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The Design, Development, And Evaluation Of A Usable And Privacy-Enhanced Telepresence Interface For Older Adults

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THE DESIGN, DEVELOPMENT, AND EVALUATION OF A USABLE AND PRIVACY-ENHANCED TELEPRESENCE INTERFACE FOR OLDER ADULTS

by

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DEDICATION

For my family and friends, Dad (Shijun), Mom (Li), Daniel, Dunpei, Shirong, HuiWu, Shiling, Benlei, Ke, Xuan, and Lauren. In memory of Huimin and Chengying.

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ABSTRACT

Maintaining health and wellness while aging-in-place independently is crucial for older adults. Telepresence technology can be potentially beneficial for this target population to stay socially connected. However, this technology is not specifically designed for older adults. For this target population to adopt such technology successfully, it is important to ensure that they do not experience usability barriers. This research uses HCI/HRI concepts and technology design principles for older adults to design, develop and test telepresence user interfaces (UI). This addresses the following research questions: 1): What are the essential usability and privacy-enhanced features needed to inform the design and development of a new telepresence UI for aging population? 2): Is the new telepresence UI perceived as more usable and private by older users compared to traditional telepresence UI design?

Thirty older adults aged above 60 in South Carolina and Georgia participated in a within-subjects user-testing with two UIs: 1) a generic UI called *Presence* designed based on currently available telepresence robots; and 2) a privacy-enhanced usable telepresence UI named *InTouch*. Participants tested both UIs in a virtual home environment developed in Unity.

Results of this study suggest that older adults perceived *InTouch* to be more usable and private. This study provides insight on what usability and privacy features are critical for the aging population to use such telepresence technology. By investigating the design of

telepresence robots for older users, and applying those findings to design recommendations, the final goal is to improve the ease of use and privacy level of telepresence robots – not only for our target users, but for all users who wish to enhance their social connectedness.

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LIST OF ABBREVIATIONS

HCI..Human-Computer Interaction

HRI.. Human-Robot Interaction

IRB...Institutional Review Board

CHAPTER 1

INTRODUCTION

Older adults prefer to age in place [1]. Technology has much promise to aid the aging population meet this goal. In particular, one such technology, called telepresence, has the tremendous potential to support older adults aging in place by facilitating engagement in social activities and promoting communication with others.

Telepresence can be defined as robotic technology that allows a person to feel or appear to be present in a location, typically through an interactive two-way video and audio on a mobile base. The word telepresence emphasizes the idea of an individual remotely being in a location in a high-fidelity manner such that the individual will feel physically present or appear. The idea of telepresence was proposed in 1980. Marvin Minksy painted a picture of people suiting up in sensor-motor jackets to work at their jobs thousands of miles away [2]. He then named this tool telepresence.

Telepresence enables interactive face-to-face communications for people located at different locations via the Internet. In addition, the system can be remotely operated, so that the user can explore the local environment while having a conversation. Figure 1.1 illustrates the mechanism of telepresence: the pilot user is defined as a user remotely logged into the system to initiate a call and controlled the system (Figure 1.1 a) while the local user is co-located with the system in the local environment to receive a call (in Figure 1.1 b).

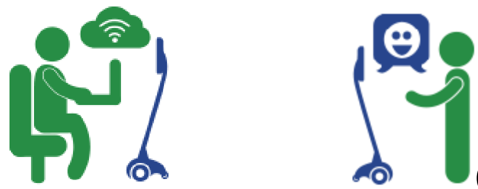
(a)  (b)

Figure 1.1 Depiction of telepresence: (a) pilot user and (b) local user.

Telepresence may be beneficial to aging population by allowing them stay socially connected with their family, friends or even caregivers while still aging in place independently. However, the capabilities, limitations as well as the needs of older adults, are quite diverse. As people age, many of the older adults may experience increase in limitations and or impairments [3]: gradually decline in cognitive, hearing, vision and mobility [4]. Thus, designing such technology requires considerations of factors related to the target user group. Even if the telepresence technology meets their needs, older adults' adoption of the technology may be hindered because the technology is not easy to use, or the older adults feel that their privacy may be compromised by using the technology [26].

The purpose of this research proposal was to encourage older adults to adopt telepresence successfully through a user-centered design system by doing following: 1) design and develop a usable and privacy-enhanced telepresence user interface (UI) *InTouch*; 2) evaluate if older adults perceived *InTouch* to be usable and private and 3) investigate what aspects of the technology can be enhanced/modified to provide a better user experience. In the following sections, I will define and discuss the design, development, and evaluation of a usable and privacy-enhanced telepresence system for aging population.

1.1 DEFINING OLDER ADULTS

Older adults are typically defined as people aged 65 years or above [5]. The population of older adults is growing rapidly worldwide, as more people are living longer [6]. In the United States, this population was 46.2 million in 2014, representing 14.5% of the U.S population [7]. This number will more than double by 2060 [7], with an estimated 92 million older adults (20% of the population). America is aging [8].

The capabilities and limitations of the growing older adult population are diverse. As previously noted, many older adults experience sensory, cognitive, and physical challenