yanco, & Uhlik (2011) that had participants drive two commercial telepresence robots (QB and VGo), it was found that while presenting accurate sensor information to the pilot user is necessary to improve pilot users' situation awareness of the robot's surroundings, it was not considered useful by participants. 7 participants drove the VGo with distance information displayed to them and 12 participants had a version without it. There was no significant difference in the number of collisions that these pilot users made. This was because the hallways in the office environment were narrow and probably the drivers quickly ignored the sensor distance warnings. In a different study described in the same paper, 20 out of 24 participants reported that they would like to have a map of the environment shown to them on the interface. Multiple cameras on the robot were also tested. The QB robot had two cameras, one facing forward and one downwards at the base of the robot. VGo had only one but it could be tilted up and down when needed. The number of hits with the VGo was higher than with the QB and the participants found the down-facing camera of the QB to be useful. In the study about initial user impressions, participants were asked to think aloud while driving the robot but only 4 out of 30 talked when driving the robot and they gave significantly more attention to the driving task than the talking task. Also two thirds of participants (21 of 31) collided with the environment while using the robot in an office space. The authors mention that collisions occur in general when the pilot's situation awareness (SA) of the robot's surroundings is not good. They argue that sensor data feedback to the pilot would improve their SA but bandwidth restrictions and cognitive overload don't make it always feasible or desirable.

The study by Keyes et al. (2010) was focused on effects of four different user interfaces for the control of an urban search and rescue (USAR) robot (iRobot ATRV-JR). This robot is not used as other MRP systems are, and it has no screen on it. A within-subjects experiment had 6 trained search-and-rescue personnel participants use either a joystick and keyboard version and a multitouch screen (DiamondTouch table was used) version of the interface. It was found that performance was not degraded by porting the interface to the multitouch screen table. The multitouch screen interface had the same or higher scores on average in all categories (2 out of 6 had statistical significance). Also the touch screen interface was reported to be easier to learn than the joystick interface but this result was on the edge of statistical significance probably due to the small sample size. The authors mentioned that the joystick interface limits users to a relatively small set of interaction possibilities, while the touch screen interface offers a large set of gestures and looks promising as an alternative interaction method. However, it was noted that designers of the interface must be careful in choosing control methods which give users clear affordances and appropriate feedback, as users are used to haptic and auditory feedback from devices.

Kiselev, Loutfi, & Kristoffersson (2014) experimented with two different orientations (landscape and portrait) of the camera (and field of view) output from the Giraff robot. 4 male university students (ages 19-21) participated. All had experience with video games. From their findings it was suggested that portrait orientation of the camera (having a limited horizontal field of view) can lead to better quality of interaction as pilot users are encouraged to orient the robot towards the local users. The authors mentioned they believe that the bigger vertical field of view can improve the driving experience as well.

Mosiello et al. (2013) studied effects of 3 different user interfaces of the Giraff robot. 23 participants (average age 22.26 years) used only one version of the interface. In the first two versions (v1.4 & v2.0a) the robot was controlled by a line which related to the trajectory that the robot was supposed to follow. The third version (v2.0b) used a projected target with the relative dimensions of the robot to the driving surface. Results showed that especially for non-gamers, version 2.0b minimized the effort needed to steer the robot, while navigation through narrow paths was simpler. The number of collisions decreased as well with version 2.0b. Nevertheless, gamers preferred the driving line while non-gamers preferred the target. It was also found that there is a difficulty in driving caused by lag between mouse click and robot movement. Novice users at first double-clicked many times before understanding how to drive properly. In addition, most participants had problems moving backwards. Especially for small movements close to the robot, a common problem was that users had difficulty understanding how the robot would move according to their commands. The authors propose that the inclusion of both types of navigation (path and target) for better perception of space and estimation of trajectory at the same time would be the best solution.

Labonte et al. (2006) compared the control interfaces of two telepresence robots: CoWorker and Magellan. The two robots had different methods for control. Both are controlled by using a mouse. In waypoint navigation that is used by CoWorker, the user clicks on the visual display (from the camera's video stream) and the robot autonomously navigates to the destination. Position point navigation that is used by Magellan, works by placing a target on a map of the environment on the screen and clicking on a “Go” button which sends the robot to the target position autonomously. A virtual joystick on the screen can be used by the pilot user at any time in position point navigation to override the robot’s path. A small number of participants, 2 trained operators who were roboticists, 2 untrained who were clinical researchers and one expert that served as a baseline for comparison, took part in the experiment and results showed that trained operators were more efficient in driving the robot with waypoint navigation, while untrained operators used position point navigation the most efficiently. Further, it was shown that position point navigation required about three times less commands by users and this seemed to decrease the effect of training on operator performance. Thus, it was suggested by the authors that an interface that combines the advantages of waypoint navigation with position point navigation would likely improve operator performances.

Riano, Burbridge, & Mcginnity (2011) used a custom-built telepresence robot to test the value of semi-autonomous navigation control, semi-autonomous face tracking and improved situational awareness on a user’s ability to communicate, feel present and navigate in a remote environment. The interface made use of a joystick for steering the robot but users could also move the robot by clicking on a 3D map of the environment. User’s satisfaction was enhanced greatly with the semi-autonomous controls of the robot.

Rodríguez Lera, García Sierra, Fernández Llamas, & Matellán Olivera (2011) used the Rovio WowWee robot to test whether using augmented reality in the video output from the robot would improve driving performance of pilot users. 8 people (aged 25-50 years) without any relationship with robotics participated in the experiment. Results showed that augmented reality can help non-expert operators drive the robot in especially hard environments.

Takayama et al. (2011) evaluated the effectiveness of an assisted teleoperation feature that was implemented for the Texai Alpha prototype MRP system. System-oriented as well as human-oriented dimensions were studied with 24 subjects that participated in the experiment. The robot was operated by a web-based GUI in which users could control the robot by clicking and dragging a point with the mouse in the two-dimensional space of the GUI. It was found that the assisted teleoperation feature reduced the number of collisions with obstacles but increased the completion times for the task. Furthermore, locus of control and experience with video games were found to be significantly influential to the completion times while people with video gaming experience found the task to be more enjoyable and less physically demanding than people with less video gaming experience.

2.2.2 The elderly as pilot users of MRP systems

In a study by Beer & Takayama (2011), 67% of the older adults (ages 63-88) participating as pilot users of the robot, reported that it was easy to operate the MRP system which was an alpha prototype of the Texai project. However, video observations showed that people had difficulties controlling the speed and direction of the system. This difficulty appeared to be commonly related to the use of the mouse and the web-based interface: "*You're not only having to watch the red ball [that was used to drive the MRP system], but you have to watch where you're going and your speed and looking out for things. So it was a lot to do, especially just controlling it with the mouse.*" p.6 (Beer & Takayama, 2011). Further, 50% of older adults in that study recommended that the system would improve by using different driving controls, other than mouse, because of "issues with fine motor movement and mapping the controls to the system's video feed". They also suggested that tutorials or user manuals that describe how the system works may help adoption and improve the ease of use of the system.

Kiselev & Loutfi (2012) conducted an experiment with the Giraff telepresence robot to evaluate the control interface of the system. 10 subjects participated (6 males, 4 females) with average age of 40.7. None of the subjects had prior experience with controlling the Giraff robot. They had different experiences with technology and belonged to different age groups. Two of the subjects that had experience with computer games mentioned that they would like to have more control over the robot's behavior and using a keyboard seems to be more convenient to them. On the other hand, other participants reported to be happy with the mouse-control as it doesn't require any specific skills for controlling the robot. An interesting observation was that all subjects seemed to initially click at a point of interest such as the docking station or a checkpoint when they started driving the robot. The oldest participant in the experiment was a 67-year-old woman who had the longest time performance of 595 seconds. The best performance was 273s made by a 47-year-old man. The same 67-year-old woman had also the second greatest number of collisions while driving the robot. She had 4 collisions while the biggest number was 5, made by a 27-year-old female. This shows that the number of collisions with the robot can be high also in pilot users of younger age.

Glas et al. (2013) used the humanoid robot Robovie R3 in an experiment where 27 people of average age 68.4 teleoperated the robot. The focus was on the creation of interaction content and utterances that the robot would execute. The robot used a text-to-speech system, had a head and two arms and it had no screen as other telepresence systems do. It had the role of a tourist guide explaining sightseeing information to tourists. The goal of the experiment was to test the effectiveness of the system when operators were using some proposed guidelines and assistive software features versus not using them. The study was only focused on making the dialog that the robot would make through its text-to-speech system. The results showed that the proposed guidelines and assistive features helped the operators in producing better interactions with the robot.

The goal of the TERESA project[2] is to develop a telepresence system with semi-autonomous navigation to be controlled by the elderly. Studies were conducted as part of this project that had 17 elderly people (mean age = 73.12) control the Girraf telepresence system

[2] http://www.teresaproject.eu

and covered approach, conversation and retreat behavior. The studies showed that all participants had some problems with steering the robot, learning to control the robot was hard, with training times that varied from 20 minutes to 1 hour, and even after the training, most of the subjects seemed to be unable to have a fluent conversation while controlling the robot at the same time.

We have conducted an informal (free of rules and tasks) pilot experiment with 2 elderly subjects (1 male, age 62 and 1 female, age 64) being instructed to try to control the Giraff robot. Both subjects had experience with computers of almost daily use (mostly web browsing). The male subject found the system very easy to learn and use and did not have any collisions with the environment. He also managed to find the basic controls of the system easily without any training at all. The female subject was at first a bit afraid of trying and eventually drove (for less than a minute in total) very cautiously until the moment she was driving the robot straight to a wall and only stopped at the last second before hitting that wall. After that moment she gave up trying. It is important to mention that the subjects did not receive any formal training for the system, only brief spoken instructions.

We are not aware of any other study with elderly people in control of a MRP system. It is also clear that improvements to the system should be made especially for the elderly as pilot users. Also alternative ways for steering the robot should be experimented with, having the elderly in control of the system. Such an alternative option to steer the robot could be using a touch screen instead of a mouse.

2.3 Benefits of touch screens versus mouse as input devices for elderly computer users

In this section, interesting findings from studies that made comparison between a touch screen and a mouse or between a mouse and other input devices are presented. The focus is on studies that had elderly subjects in the experiments and also on the overall benefits (or drawbacks) of touch screens for users. The goal is to see how a touch screen can affect the ways in which elderly users and also users with limited computer experience use a computer, in order to examine if it seems to be more beneficial (than a mouse) as an alternative input device for the elderly to control a telepresence robot with.

A study by Walker, Millians, & Worden (1996) that compared older and younger experienced computer users on their ability to use a mouse to position a cursor, has shown that older adults are less accurate and slower when using a mouse compared to younger computer users. That makes using a mouse difficult and reduces their confidence in dealing with new situations so it can promote hesitation to deal with new tasks (Zajicek, 2001). Further, no age differences were found when mouse was compared to trackball in a study that had 10 younger (mean age = 32) and 10 older adults (mean age = 70) make simple point-and-click and click-and-drag movements to targets of varying distance and widths and also a greater percentage of their maximum voluntary contraction is required in order to use the mouse or trackball compared to younger adults which is due to their reduced grip and pinch force compared to younger adults (Chaparro, Bohan, Fernandez, Choi, & Kattel, 1999).

A benefit of using a touch screen according to Srinivasan & Basdogan (1997) is that the ability to touch, feel and also manipulate objects on a screen, while also seeing and hearing them, provides a sense of immersion. Further, according to Greenstein & Arnaut (1988) the most obvious advantage of touch screens is that the input device is also the output device.

In the study of Holzinger (2002) it was found that the operation of their (touch screen operated) system was easy for all of their older adult (60-82 years old) patient participants due to the use of direct eye-hand co-ordination. Moreover, most of the subjects reported that they "liked this kind of computer". All of the subjects, found the touch screen interface simple to use and they had no computing experience. However, the experiment did not include comparison of results with input from a mouse compared to touch screen.

Canini et al. (2014) found from comparison of reaction times and test performance of 38 healthy participants (age mean = 64.4) that using a touch screen or mouse had no significant overall differences, suggesting that both can be chosen equally well as input devices. Their study confirmed the findings of Holzinger (2002) as subjects felt comfortable while using the touch screen device and did not feel fatigued or experience uneasiness while performing the tests. All subjects had limited experience with these types of devices and some of them had never experienced a touch-screen tablet before. In addition, Canini et al. (2014) argue that:*"When using a direct input device, the distance between the subject (his/her fingers) and the causal effect he/she carries on the environment modification (touching stimuli on the screen, as required by the task) is reduced. Touch-screen devices, in this framework, lead a virtual environment to a more tangible and ecological dimension. One possible consequence of such phenomenon could be an increase in self-commitment or in self-perceived efficacy towards the task, and this could lead to an enhancement by establishing a direct link between the subject and the task reality. In other words, a different perception of the self-commitment could be associated with responses given with direct input devices, shifting the task environment perception into a more concrete entity on which the subject acts as a physical agent. Thus, critically, the subject involvement into the task could have been enhanced. Under this light one would expect to observe a greater effect for those trials requiring a greater cognitive demand (i.e., incongruent trials). A greater involvement could translate into greater resources dedicated to task solution."*

Wood (2005) demonstrated how input devices such as light pens or touch screens are very intuitive as they have the advantage of bypassing the keyboard. They allow subjects to focus their attention to the video display terminal directly and not having to switch from focusing on finding a particular key on the keyboard and then back on the screen. They also found that touch screens and light pens can have some important disadvantages in the elderly users as they require subjects to hold their hands in an "up" position moving them across the screen with the effect of causing them fatigue and some variation in their reaction time.

It seems that touch screens are likeable, simple and comfortable to use by elderly with limited computer experience, they do not make them feel fatigued or experience uneasiness. They also have the benefit of not requiring users to use more grip and pinch force (especially useful for the elderly) and they provide direct hand-eye co-ordination. They are especially useful because they allow subjects to focus directly on the screen, while providing the ability to touch, feel and manipulate objects on it. Moreover, subjects do not have to learn how to master the use of another device. Finally, they do not seem to affect reaction times (when compared to a mouse) in elderly users but they have the disadvantage of requiring subjects to hold their hands in an “up” position that causes them fatigue. Based on these findings, a touch screen seems to be a good alternative option for controlling a telepresence robot by the elderly. Thus, in the next chapter we propose an experiment design in order to test this assumption.

3 Method

This chapter describes the experimental method that we followed to test our hypotheses. That includes information about the experimental procedure (section 3.1), the task that participants had (section 3.2), general information about participants and how they were recruited (section 3.3), the independent and dependent variables that were measured (sections 3.4 and 3.5 respectively) and finally the materials that we used for the experiment (section 3.6).

The experiment was reviewed and approved by the Ethics Committee of the Electrical Engineering, Mathematics and Computer Science faculty of the University of Twente.

3.1 Procedure

We conducted a within-subjects experiment and between subjects for age effects, where a comparison between 2 different versions of the Giraff MRP system interface was made: Touch screen input versus mouse input.

The experiment took place in two buildings (Zilverling and Gallery) of the University of Twente (Enschede, The Netherlands), in the days between 12-5-2015 and 24-6-2015. Participants were located along with an experimenter in a room in “Zilverling” building (see **Figure 3**) while the Giraff robot was located in the “Interact” room of the Gallery building (see **Figure 4**).

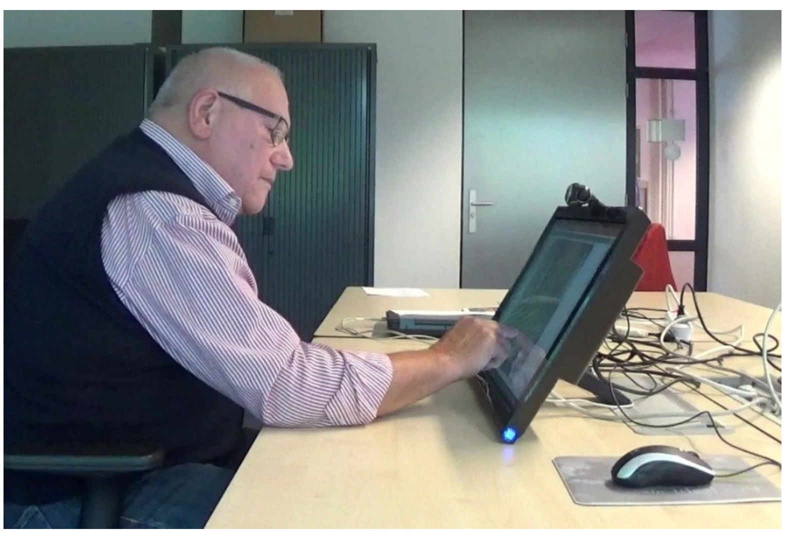

Figure 3. A participant controlling the robot with the touch screen

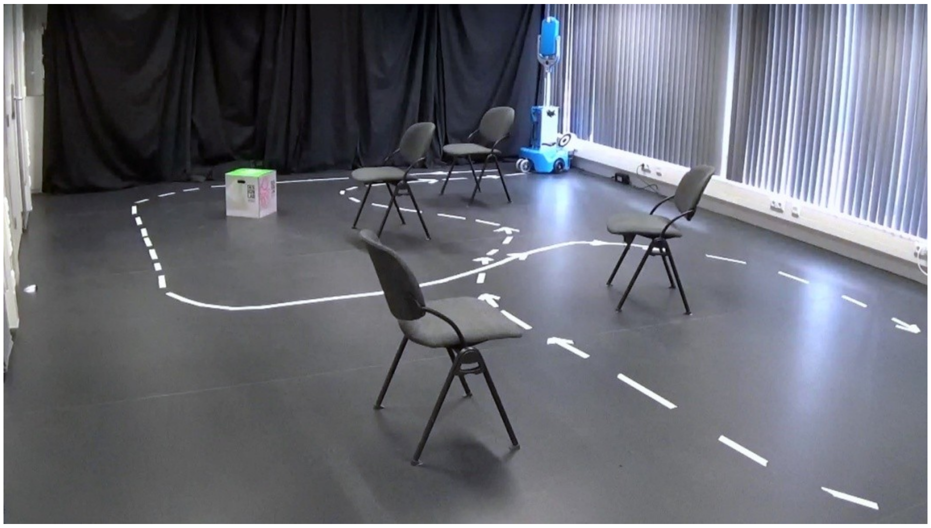

Figure 4. The room with the robot and the local user

After signing a consent form (see **Appendix F**), participants had two driving sessions (including some basic conversation with the local user), one after another. One session with using the mouse only, and one session using the touch screen only. The order of sessions was counterbalanced. The local user was a confederate that was always sitting in the same position in the room where the robot was located.

Before each of the two sessions, participants were given training to the system, according to the input device that they were going to use immediately after. Training was given by the experimenter that was in the same room with them, in the form of verbal instructions and also test-drive by the participants. The instructions covered all the basic functionalities of the system (except from the camera up-down movement as it was not used in this experiment). For the test-drive they had to undock the robot, perform all actions (such as make a U-turn or do an emergency stop), ride two circles around a chair, move near a desk and move back to the docking station and dock the robot. We excluded the camera movement option that is performed with the scroll wheel because the interface of the system did not support an alternative method for moving the camera that could be used with the touch screen as well. To address this issue, at first we thought using some special software that can create finger gestures for touch screens and we could create a 2 or 3 finger gesture equivalent to scrolling with a mouse wheel but in the end we decided that it is not important to use this feature in the experiment.

After participants finished with the second session and had answered the session questionnaires (see section 3.5 and **Appendix D**), they were asked to try one more time to control the robot but this time they were told that they could freely choose to use either input device and they could change between the two at any time they wished. After they finished with that last session, participants were asked to fill-in a profiling questionnaire (see **Appendix E**) that collected demographical data including their experience with telecommunication products and video games as these can have an impact on results (Takayama et al., 2011). No session questionnaire was handed to participants for the third session.

3.2 Task

For the task, we wanted participants to experience the full docking and undocking feature of the Giraff robot, because it is an essential part of the system and because users in experiments had difficulties with the docking feature of the Giraff (such as in the study by Gonzalez-Jimenez et al. (2012)). In addition, we wanted to have a path with arrows drawn on the floor that participants would have to drive on (similar to Kiselev & Loutfi (2012)). With this path, we would be sure that every participant drives the robot on the same route in every session. They would not have to stop driving in order to think (or to ask the experimenter) where to turn next. Moreover, they would have to drive near obstacles that would make it look more like a home environment in which it is common that pilot users have to drive across narrow spaces and avoid obstacles such as chairs. Further, as it is common for pilot users of MRP systems to have a conversation with a local user while simultaneously driving the robot, and as elderly participants in the study of the TERESA project (TERESA, 2014) had difficulties controlling the robot while having a fluent conversation at the same time, we wanted to include a simple conversation that participants would have with the local user (confederate) in the task.

So in the 2 sessions, the task was to first undock the robot from the docking station. Next, they had to follow a predefined path that was marked with arrows on the floor that was guiding them to drive across the room and back to the docking station where they had to dock the robot for the session to finish. Before the start of the session, participants were instructed that they would expect to have a brief conversation with the confederate (local user) at the same time but that they did not have to stop driving. Participants were not instructed to drive as fast as possible but only to follow the path on the floor.

The room (5.62m x 9.20m) (see **Figure 8** for the floor plan) was cluttered with 4 chairs and one small box while on the other side of the room the confederate was sitting on a fifth chair in front of a desk that was touching the wall (see **Figure 5** and **Figure 6**). All chairs and the box were strategically placed so that participants needed to be focused in order to avoid bumping into them (see **Figure 5** and **Figure 7**).

Figure 5. Obstacles in the robot room

Figure 6. The confederate was sitting in the fifth chair in the lower right of the picture

Figure 7. The distance between the last two chairs in the driving path was 84cm. That was small enough to simulate passage through a doorway

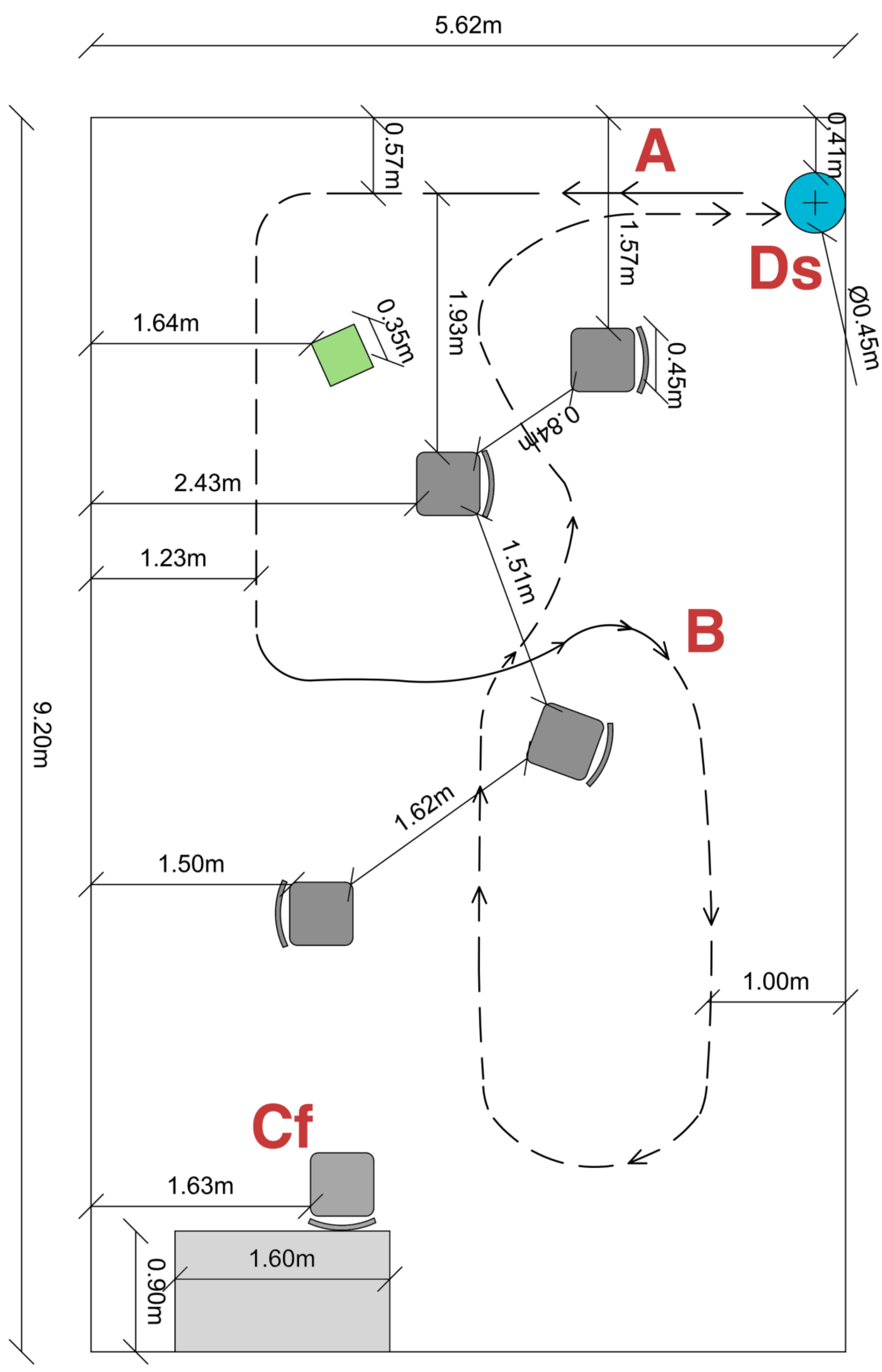

Figure 8. Floor plan of the room where the robot and confederate were situated. The blue circle in the top right corner of the room represents the docking station (Ds) of the robot. The confederate (Cf) was sitting in the lower left chair next to the desk. The arrows represent the actual arrows that were visible on the floor. A and B are the checkpoints between which we measured driving times of participants

In order to test how the input device influences the subjects' ability levels to talk with the local user and control the robot at the same time, simple conversation of interview type was added to the task: when the robot was successfully undocked by the pilot user and started moving (near checkpoint A), the local user (confederate) greeted them at first with a "Hello!". When the participant replied (if they did not reply, they were greeted again), the confederate asked them: "What is your first name?" when they were in their first session and "What is your last name?" when they were in the second session. When participants reached checkpoint B (which was near the middle of the room) the confederate asked them: "What is your favorite food? And why?" when they were in the first session and "What is your favorite drink? And why?" when they were in the second session. These questions were selected because they were easy to understand and to answer, allowed answers of a few or many words and were very similar in nature so they could be comparable in the two sessions. For the elderly participants only, this conversation was made in Dutch.

The sessions ended when participants docked the robot in its place successfully. This way the full (un)docking feature was included as well (first with undock and second with dock) and also the robot was in the right position for the next session to start. In total, the experiment lasted for around 45 minutes per participant but some of the young participants finished in 30 minutes or even less.

3.3 Participants

7 elderly (ages 59 - 78) and 16 young adults (ages 22 - 43) took part in the experiment.

Elderly participants (4 males, 3 females) with ages ranging from 59 to 78 (M = 68.86, SD = 5.79) were invited to the Zilverling building where the laptop computer with the touch screen was situated. Participants were recruited by phone and e-mails and they were all acquaintances of an employee of the Human Media Interaction group which helped us come into contact with them. All participants were rewarded with a chocolate candy. Our initial plan was to have at least 15 elderly participants so we arranged to travel to the Ariënsstaete, an elderly house in Enschede in order to conduct experiments with residents of that elderly house. However, due to one technical problem related to a firewall of their network that was blocking connections to the port that the Giraff pilot software uses to connect with the robot, we had to cancel the experiment and find other means to get participants.

Young participants were 16 young adults (12 males, 4 females) aged from 22 to 43 (M = 27.69, SD = 5.39). Most of the young participants were either master students or PhD candidates of the University of Twente. They were recruited by an e-mail advertisement that was sent to all master students and staff of the Human Media Interaction group of the University of Twente, by a poster advertisement that was put in 2 buildings of the University, by an advertisement that was posted on Facebook groups that are used by students and finally by asking friends and acquaintances to participate. Participants were rewarded with a chocolate candy.

3.4 Independent variables

A repeated-measures design was used with the within-participants independent variable *input device* (mouse input only, touch screen input only).

3.5 Dependent variables

After each of the two sessions, participants were asked to fill in a session questionnaire (in printed form) (see **Appendix D**) that was given in English to young participants and in Dutch to elderly ones, because all elderly participants were native Dutch speakers so they were more comfortable using Dutch. This questionnaire included a SUS questionnaire (question 1-10) (Brooke, 2013) to measure changes in the *usability score* of the system (as mentioned in our first and consequently third hypotheses). Two questions (question 11-12) regarded the ease of use of the robot (*control of the robot*) similar to Kristoffersson (2013). These questions also measured usability but they were more focused in usability of controlling the robot. To measure the quality of interaction (for hypotheses H1 and H3) through the system as this is something important for MRP systems and could be influenced by the input device used, we used two variables: *co-presence* and *attentional engagement.* Both were taken from the Networked Minds Social Presence Inventory (Biocca & Harms, 2003) and are related to the feeling of presence in the remote location and consequently affect the quality of the interaction of pilot users with local users. Four questions (question 13-16) measured the level of *co-presence* and the next two questions (question 17-18) measured the level of *attentional engagement*. All of these questions were given in a 5-point Likert scale where 1 was "Strongly disagree" and 5 was "Strongly agree". All these questions were used to gather quantitative data. The questionnaire included four more open questions (question 19 - 22), which asked participants to write in their own words what they liked or disliked about the interface and what they found easy or difficult with this input device. This way, qualitative data were also gathered using these four questions that could give us insight on what works well for users and what does not.

The SUS questionnaire was chosen because it is a reliable tool in measuring usability and has become an industry standard with references in hundreds of papers and publications. Also it can be used reliably when the sample size is small.

The Networked Minds Social Presence Inventory for the quality of interaction questions, was chosen as in the study by Kristoffersson, Severinson Eklundh, et al., (2013) because it is designed to be cross-media compatible and not virtual-reality-only and was considered to be a good basis to measure presence in MRP systems. From this questionnaire only the dimensions of *co-presence* and *attentional engagement* were used as they were more compatible with our study. Co-presence measures "*the degree to which the users feel as if they are together in the same space,*" p. 5 (Biocca & Harms, 2003). Attentional engagement measures "*the degree to which the users report attention to the other and the degree to which they perceive the other's level of attention towards them,*" p. 10 (Biocca & Harms, 2003) and were both included as a way to measure the quality of the interaction of the pilot user with the confederate through the system. In the studies of Kristoffersson, Severinson Eklundh, et al., (2013) and Kristoffersson, Coradeschi, Eklundh, et al., (2013), quality of interaction was measured from social and spatial presence elements. In our experiment, quality of interaction refers only to the feeling of social presence by pilot users. We did not include measures of spatial presence (from spatial formations) as well, because they were incompatible with the driving task (a predetermined path to follow, simultaneous with talking). For this experiment only the quality of the interaction from the pilot user perspective could be measured as we used the same local user (confederate) with all participants.

For the second hypothesis, users' *interface preference* (for mouse or touch screen), was collected with the final questionnaire that also collected demographics data such as computers/internet/video game experience and experience with robots (see **Appendix E**). The first question in that questionnaire asked participants to write in their own words which interface they preferred and why (combination of quantitative and qualitative data). The demographics questionnaire was given in Dutch to elderly participants.

Apart from the questionnaires and as a way to get objective quantitative data (for hypotheses H1 and H3) about the influence of the input device on pilot users' driving performance (and similar to Kiselev & Loutfi, (2012)), we measured the *time* that participants took to drive the robot *between checkpoints* A (first arrow on the floor) and B (fifth arrow on the floor) (see **Figure 8**). These were measured (in seconds) from the video recordings for each of the two sessions that participants had. These checkpoints were chosen because from checkpoint A, participants already had a steady driving pace, and until checkpoint B they had to only answer to the greeting by the confederate and the first question about their name which was easy for all participants. After they passed from checkpoint B, participants had to answer the second question by the confederate (while driving) which was a bit more complicated than the first one and a few participants stopped driving at that moment to answer the question so we did not want to include the influence of the second question in their driving times. The *number of collisions* (also similar to Kiselev & Loutfi, (2012)) that participants had with the environment in each of the two sessions was also counted from video recordings for each of the two driving sessions. This was another way to get objective quantitative data on their driving performance and collisions with the environment seem to be an important problem when driving a telepresence robot.

3.6 Materials

For the experiment we used a number of materials that are presented in the following subsections.

3.6.1 The Giraff MRP

The MRP system that we used in this study was the Giraff MRP (see **Figure 9**). The Giraff is a 1.62m tall MRP system with a mobile robotic base which has a PC running Microsoft Windows 7.

Its weight is 13kg and it has a movable pole where an also movable screen of 14.1” along with a 2.0 megapixel wide angle camera (lens with 120 degrees field of view), speakers and a microphone are mounted. It uses the proprietary software VSee as its videoconference system.

The robot can be controlled through the internet by any PC that is running the Giraff Pilot software (see **Figure 10**). The software allows users to navigate in the local user’s environment through its interface where they can control the robot by clicking their mouse on the video feed from the robot camera. When users hover the mouse pointer over the live video feed, a dark green line is drawn that starts from the base of the robot and shows the approximate trajectory of the robot. When the left mouse button is pressed and held, the line turns bright green and the robot starts driving. The length and orientation of the line determine the robot’s speed and direction respectively. When the mouse button is released, the robot stops and the line turns dark green again. It is possible to move the robot slightly backwards by pressing the “back up” button on the lower left corner of the screen. The “u-turn” button makes the robot turn 180 degrees. Double clicking at any point on the video feed makes the robot turn to face in that direction.

There are some other options as well such as the vertical movement of the camera and screen of the robot with the scroll wheel of the mouse but we did not include them in this experiment.

Figure 9. The Giraff robot in its docking station

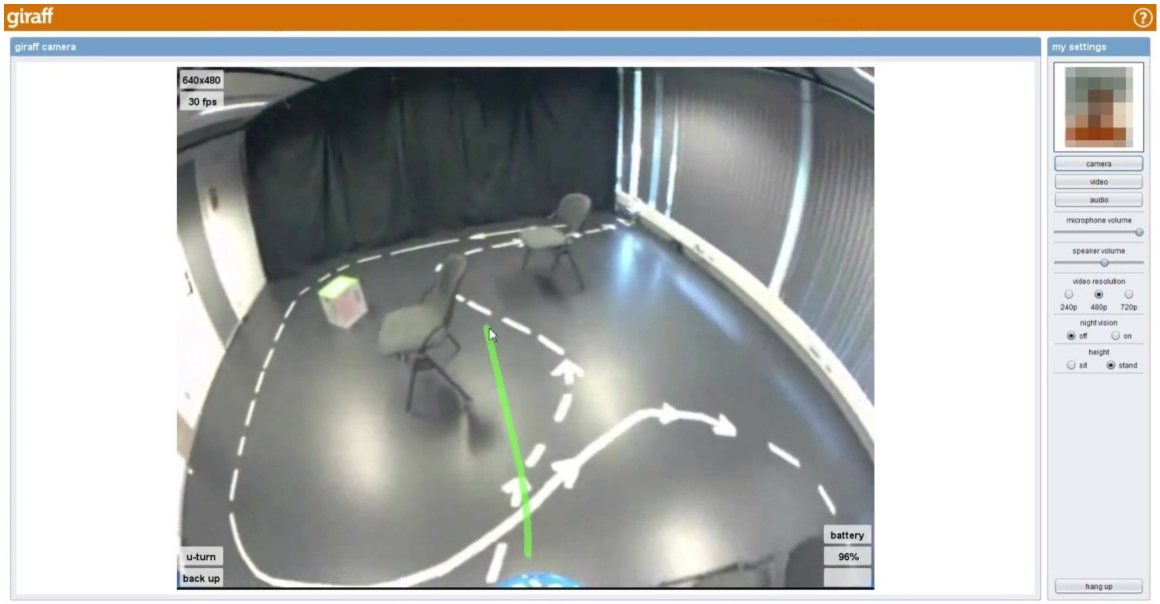

Figure 10. The Giraff Pilot interface (version 2.4.0.2)

3.6.2 Materials for the robot room

To set up the task as described in section 3.2, we used the following materials for the robot room (see **Figure 4** and **Figure 5**):

- Giraff robot with docking station (see **Figure 9**)
- 5 chairs
- Small box
- Desk
- White duct tape for making the marks on the floor
- Black curtains to cover the mirrors on the left wall of the room
- Camera with tripod for recording the interaction of the robot with the environment and the confederate

3.6.3 Materials for the pilot user room

The materials that we used in the pilot user room (see **Figure 3**) for controlling the robot were the following:

- Laptop computer running Microsoft Windows 7
- Giraff pilot software version 2.4.0.2
- Optical wired mouse (Logitech laser mouse RX1000)
- 23" touch screen device (Acer T231H)
- Logitech webcam (2 Megapixels) with embedded microphone
- Mouse pad
- Recording material
    - Camera with tripod for recording the pilot user

    - Screen capture software (Open Broadcaster Software[3]) that captured the interaction on the interface
- Paperwork
    - Consent forms (see **Appendix F**)
    - Session questionnaires (see **Appendix D**)
    - Demographics questionnaires (see **Appendix E**)

[3] https://obsproject.com/

4 Results

4.1 General description

In total, 24 people participated in the experiment. We did not use any data from the first participant (female, age = 29) as it was only for testing the experiment procedure and we changed the protocol after that. Out of the 23 participants that took part in the formal experiment, 16 were "young", 12 males and 4 females with ages ranging from 22 to 43 (M = 27.69, SD = 5.39). 7 were "elderly", 4 males and 3 females with ages ranging from 59 to 78 (M = 68.86, SD = 5.79).

Due to a technical difficulty that occurred one day that was caused by the robot falling over right before the experiment, one of the young participants (male, age = 27) finished only the first session of the experiment (with mouse) because directly after the first session ended, the robot lost network connection and it was impossible to reconnect. This participant was instructed to only fill-in the demographics questionnaire (without the first question regarding his preferred interface). We only used data from this participant for demographics purposes and in only one statistical test about the training time of the first session (described in section 4.4).

All young participants had a university or college or equivalent education. Out of the 7 elderly participants, 4 had a university or college or equivalent education, one had an intermediate between secondary level and university education and 2 had secondary school education.

All young participants reported that they use computers every day or almost every day while for the elderly 6 reported that they use computers every day or almost every day and one that uses computers occasionally.

12 young participants use video communication systems (such as Skype) often and 4 sometimes, while 3 of the elderly use them sometimes and 4 never use them.

All young participants used mobile phones often. 2 elderly used them often and 5 sometimes.

6 of the young participants reported playing video games often, 6 sometimes and 4 that they never play them. 3 elderly play video games sometimes and 4 never play them.

DVD/VHS technology was reported as being used often by 5 young participants, 9 use them sometimes and 2 never. 1 elderly uses them often, 5 sometimes and 1 never uses them.

For digital camera, 9 young participants use them often, 6 sometimes and 1 never. 5 elderly use them often, 1 sometimes and 1 never uses them.

Regarding prior experience with robots, 4 of the young participants reported having no experience with robots, 3 had seen robots before, 4 had played with robots, 3 had worked with or programmed robots before and 2 had built robots themselves. 4 of the elderly reported having no experience with robots, 1 had seen robots before and 2 had played with robots before.

As of experience with telepresence robots, 8 of the young participants had no experience with telepresence robots, 3 had seen telepresence robots before, 4 had interacted with telepresence robots before and 1 had worked with or programmed telepresence robots before. 6 of the elderly had no experience with telepresence robots and 1 had seen telepresence robots before.

4 of the young and 2 of the elderly participants reported having problems with their eyesight, while in a different question regarding use of glasses and/or lenses, 10 young and 6 elderly participants answered that they use them.

None of the young participants reported having hearing problems or using hearing aids, while 4 elderly participants reported having hearing problems and 4 reported using hearing aids.

4.2 Hypotheses

As discussed before, for the analysis of the data collected, we split participants into two groups: young (N = 16, ages 22 - 43) and elderly (N = 7, ages 59 - 78). We then tested normality of the data using the Shapiro-Wilk test (for details see **Appendix A**). That was taken into account for the selection of the statistical tests which we conducted further. Results of these statistical tests are presented in the following subsections.

4.2.1 H1: The usability and quality of interaction of the system will be improved for the elderly when a touch screen is used instead of a mouse for the control

In order to test whether our first hypothesis is true (*H1: The usability and quality of interaction of the system will be improved for the elderly when a touch screen is used instead of a mouse for the control*), we used paired-samples t-tests (within subjects) when the data from the variables we wanted to compare was normally distributed and sign tests when it was not. One alternative non-parametric test for non-normal data we could use (other than the sign test) is the Wilcoxon signed-rank test. However, this test makes the assumption that the population distributions of the paired differences are symmetrical in shape and in our case they were not. For this reason we chose the sign test instead.

The variables that we tested for significant differences in the two conditions (mouse, touch screen) were the *SUS scores*, the *control of the robot* (mean of answers 11 and 12 that were given on the session questionnaire), the *level of co-presence* (mean of answers 13, 14, 15, 16), the *level of attentional engagement* (mean of answers 17 and 18), the *time between checkpoints* (in seconds) and the *number of collisions* that the robot had with the environment. We performed tests for the elderly group (see **Table 1**) but also for the young (see **Table 2**). All tests showed no statistically significant differences between the two conditions (mouse, touch screen) and for both age groups.

Table 1. Main findings for H1 (for elderly group)

Elderly group (N = 7)				
Variable	**Mouse**	**Touch screen**	**Test**	**Result**
SUS	*M*=70.71 *SD*=23.88	*M*=61.79 *SD*=26.60	Sign test	p=.375
Control of the robot	*M*=3.79 *SD*=0.91	*M*=3.92 *SD*=0.98	Paired-samples t-test	t(6)=-.0505, p=.631, d=0.14
Co-presence	*M*=3.79 *SD*=0.44	*M*=3.57 *SD*=0.75	Paired-samples t-test	t(6)=1.162, p=.289, d=0.36
Attentional engagement	*M*=3.36 *SD*=0.99	*M*=3.14 *SD*=1.03	Sign test	p=1.000
Time between checkpoints	*M*=63.00 *SD*=36.88	*M*=37.86 *SD*=13.56	Paired-samples t-test	t(6)=1.621 p=.156, d=0.90
Number of collisions	*M*=0.71 *SD*=1.11	*M*=0.57 *SD*=0.98	Sign test	p=1.000

Table 2. Main findings for H1 (for young group)

Young group (N = 15)				
Variable	**Mouse**	**Touch screen**	**Test**	**Result**
SUS	*M*=79.67 *SD*=14.94	*M*=76.33 *SD*=17.16	Paired-samples t-test	t(14)=.758, p=.461, d=0.21
Control of the robot	*M*=4.10 *SD*=0.91	*M*=4.13 *SD*=0.55	Sign test	p=1.000
Co-presence	*M*=3.48 *SD*=0.83	*M*=3.30 *SD*=0.75	Paired-samples t-test	t(14)=1.140, p=.274, d=0.23
Attentional engagement	*M*=3.83 *SD*=1.05	*M*=3.77 *SD*=0.80	Sign test	p=.289
Time between checkpoints	*M*=26.93 *SD*=6.78	*M*=27.40 *SD*=10.18	Sign test	p=1.000
Number of collisions	*M*=0.07 *SD*=0.26	*M*=0.27 *SD*=0.70	Sign test	p=1.000

4.2.2 H2: The elderly users will prefer to use a touch screen device instead of a mouse for control of the system after they have tried both ways of input

For testing our second hypothesis *(H2: The elderly users will prefer to use a touch screen device instead of a mouse for control of the system after they have tried both ways of input*) we performed a Mann-Whitney U test between subjects of the two age groups, based on their answer on their interface preference (see **Figure 11**). The test showed no significant difference between the elderly group interface preference (Mdn = 1) and the young group interface preference (Mdn = 1), $U = 44$, $p = .458$, $r = .16$

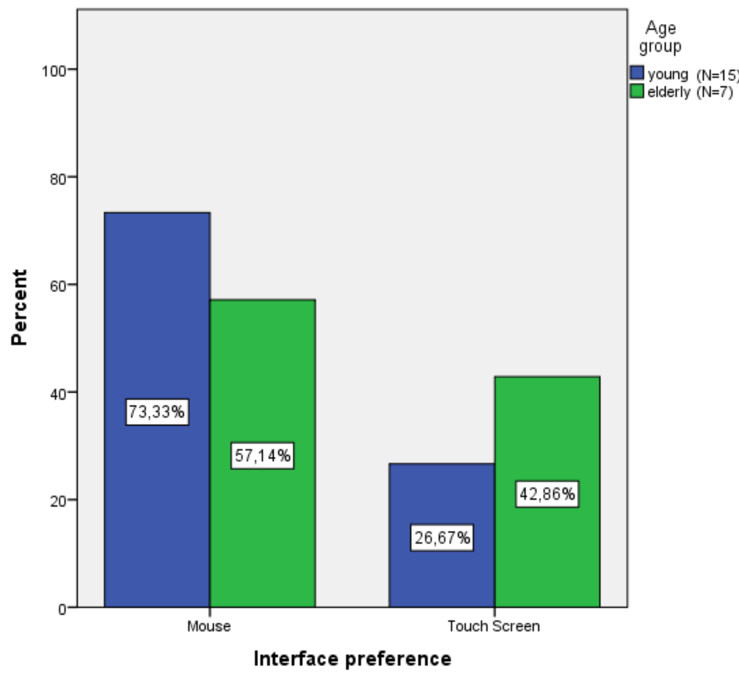

Figure 11. Comparison of preferences for the two age groups

4.2.3 H3: The benefits of a touch screen for elderly users will be better than those for younger users.

For the third hypothesis *(H3: The benefits of a touch screen for elderly users will be better than those for younger users.)* we performed Mann-Whitney U tests between the two age groups on the *SUS scores*, *SUS score difference (touch screen - mouse)*, the *time between checkpoints*, *time between checkpoints difference*, the *number of collisions* that the robot had with the environment, the *number of collisions difference (touch screen - mouse)*, the *control of the robot*, the level of *co-presence* and the level of *attentional engagement* (see **Table 3**). For visual comparison of differences between the two age groups see **Figure 12** - **Figure 19**. From the visual comparisons, a small difference between age groups in favor of the mouse on the *SUS* *scores* for the two devices is shown. There is a difference on the *time between checkpoints* that elderly participants had with the touch screen compared to mouse (less time with the touch screen) and that difference is not shown for young participants. It is also shown that with the touch screen, elderly participants had a bit fewer collisions compared to mouse while for young participants the opposite is shown. *Control of the robot* rating seems to be slightly improved with the touch screen compared to mouse for both age groups while *levels of co-presence* and *attentional engagement* seem to be slightly lower with the touch screen compared to mouse for both age groups.

Statistically significant difference was found in the *time between checkpoints* (for mouse) where the *time between checkpoints* of young participants (Mdn = 26) was statistically significantly lower than that of elderly participants (Mdn = 58), U = 14.5, p = .007, r = .57 and also for touch screen where the *time between checkpoints* of young participants was significantly lower than that of elderly participants, U = 23.5, p = .039, r = .44. Another statistically significant difference was found for the *number of collisions* (for mouse only) where the *number of collisions* of young participants (Mdn = 0.00) was statistically significantly lower than that of elderly participants (Mdn = 0.00), U = 33, p = .041, r = .44:

Table 3. Main findings on the effects of the two input devices between the two age groups

Differences (touch screen - mouse)				
Variable	**Young**	**Elderly**	**Test**	**Result**
SUS score difference (touch screen - mouse)	(*M*=-3.33 *SD*=17.03) Mdn=-2.50	(*M*=-8.93 *SD*=18.92) Mdn=-5.00	Mann-Whitney U	*U*=42, p=.456, r=.16
Time between checkpoints difference (touch screen - mouse)	(*M*=0.47 *SD*=7.95) Mdn=0.00	(*M*=-25.14 *SD*=41.05) Mdn=-31.00	Mann-Whitney U	*U*=38.5, p=.323, r=.21
Number of collisions difference (touch screen - mouse)	(*M*=0.20 *SD*=0.78) Mdn=0.00	(*M*=-0.14 *SD*=0.69) Mdn=0.00	Mann-Whitney U	*U*=42, p=.345, r=.20

Table 4. Main findings on the effect of mouse between the two age groups

Mouse				
Variable	**Young**	**Elderly**	**Test**	**Result**
SUS	(*M*=79.67 *SD*=14.94) Mdn=85.00	(*M*=70.71 *SD*=23.88) Mdn=82.5	Mann-Whitney U	*U*=42.5, p=.479, r=.15
Control of the robot	(*M*=4.10 *SD*=0.91) Mdn=4.00	(*M*=3.79 *SD*=0.91) Mdn=3.50	Mann-Whitney U	*U*=40.5, p=.389, r=.18
Co-presence	(*M*=3.48 *SD*=0.83) Mdn=3.50	(*M*=3.79 *SD*=0.44) Mdn=3.75	Mann-Whitney U	*U*=40, p=.371, r=.19
Attentional engagement	(*M*=3.83 *SD*=1.05) Mdn=4.00	(*M*=3.36 *SD*=0.99) Mdn=3.50	Mann-Whitney U	*U*=36, p=.239, r=.25
Time between checkpoints	(*M*=26.93 *SD*=6.78) Mdn=26.00	(*M*=63.00 *SD*=36.88) Mdn=58.00	Mann-Whitney U	*U*=14.5, p=.007, r=.57
Number of collisions	(*M*=0.07 *SD*=0.26) Mdn=0.00	(*M*=0.71 *SD*=1.11) Mdn=0.00	Mann-Whitney U	*U*=33, p=.041, r=.44

Table 5. Main findings on the effect of touch screen between the two age groups

Touch screen				
Variable	**Young**	**Elderly**	**Test**	**Result**
SUS	(*M*=76.33 *SD*=17.16) Mdn=80.00	(*M*=61.79 *SD*=26.60) Mdn=60.00	Mann-Whitney U	*U*=37.5, p=.290, r=.23
Control of the robot	(*M*=4.13 *SD*=0.55) Mdn=4.00	(*M*=3.92 *SD*=0.98) Mdn=4.00	Mann-Whitney U	*U*=47, p=.682, r=.08
Co-presence	(*M*=3.30 *SD*=0.75) Mdn=3.25	(*M*=3.57 *SD*=0.75) Mdn=3.75	Mann-Whitney U	*U*=37, p=.271, r=.23
Attentional engagement	(*M*=3.77 *SD*=0.80) Mdn=4.00	(*M*=3.14 *SD*=1.03) Mdn=3.50	Mann-Whitney U	*U*=35.5, p=.221, r=.26
Time between checkpoints	(*M*=27.40 *SD*=10.18) Mdn=25.00	(*M*=37.86 *SD*=13.56) Mdn=34.00	Mann-Whitney U	*U*=23.5, p=.039, r=.44
Number of collisions	(*M*=0.27 *SD*=0.70) Mdn=0.00	(*M*=0.57 *SD*=0.98) Mdn=0.00	Mann-Whitney U	*U*=44.5, p=.399, r=.18

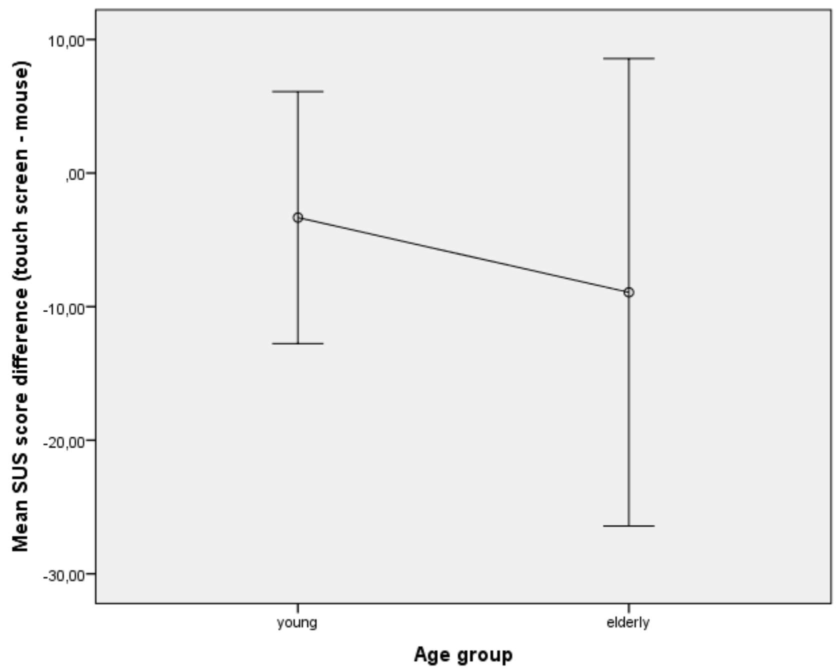

Figure 12. 95% Confidence intervals for SUS score difference means for the two age groups.

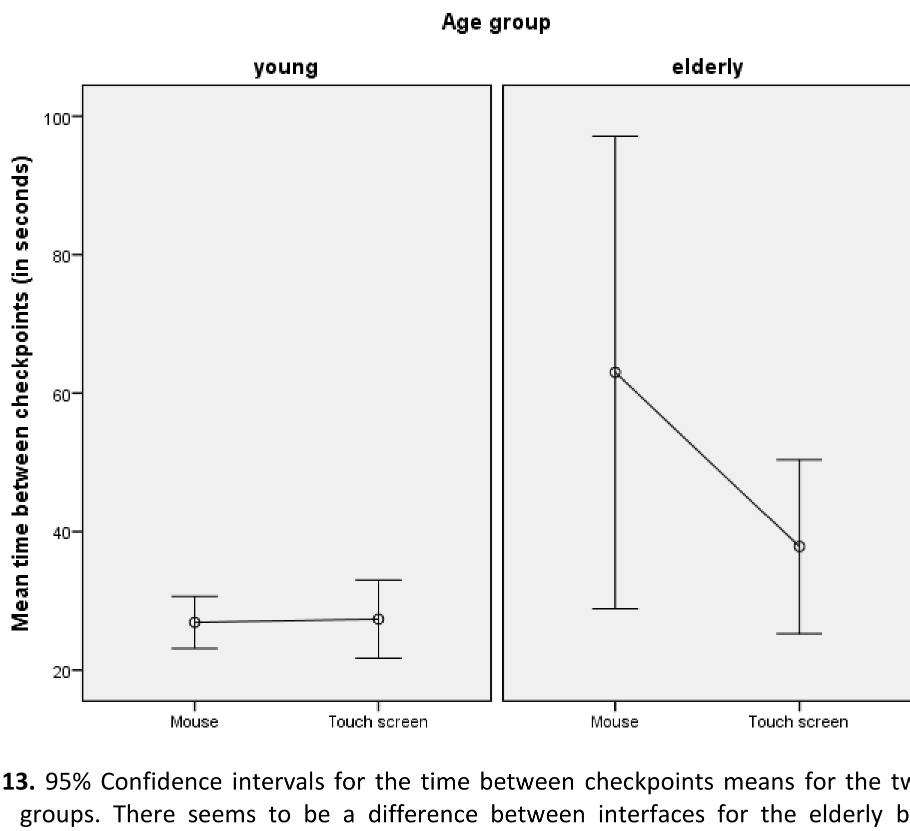

Figure 13. 95% Confidence intervals for the time between checkpoints means for the two age groups. There seems to be a difference between interfaces for the elderly but the paired-samples t-test showed no statistical significance, maybe due to the low number of elderly participants (see section 4.2.1).

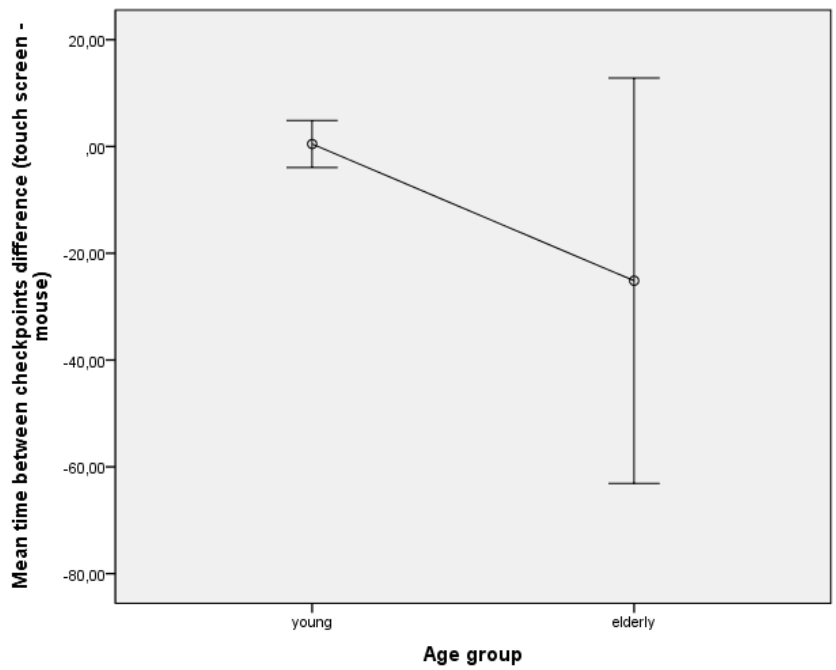

Figure 14. 95% Confidence intervals for the time between checkpoints difference (touch screen - mouse) means for the two age groups.

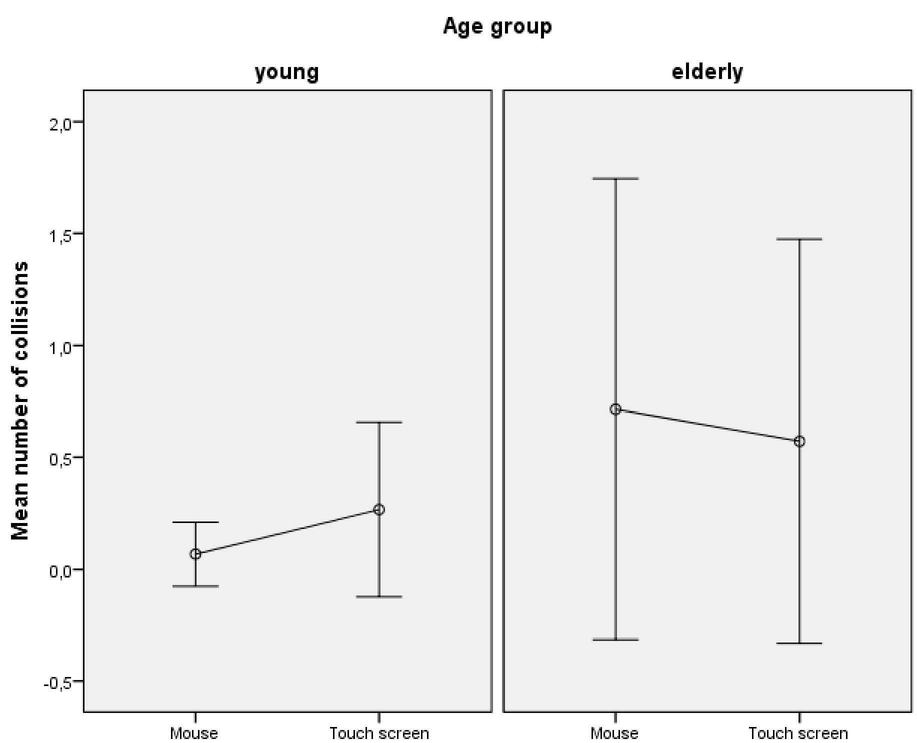

Figure 15. 95% Confidence intervals for the number of collisions means for the two age groups. It is visible that on average, the elderly had more collisions but also that with the touch screen the number was lower (only for the elderly)

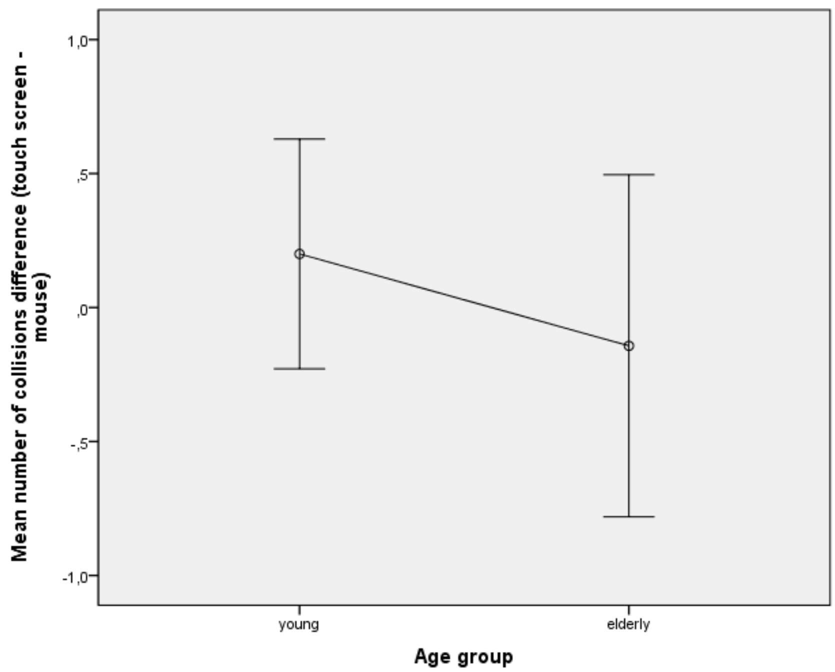

Figure 16. 95% Confidence intervals for the number of collisions difference (touch screen - mouse) means for the two age groups. Negative values represent advantage of the touch screen

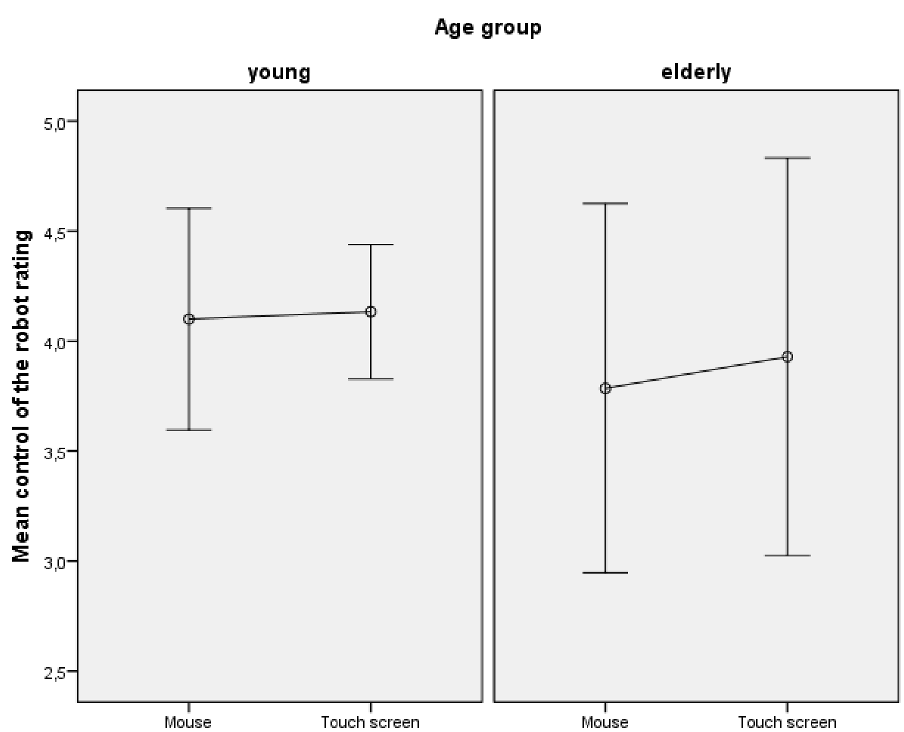

Figure 17. 95% Confidence intervals for the control of the robot means for the two age groups. We can see that the elderly showed an improvement in their answer when they used the touch screen but the difference is small.

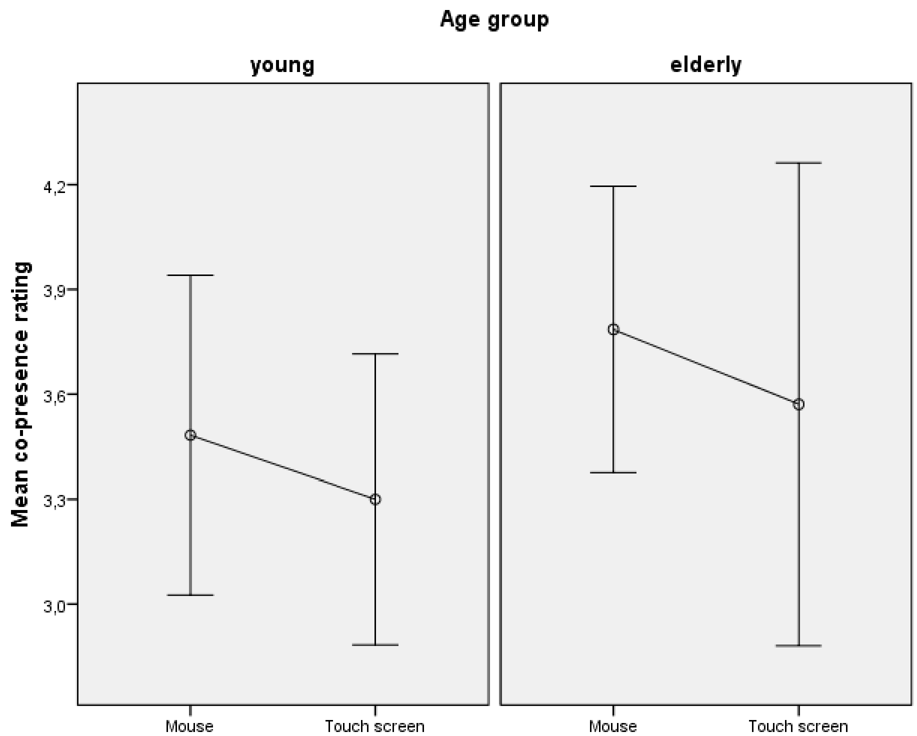

Figure 18. 95% Confidence intervals for the level of co-presence means for the two age groups

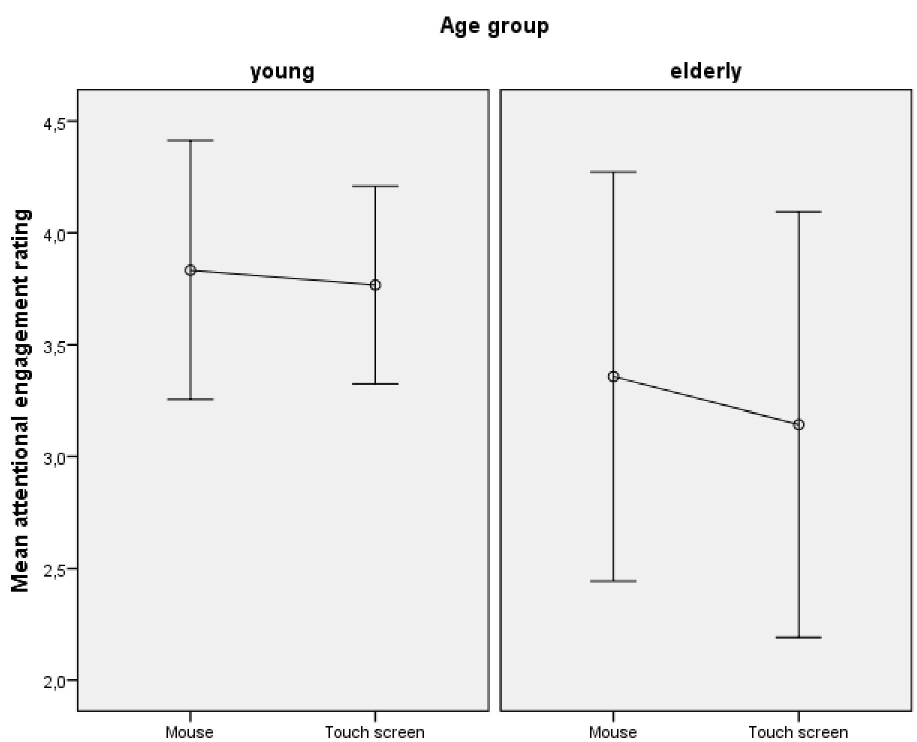

Figure 19. 95% Confidence intervals for the level of attentional engagement means for the two age groups.

4.3 Video games effect

Similarly to the study by Kristoffersson, Coradeschi, Eklundh, et al. (2013) we also examined if the different levels of video game experience as reported by participants in the questionnaire (Often, Sometimes, Never) influenced *SUS scores* and *control of the robot* ratings. We performed Kruskal Wallis H tests on the data of all participants (N = 22) on the *SUS scores*, *SUS score difference (touch screen - mouse)*, *time between checkpoints difference (touch screen - mouse)* and *number of collisions* for mouse and for touch screen but found no significant differences. For details see **Appendix B**

4.4 Training time of first session (mouse or touch screen)

The training time for the first session that participants had (either with mouse or with touch screen) was measured in seconds. The measurement was not absolute but shows the general tendency (for visual comparison see **Figure 20**). A between subjects Mann-Whitney U test (elderly, N = 7, versus young, N = 16) showed that first training time was statistically significantly higher in the elderly group (U = 8, p = .001, r = .67). The difference between standard deviations of the two groups was also big (young SD = 103.9, elderly SD = 740.48). This could mean that the elderly have more varied needs for training of the system which depend on the specific person. Please note that for this test only, we also used data from the participant who only finished the first session. So for the young group N = 16 instead of 15.

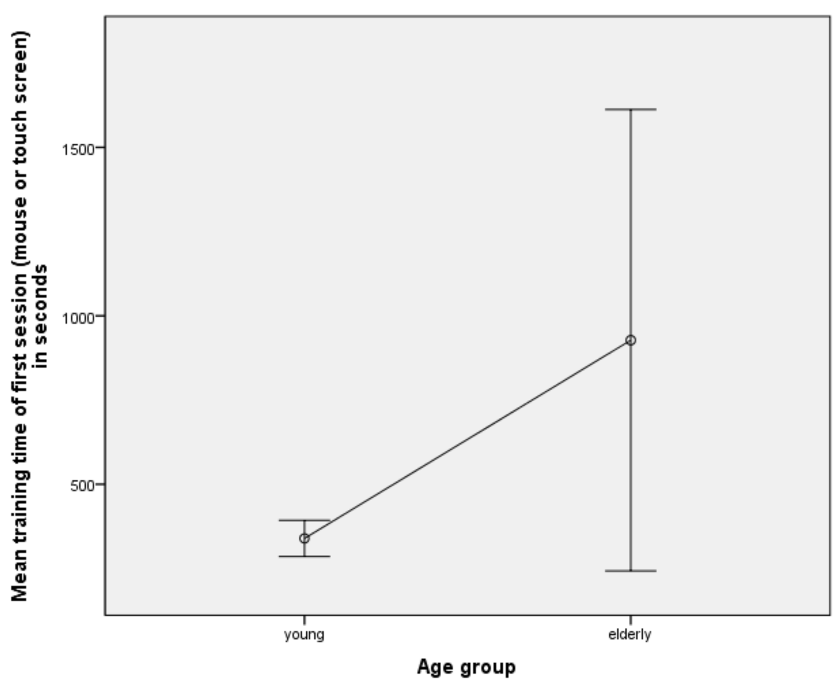

Figure 20. 95% Confidence intervals for the training time means of first session (either with mouse or touch screen) for the two age groups. The difference between age groups is statistically significant. For this test only, the number of young participants was 16

instead of 15 as we used the data from the participant who completed only the first session

4.5 Order of input device effect

In order to check whether there was any effect from the order that participants used the two input devices, we performed Mann-Whitney U tests on all variables that we measured. For the two age groups separately, we found no significant differences for all variables. When performed on the data of the total number of participants (N = 22), statistical significance was found only in the *control of the robot* rating (for touch screen only) where the *control of the robot* rating (with the touch screen) of participants who used the touch screen in the second session (Mdn = 4.75) was statistically significantly higher than that of participants who used the touch screen in the first session (Mdn = 4.00), $U = 30.5$, $p = .05$, $r = .44$.

4.6 Video observations

From the video analysis we conducted, we took note of some interesting findings (more detailed descriptions in **Appendix C**):

With the touch screen, users don't get to see the dark green line that shows the expected track of the robot when you hover the mouse pointer without tapping one time first because you cannot use the mouse-over function with the finger on the touch screen but you can only click or click and drag.

Small but fast movements of the mouse (depending on mouse settings) can correspond to relatively large movements of the pointer on the screen. For the touch screen, the case is different as moving distance of finger on the screen is the exact same distance that the pointer will make on the screen. Two participants of the young group moved the mouse pointer so fast that they moved it over the video boundaries while driving the robot with the mouse and that made the robot stop (see **Figure 21**). They did not show the same behavior when controlling the robot with the touch screen.

Figure 21. While the participant was turning left, he moved the mouse pointer out of the left video boundary and that made the robot stop. This behavior was only shown with the mouse

Three participants of the young group were holding their hand on the touch screen in a way that obstructed their view of the robot path so at some point they had to move or change hands to get a better view of the screen. One of them had his fingers stretched as well so he was covering a large percentage of the screen (see **Figure 22**).

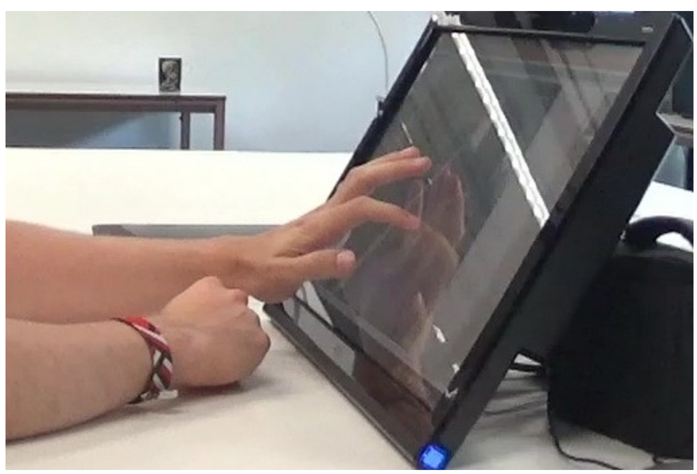

Figure 22. Participant covering a large area of the screen with his hand

An elderly participant ("B") that was in training session with mouse was pointing to a location very far away from the robot and through the chairs so he probably did not understand fully how the robot would behave (see **Figure 23**). Almost in all collisions that this person had with the environment, he was not trying to stop the robot after impact (not even slow down) even though it was clear that there was an obstacle in front and the robot could not move freely in that direction (see **Figure 24**). He showed this behavior with both input devices. That probably means that this was more of a cognitive issue (perhaps lack of proper training) than an input device use issue. Another elderly participant mentioned after the experiment that she had the impression that the robot was hanging from the ceiling, so she had not understood that it was actually moving with wheels on the ground. Probably she had this impression due to the height of the camera (which is on top of the robot) and the wide angle lens, combined with the fact that when driving, you only see a small part of the base of the robot. So it could seem as if you are closer to the ceiling than to the floor and in her case this caused confusion.

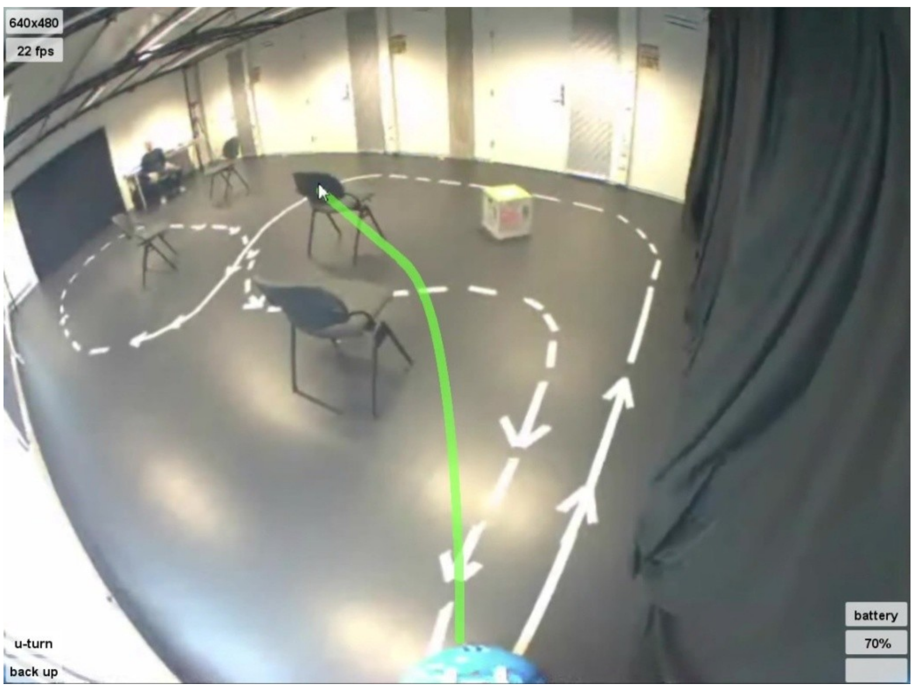

Figure 23. Elderly participant "B" in his training session with the mouse. He points and clicks at the second chair to start driving

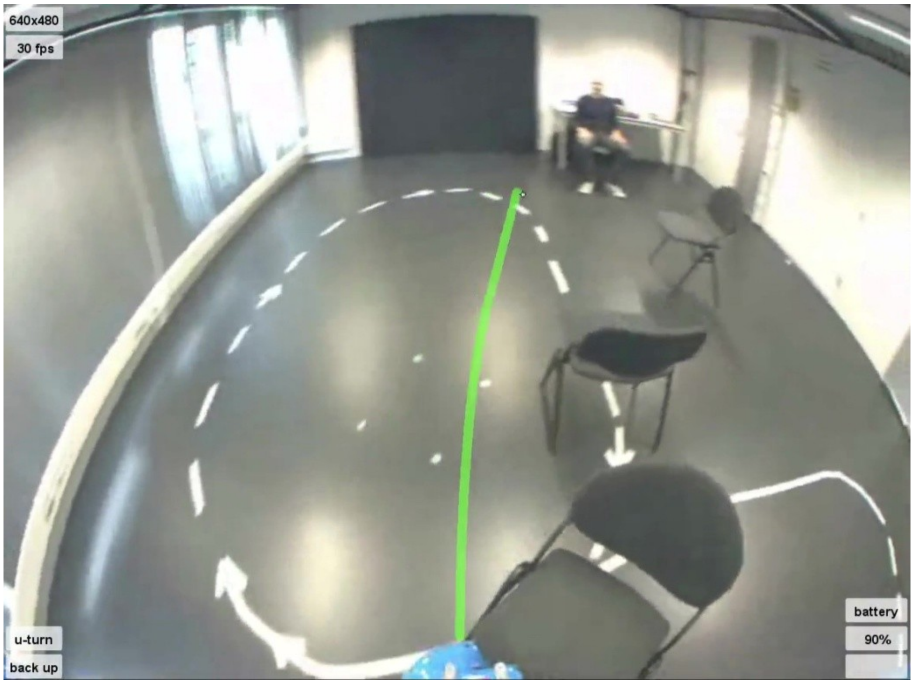

Figure 24. Elderly participant "B" during his training session with the touch screen. It is clear that the chair is blocking the robot but the participant does not stop or reduce speed

It seems that some participants had problems with figuring out the distance of the robot from obstacles as two participants (one young and one elderly) moved very close to the confederate during their training sessions. The young participant (while in a safe distance) asked the confederate to tell him what his distance from the robot at that moment was and to lift his hand in front of him and towards the robot in order to understand the distance better. The elderly participant moved so close to the chair that the confederate had to move his legs in order to avoid getting hit by the robot.

5 Discussion and conclusions

In this study, we conducted an experiment with a MRP system, in which a comparison between a mouse versus a touch screen as input device for controlling the robot was made. The goal of the study was to improve the control of the system especially for the elderly. Participants had to control the Giraff telepresence robot through a cluttered environment while answering simple questions to a confederate through the robot. They had two formal driving sessions: one by using a mouse and one by using a touch screen.

For our first hypothesis (that the usability and quality of interaction will be improved with the touch screen) results showed that the differences between the two versions were not statistically significant for all the tests we performed. However, this may be due to the small number of elderly and young participants in the experiment (N = 7 and N = 15 respectively). The *SUS score* mean was a bit lower for the elderly and the young group when using the touch screen but the *control of the robot* rating by participants, the *number of collisions* and the *time between checkpoints* were in favor of the touch screen for the elderly even though we did not find statistical significance. It is worth noting here that for the young participants the touch screen seemed to have the opposite effect in the *number of collisions* that the participants had with the environment and the *time between checkpoints*. In their case it seems that the touch screen made them make more collisions than with the mouse and they did longer time to drive the robot. Further, it is important mentioning that with the mouse, two of the participants were moving the cursor much faster than their finger on the screen and out of the video boundaries and this made the robot stop while they did not show the same behavior with the touch screen. Probably this is because with a touch screen one has more precise control of the cursor movement where movements of the finger on the screen relate to the exact same movement distance of the cursor while for the mouse this is not the case.

An interesting observation from the data is that the means of the levels of *attentional engagement* were lower for the elderly group, with the touch screen having a lower mean than mouse in both age groups while the means of the level of *co-presence* were higher in the elderly group but again the touch screen had a lower mean than mouse in both groups. So it seems that the touch screen decreased the levels of *co-presence* and *attentional engagement* compared to mouse in both age groups. Maybe this was because of an effect that the hand in front of the screen has. Maybe it means that users feel less “telepresent” and pay less attention to the other person when having their hand in front of the screen but the difference in means was low and we also did not find statistical significance for these effects.

For the second hypothesis the difference in user preference of the two devices is much smaller for the elderly (57.2% for mouse, 42.86% for touch screen). Also the percentage of touch screen preference for the elderly (42.86%) is higher than that of young participants (26.67%). 3 of the participants preferred the mouse even though their touch screen *SUS score* was higher than that of mouse *SUS score*. 2 preferred the mouse while the *SUS scores* were equal for mouse and touch screen. 2 of the participants that preferred the touch screen had higher *SUS score* with the mouse and one preferred the touch screen while *SUS scores* where equal. Even though the preference for mouse was higher than for touch screen, the difference was not statistically significant but still the touch screen preference has a pretty high percentage number which suggests that when given the option, a large number of elderly participants would prefer to use the touch screen instead of the mouse. However, as we saw no statistical significance on the difference on the interface preference for both elderly and young participants, the hypothesis is rejected. Nevertheless, it is our belief that with a larger number of participants and also with more elderly participants with low levels of computer experience, statistical significance could be found even for greater preference for touch screen than for mouse.

Our third hypothesis was that the benefits of a touch screen for the elderly would be better than for young participants. We found no statistical significance in the tests but it is remarkable that significant difference between the two groups on the *number of collisions* was found for the mouse interface but not for the touch screen interface. This suggests that the use of the mouse causes significantly more collisions with the environment in elderly users than in young users and that is an effect which is not shown with the touch screen (tests showed no significance for touch screen). As no statistical significance was found in the difference between the two input devices in the *number of collisions* with the environment (for both elderly and young) we should be careful when interpreting this finding.

Based on the questionnaire data we gathered from participants, we saw that some participants mentioned lag issues with the input device. That is a common finding with Mosiello et al. (2013). Some were from the mouse and some from the touch screen session so we assume it is a general interface or network issue. The major advantages of the touch screen that participants mentioned were that it seemed to be more precise, that it is much simpler, easier and funnier to control than the mouse, that they could steer without much effort, that they understand precisely how it works, that it feels more natural, that it might be beneficial to people with less computer experience and that one can get experienced to it quickly. The most common issues some of them had were mostly related to their hands blocking their view of the path, some lag issues that could also be caused by the system in general, the fact that you have to move your arm a lot, one participant mentioned that he could not move his fingers easily on the screen, and finally because they are more used to working with a mouse so the mouse feels more natural. Most of the advantages of the mouse were about it being fast and easy to use and that they are more used to it as they use it every day.

Another important finding is that at least for some participants (not only elderly) it seems that their difficulty with driving the robot and having collisions with the environment was more likely caused by a cognitive issue than by an input device issue. We believe that the problem is due to misunderstanding of what the robot looks like, or what its exact size is, miscalculation of distances of things close to the robot and how exactly it will respond to the user's commands. For example, some participants were observed trying to drive the robot in a way that was clearly wrong (independently of input device used). More particularly, they were insisting on driving forward even after it was clear that they hit an obstacle which was blocking their way (usually a chair) and they were not even trying to slow down. Some of the participants mentioned in the questionnaire that they were not completely aware of the robot's surroundings, they could not see how big the robot is, and that made it harder to avoid obstacles, or that it was hard to estimate how close they were to an object. One of the young participants in his training session with the mouse moved close to the chair where the confederate was sitting and asked to be told the approximate distance of his position from the robot. An elderly participant even mentioned after the experiment was over that she had the impression that the robot was hanging from the ceiling. 4 participants (1 elderly) mentioned in questionnaires that it was hard to control the speed of the robot (independently of input device). One of these participants (young) also tried to explain why: *"The fact that the bigger the line the quicker it goes sometimes can be difficult, as you keep in mind that you show it the point that you want it to be and you forget that it goes faster, so sometimes it hits several objects".* That is interesting because it shows that there is a misunderstanding in what the user feels that the robot will do when they click at a point on the screen versus what the robot actually does. In this case the participant has the impression that the robot will just move to the point they have clicked on, when in reality the robot just moves to the general direction of the pointer, so you actually have to point and click at a nearest point to the robot (instead of just to your desired final destination) and constantly move the pointer left/right and up/down to adjust the direction and speed accordingly in relation to the position of the robot in space. 2 more participants seem to have the same impression: one (young) mentioned that at first he did not expect to hold his finger on the mouse button for the robot to keep moving (and he disliked it also), probably meaning that he expected to just click on the final destination once. The other participant (elderly) who mentioned something similar said that she disliked the green line because it does not point to the precise location and is not easy to get used to this. These are similar findings to those of Mosiello et al. (2013) where participants in their study (with the Giraff robot as well) also had a difficulty understanding how the robot would move according to their commands.

Most of these problems seem that could be improved with more training and practice time but also with better training in general. To test whether practice time with the system made a difference, we conducted statistical between-subjects tests to check whether results from the second session of participants were better than their first. We only found statistical significance for touch screen results for the *control of the robot* rating, where participants who had first used the mouse, rated the control of the robot with the touch screen higher compared to the rating when the order of devices was opposite. No statistically significant difference was found for the *control of the robot* with the mouse rating so we assume that this was not related to practice time with the system in general, but it is not easy to interpret this result. The training time of the system was much longer for the elderly than for young participants and that was something we expected as elderly people generally need more time to learn a new computer skill than younger people do (Charness, Kelley, Bosman, & Mottram, 2001). So especially for the elderly the case seems to be that they certainly need more practice time and probably some additional forms of training such as watching a video that shows what the robot looks like and how it moves into space.

Even though we did not find many statistically significant differences between the two input devices, it seems that at least the touch screen has an advantage in the driving time, *control of the robot* rating and *number of collisions* of elderly participants, therefore it is our belief that with more elderly participants in the experiment we could see statistical significance for these effects. Further, it is clear that the input device that is used for the control plays a role in usability of the system but there are also other probably more important issues that relate to perception of robot dimensions, space and distances in the remote environment or clear understanding of how the navigation system works, for example.

Based on these findings, we can recommend that makers of MRP systems could improve their interfaces (not only for the elderly) by using a more intuitive navigation system such as one that you can just point and click once at a target that you want the robot to move towards, they could implement automatic obstacle avoidance systems into the robots and also make them move more autonomously. Moreover, a way to inform the pilot user of the distance that objects have near the robot (especially near the base) would be useful for avoiding obstacles. That could be realized as an auditory indicator that would work similarly to audio warnings in parking assistance radar systems in cars or as visual indicators on the four edges of the video output of the system that would light (possibly with different intensities or colors) when an object would be very close to the robot in the analogous direction. Also the robot could have an automatic stopping feature when the distance from an obstacle would be detected as being too short. Possibly even a way to visualize the shape and size of the robot into the video output such as by inserting a 3D model of the robot as in augmented reality applications would help users understand how much space the robot will occupy. In addition, as a way to have people get a more clear picture of what the robot looks like and how it behaves, it would be a good option to have a video demonstration as an optional tutorial into the interface. This could be shown by default to first time users for example. Furthermore, an option to make the interface more useable for touch screens for people who prefer to use a touch screen would be a good idea. That could be made by making the buttons on the interface bigger so that they can be pressed easier with a finger and also that some controls such as for the movement of the camera (with the mouse wheel in the case of the Giraff) can be used with the touch screen as well (such as with a 2 or 3 fingers gesture on the screen).

For the future, more similar studies are needed, with more elderly participants in control of MRP systems in order to confirm our findings and it would be best to include a different type of training such as first having participants watch a video of the robot in use or even have them watch the robot in person as that might improve their understanding of the system and eventually, their control of it. In addition, as this study was conducted with a specific

MRP system (the Giraff), our findings might be more applicable to this particular system so it is important to also conduct similar studies with different MRP systems as well.

In conclusion, even though the number of participants in our study was low, the results indicate that touch screens can indeed help at least some of the elderly drive faster and with fewer collisions, while being a reasonably good alternative to mouse as input device for a MRP system.

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Appendix A: Normality tests

Below you can find an example of the normality tests we conducted for all the variables that we did statistical tests. In this example, the tables, normality tests, histograms and plots that we used for checking the normality of the mouse *SUS scor*e variable (separated by age group) are presented.

Mouse SUS score

Descriptives

	Age group			Statistic	Std. Error
Mouse SUS Score	young	Mean		79,6667	3,85655
		95% Confidence Interval for Mean	Lower Bound	71,3952	
			Upper Bound	87,9382	
		5% Trimmed Mean		80,1852	
		Median		85,0000	
		Variance		223,095	
		Std. Deviation		14,93637	
		Minimum		52,50	
		Maximum		97,50	
		Range		45,00	
		Interquartile Range		27,50	
		Skewness		-,621	,580
		Kurtosis		-,544	1,121
	elderly	Mean		70,7143	9,02566
		95% Confidence Interval for Mean	Lower Bound	48,6293	
			Upper Bound	92,7993	
		5% Trimmed Mean		71,6270	
		Median		82,5000	
		Variance		570,238	
		Std. Deviation		23,87966	
		Minimum		35,00	
		Maximum		90,00	
		Range		55,00	
		Interquartile Range		50,00	
		Skewness		-1,121	,794
		Kurtosis		-,916	1,587

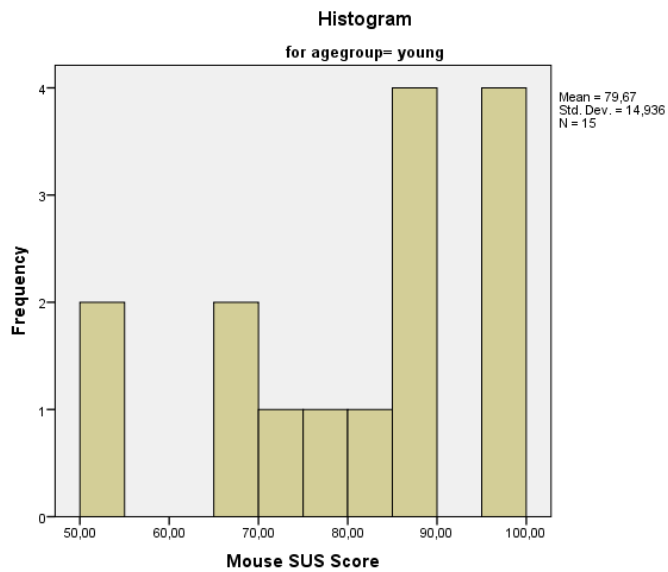
Tests of Normality

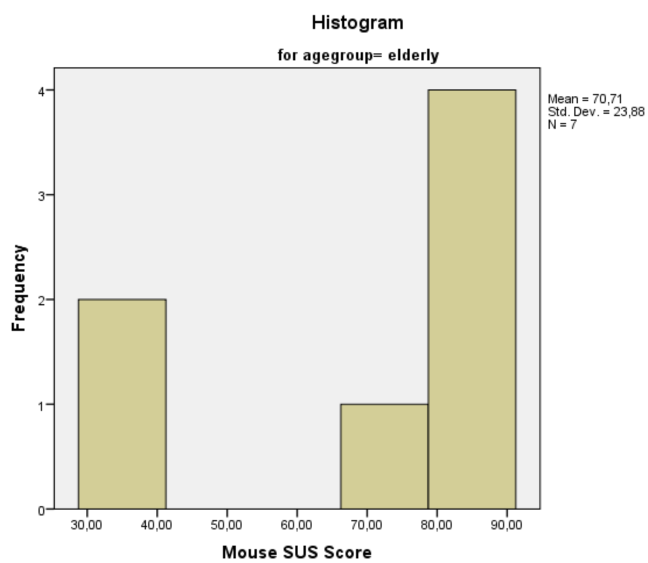
	Age group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Mouse SUS Score	young	,173	15	,200*	,911	15	,138
	elderly	,326	7	,023	,745	7	,011

*. This is a lower bound of the true significance.

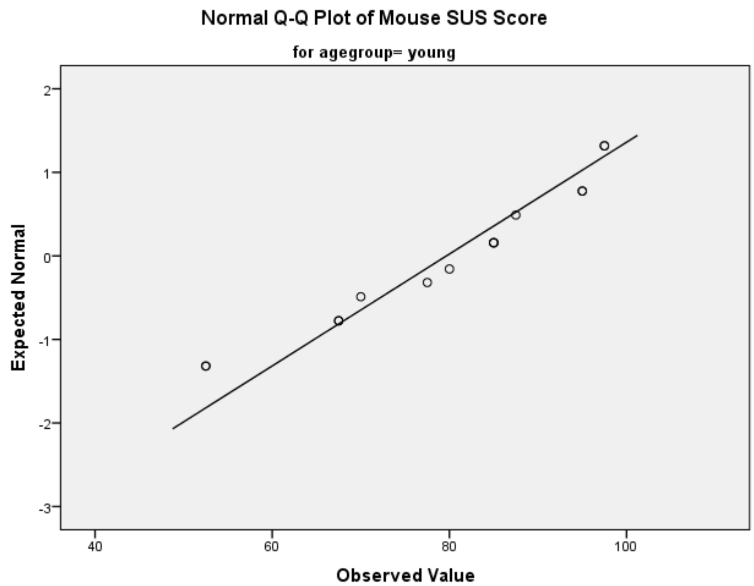
a. Lilliefors Significance Correction

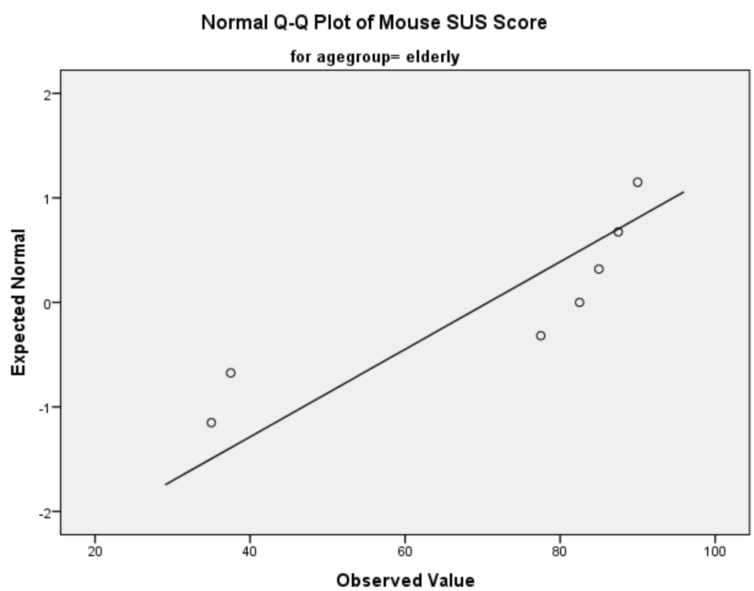
Histograms



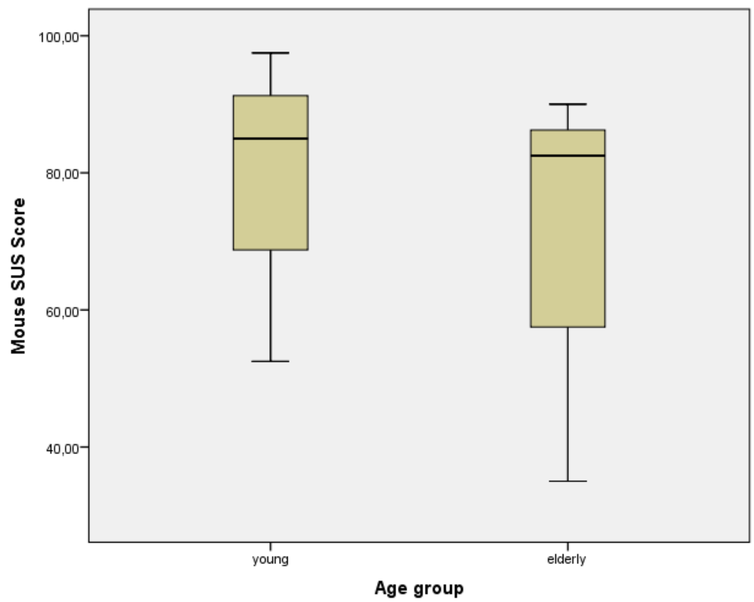


Normal Q-Q Plots





Detrended Normal Q-Q Plots


100,00
80,00
60,00
40,00
Mouse SUS Score
young
elderly
Age group

Appendix B: Statistical tests for video games effect

Mouse SUS score: Kruskal-Wallis H test: no statistical significance: $\chi^2(2) = 1.937$, $p = .380$ (mean rank scores of 13.56 for Never, 9.28 for Sometimes and 12.20 for Often).

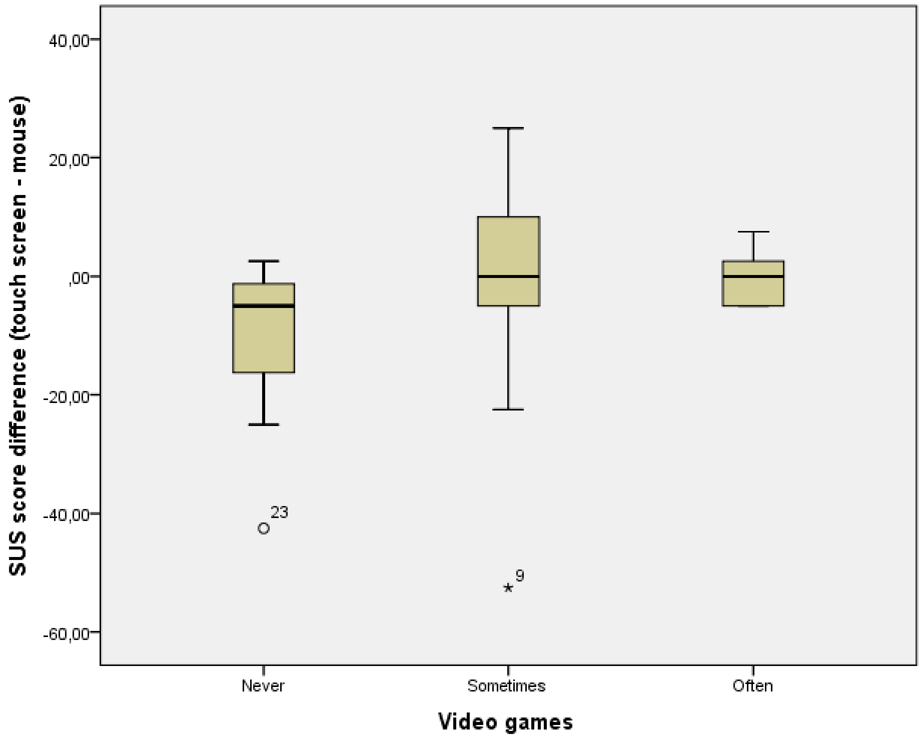
Touch screen SUS score: Kruskal-Wallis H test: no statistical significance: $\chi^2(2) = 1.113$, $p = .573$ (mean rank scores of 11.19 for Never, 10.33 for Sometimes and 14.10 for Often).

SUS score difference (touch screen - mouse): Kruskal-Wallis H test: no statistical significance: $\chi^2(2) = 2.726$, $p = .256$ (mean rank scores of 8.50 for Never, 13.28 for Sometimes and 13.10 for Often).

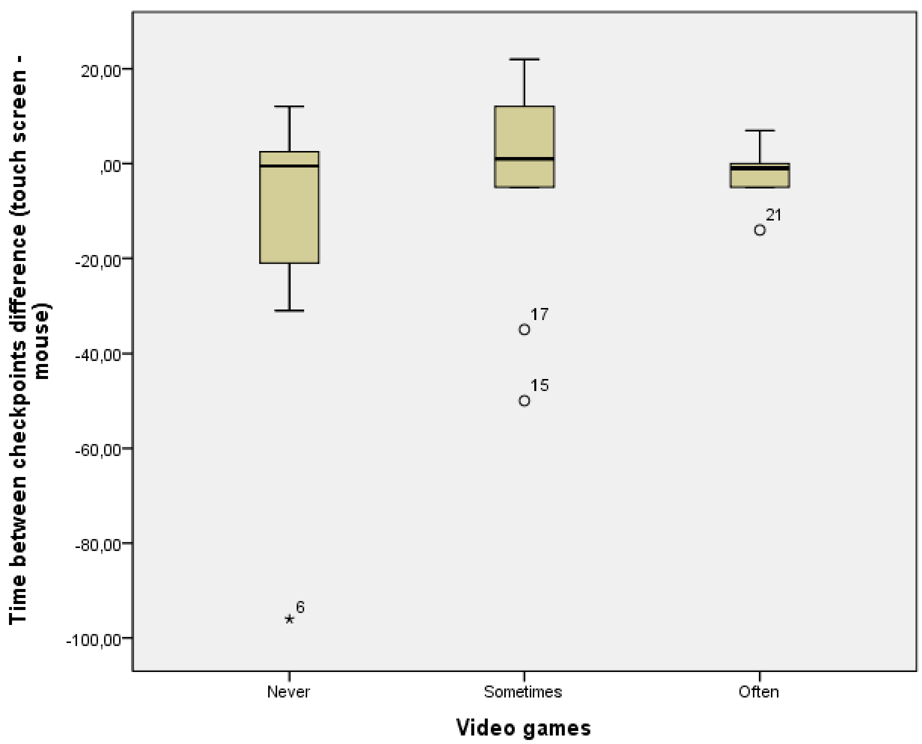
Time between checkpoints difference (touch screen - mouse): Kruskal-Wallis H test: no statistical difference: $\chi^2(2) = .700$, $p = .705$ (mean rank scores of 10.50 for Never, 12.89 for Sometimes and 10.60 for Often).

Number of collisions (mouse): Kruskal-Wallis H test: no statistical difference: $\chi^2(2) = 1.428$, $p = .490$ (mean rank scores of 12.38 for Never, 11.83 for Sometimes and 9.50 for Often).

Number of collisions (touch screen): Kruskal-Wallis H test: no statistical difference: $\chi^2(2) = 1.394$, $p = .498$ (mean rank scores of 12.25 for Never, 11.94 for Sometimes and 9.50 for Often).



40,00
20,00
,00
-20,00
-40,00
-60,00
SUS score difference (touch screen - mouse)
23
9
Never
Sometimes
Often
Video games



20,00
,00
-20,00
-40,00
-60,00
-80,00
-100,00
Time between checkpoints difference (touch screen - mouse)
21
17
15
6
Never
Sometimes
Often
Video games

Appendix C: Video observations

Subject: 10

File: 2015-05-27-095204.mp4

Position:00:20:25 and 00:20:35, 00:25:09

Comment: It seems that the participant uses the mouse more quickly than his finger on the touch screen (and this makes sense as the mouse pointer moves much faster than your finger on the screen. Small but fast movements of the mouse correspond to relatively large movements of the pointer on the screen. For the touch screen, the case is different as moving distance of finger on the screen is the exact same distance that the pointer will make on the screen). At this moment we see that he is able to drive so fast that he basically puts the mouse pointer out of the video boundaries and that makes the robot actually stop. This is a behavior that is not shown when using the touch screen. Maybe it means that with touch screen, users get more feedback about where they are actually pointing to on the screen or that they just have more fine control of the robot.

Subject: 13

File: MAH0013.MP4

Position: 00:19:00

Comment: Subject lifts and turns his elbow in the air in order to see better the base of the robot.

Position: 00:19:32

Comment: In the training session with the touch screen, the subject changes his hand and has all his fingers stretched. He says "the disadvantage here I think is that your hand is in front of you. Besides that, it's very.. it's ok"

Position: 00:19:59

Comment: In the training session with the touch screen, when he learns that he can double click things to face them he mentions: "that's more.. that's better.. like.. I want to look at stuff"

Position: 00:21:34

Comment: Subject switches hand on the screen (from right to left) to get better view of the right side of the screen. He then has his fingers stretched blocking a large space of the view on the left side

Subject: 18

File: 2015-06-04-1001-07.mp4

Position: 00:12:05, 00:12:55 (training session with mouse)

Comment: Here the subject puts the mouse pointer out of the video boundaries and that makes the robot actually stop. This is a behavior that is not shown when using the touch screen (similar to subject 10)

Subject: B (elderly group)
File: 2015-06-23-0859-18.mp4
Position: 00:37:18 (training session with mouse)
Comment: Here the subject aims the pointer very far away from the robot (near the second chair). Maybe he expects that the robot will drive there avoiding the obstacles by itself.

Position: 00:28:36 and 00:28:42 and almost all of the collisions (such as 00:10:28) in all sessions (touch screen and mouse also)
Comment: After both collisions with the chairs, the subject does not take his finger away from the screen to stop but keeps pressing it (even without trying to slow down) even though it's clear that the robot pushes the chair away and cannot move freely. This may hint that frequent collisions by the elderly are more of a cognitive issue than an input device skill issue.

Appendix D: Session questionnaire

(English version)

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

	Strongly disagree				Strongly agree
11. It was easy to navigate with the robot	1	2	3	4	5
12. It was easy to make the robot do what I want	1	2	3	4	5
13. I felt that the person in the remote room and I were in the same place	1	2	3	4	5
14. I believe that the person in the remote room felt as if we were in the same place	1	2	3	4	5
15. I was aware of that the person in the remote room was there	1	2	3	4	5
16. The person in the remote room was aware that I was there	1	2	3	4	5
17. I paid attention to the person in the remote room	1	2	3	4	5
18. The person in the remote room paid attention to me	1	2	3	4	5

19. What did you like about the interface?

20. What did you dislike about the interface?

21. What did you find easy about controlling the robot with this input device?

22. What did you find difficult about controlling the robot with this input device?

For the experimenter

Subject ID:...... Session:......

Session questionnaire (Dutch version)

	Helemaal mee oneens				Helemaal mee eens
1. Ik denk dat ik dit systeem vaak zou gebruiken	1	2	3	4	5
2. Ik vond dit systeem onnodig complex	1	2	3	4	5
3. Ik vond het systeem makkelijk te gebruiken	1	2	3	4	5
4. Ik denk dat ik ondersteuning van een technisch persoon nodig zou hebben om dit systeem te kunnen gebruiken.	1	2	3	4	5
5. Ik vond de verschillende functies in het systeem goed geïntegreerd.	1	2	3	4	5
6. Ik vond dat er te veel inconsistentie in het systeem zat	1	2	3	4	5
7. Ik kan me voorstellen dat de meeste mensen zeer snel kunnen leren om dit systeem te gebruiken	1	2	3	4	5
8. Ik vond het systeem omslachtig in het gebruik	1	2	3	4	5
9. Ik voelde me erg zelfverzekerd bij het gebruik van het systeem	1	2	3	4	5
10. Ik moest veel leren voor ik het systeem goed kon gebruiken	1	2	3	4	5

	Helemaal mee oneens				Helemaal mee eens
11. Het was makkelijk om te navigeren met de robot	1	2	3	4	5
12. Het was makkelijk om de robot te laten doen wat ik wou	1	2	3	4	5
13. Ik had het gevoel dat de persoon in de andere ruimte en ik op dezelfde plek waren	1	2	3	4	5
14. Ik geloof dat de persoon in de andere ruimte het gevoel had dat wij op dezelfde plek waren	1	2	3	4	5
15. Ik was mij ervan bewust dat de persoon in de andere ruimte er was	1	2	3	4	5
16. De persoon in de andere ruimte was zich ervan bewust dat ik er was	1	2	3	4	5
17. Ik heb gelet op de persoon in de andere ruimte.	1	2	3	4	5
18. De persoon in de andere ruimte heeft op mij gelet	1	2	3	4	5

19. Wat vond u fijn aan de interface?

20. Wat vond u niet fijn aan de interface?

21. Wat vond u makkelijk aan het besturen van de robot met dit invoerapparaat?

22. Wat vond u moeilijk aan het besturen van de robot met dit invoerapparaat?

Voor de experimentleider

ID:...... Sessie:......

Appendix E: Demographics questionnaire

(English version)

Please fill in all the questions below. If anything is unclear you can ask the experimenter.

1. **Do you prefer any of the two interfaces you have tried? Why?**

2. **Are you male or female?**

☐ Male

☐ Female

3. **What is your age?**

....

4. **What is the highest level of education you have completed?**

☐ University or college or equivalent (Universiteit/HBO)

☐ Intermediate between secondary level and university (MBO)

☐ Secondary school (Middelbare school)

☐ Primary school (Basisschool)

5. **What technological tools do you have experience in using? Check all that apply.**

Mobile phone:

☐Often ☐Sometimes ☐ Never

Video communication systems (such as Skype):

☐Often ☐Sometimes ☐ Never

Computer/Internet:

☐Often ☐Sometimes ☐ Never

Video games:

☐Often ☐Sometimes ☐ Never

DVD/VHS:

☐Often ☐Sometimes ☐ Never

Digital camera:

☐Often ☐Sometimes ☐ Never

6. **Do you have experience with computers?**
   - ☐ I use computers every day or almost every day
   - ☐ I use computers occasionally
   - ☐ I rarely use computers
   - ☐ I have no experience with computers
7. **Do you have prior experience with robots?**
   - ☐ I have seen robots before
   - ☐ I have played with robots
   - ☐ I have worked with / programmed robots before
   - ☐ I built robots myself
   - ☐ I have no experience with robots
8. **Do you have prior experience with telepresence robots? (Like the one you drove now)**
   - ☐ I have seen telepresence robots before
   - ☐ I have interacted with telepresence robots before
   - ☐ I have worked with / programmed telepresence robots before
   - ☐ I have no experience with telepresence robots
9. **Do you have problems with your eyesight?**
   - ☐ Yes
   - ☐ No
10. **Do you have problems with hearing?**
    - ☐ Yes
    - ☐ No
11. **Do you use glasses and/or lenses?**
    - ☐ Yes
    - ☐ No
12. **Do you use a hearing aid?**
    - ☐ Yes
    - ☐ No

For the experimenter

Subject ID:……

Demographics questionnaire (Dutch version)

Beantwoord alstublieft alle onderstaande vragen. Als er iets onduidelijk is, kunt u dat aan de experimentleider vragen.

1. **Heeft u een voorkeur voor een van twee gebruikte invoerapparaten? Waarom?**

2. **Wat is uw geslacht?**

☐ Man

☐ Vrouw

3. **Wat is uw leeftijd?**

....

4. **Wat is de hoogste opleiding die u hebt afgerond?**

☐ Universiteit/HBO

☐ Beroepsopleiding (MBO)

☐ Middelbare school

☐ Basisschool

5. **Hoe vaak gebruikt u de volgende technologieën?**

Mobiele telefoon:

☐Vaak ☐Soms ☐ Nooit

Videobellen (bijvoorbeeld met Skype):

☐Vaak ☐Soms ☐ Nooit

Computer/Internet:

☐Vaak ☐Soms ☐ Nooit

Computerspellen:

☐Vaak ☐Soms ☐ Nooit

DVD/VHS:

☐Vaak ☐Soms ☐ Nooit

Digitale camera:

☐Vaak ☐Soms ☐ Nooit

6. Heeft u ervaring met computers?

- ☐ Ik gebruik dagelijks computers
- ☐ Ik gebruik af en toe computers
- ☐ Ik gebruik zelden computers
- ☐ Ik heb geen ervaring met computers

7. Heeft u ervaring met robots?

- ☐ Ik heb eerder robots gezien
- ☐ Ik heb eerder dingen gedaan met robots
- ☐ Ik heb gewerkt met robots of ze geprogrammeerd
- ☐ Ik heb zelf robots gebouwd
- ☐ Ik heb geen ervaring met robots

8. Heeft u ervaring met telepresentie robots (zoals degene die u zojuist gebruikt heeft)?

- ☐ Ik heb eerder telepresentie robots gezien
- ☐ Ik heb telepresentie robots gebruikt
- ☐ Ik heb gewerkt met telepresentie robots of ze geprogrammeerd
- ☐ Ik heb geen ervaring met telepresentie robots

9. Heeft u beperkingen in uw zicht?

- ☐ Ja
- ☐ Nee

10. Heeft u beperkingen in uw gehoor?

- ☐ Ja
- ☐ Nee

11. Gebruikt u een bril en/of lenzen?

- ☐ Ja
- ☐ Nee

12. Gebruikt u een gehoorapparaat?

- ☐ Ja
- ☐ Nee

Voor de experimentleider;   ID:……

Appendix F: Consent form

(English version)

Group	PP nr.

Consent form

UNIVERSITY OF TWENTE.

The University of Twente and the Department of EEMCS support the practice of protecting research participants' rights. Accordingly, this project was reviewed and approved by an Institutional Ethical Board. The information in this consent form is provided so that you can decide whether you wish to participate in our study. It is important that you understand that your participation is considered voluntary. This means that even if you agree to participate you are free to withdraw from the experiment at any time, without penalty.

The aim of this study is to collect data on how people operate a telepresence robot. The audio, video, and questionnaire data thus collected will be used to make user interface decisions for the improvement of control of these robots for the elderly. This research will be carried out by the Human Media Interaction group of the University of Twente as part of the EU FP7 project TERESA (FP7-ICT-611153)

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During the study you will control a telepresence robot situated in a remote location and have a small discussion with a person sitting in the same room as the robot. You will be asked to drive the robot following the arrows on the floor of the room while answering some simple questions. In order to inform the driving behaviour of robot controllers, small questionnaires will be presented during the experiment. After the experiment, you will be asked to fill out a post-experiment questionnaire and receive a debriefing. The total duration of this experiment is approximately 45 minutes.

Only the researchers and the partners from the TERESA project will have access to identifiable data. This data will be carefully stored for at most five years (until May 2020). This experiment poses no known risks to your health. If you have any questions not addressed by this consent form, please do not hesitate to ask.

Declaration of consent (please tick each checkbox if you consent)

☐ **1.** I agree to participate in this study
☐ **2.** I have read the instructions above and understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
☐ **3.** I understand that my identifiable data is recorded for research purposes as described above, and can be stored until May 2020.
☐ **4.** I agree for the researcher to use video and audio data of me collected during the experiment in academic articles and presentations (optional).

____________________________ ________________

Name and signature participant Date

____________________________ ________________

Name and signature researcher Date

(Dutch version)

ID

Akkoordverklaring

UNIVERSITY OF TWENTE.

De Universiteit Twente en de faculteit EWI beschermen de rechten van proefpersonen. Dit onderzoek is dan ook geïnspecteerd en goedgekeurd door de Ethische Commissie van de faculteit. Dit document bevat informatie over het onderzoek, zodat u op basis daarvan kunt besluiten of u deel wilt nemen. Uw deelname is uiteraard volledig vrijwillig. Dit betekent dat ook als u al hebt aangegeven deel te willen nemen, u op elk moment uw deelname aan het experiment mag en kan beëindigen.

Het doel van dit onderzoek is om informatie te verzamelen over hoe mensen telepresentie robots besturen. Specifiek zullen wij filmopnames (met geluid) maken en vragenlijsten gebruiken. Het onderzoek is opgezet door de vakgroup 'Human Media Interaction' van de Universiteit Twente en is onderdeel van het Europese project TERESA (FP7-ICT-611153).

Tijdens het onderzoek zal van u worden gevraagd een telepresentie robot die zich in een andere ruimte bevindt vanaf een afstand te besturen en te gebruiken om een kort gesprek te hebben met een persoon die zich in dezelfde ruimte bevindt als de robot. Tevens zullen we u korte vragenlijsten aanbieden, waarin u kunt aangeven hoe u het besturen van de robot ervaren hebt. Na het experiment zullen we u vragen om een laatste vragenlijst invullen en beantwoorden we alle verdere vragen die u nog mocht hebben. Het onderzoek zal in totaal ongeveer 45 minuten duren.

Contact informatie
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Enkel de onderzoekers en partners van het TERESA project zullen toegang hebben tot materiaal waarop u te identificeren bent. Deze data zal zorgvuldig worden bewaard voor ten hoogste vijf jaar (tot mei 2020). Er zijn voor zover bekend geen gezondheidsrisico's verbonden aan dit onderzoek. Mocht u vooraf nog vragen hebben die hier niet afdoende besproken zijn, vraagt u dan alstublieft gerust.

Akkoordverklaring *(vink alstublieft alle items aan waar u mee akkoord bent)*

- ☐ **1.** Ik stem er mee in om deel te nemen aan dit onderzoek
- ☐ **2.** Ik heb bovenstaande informatie gelezen en weet dat mijn deelname vrijwillig is en dat ik op elke moment mijn instemming om deel te nemen mag intrekken, zonder opgaaf van redenen.
- ☐ **3.** Ik begrijp dat video-materiaal waarop ik te identificeren ben wordt opgenomen voor de bovengenoemde onderzoeksdoeleinden en kan worden bewaard tot mei 2020.
- ☐ **4.** Ik stem ermee in dat het video-materiaal van mij dat is verzameld tijdens het onderzoek ook gebruikt mag worden in wetenschappelijke artikelen en presentaties (optioneel; u kunt ook deelnemen aan het onderzoek als u hier niet mee instemt).

______________________________ ________________

Naam en handtekening proefpersoon — Datum

______________________________ ________________

Naam en handtekening experimentleider — Datum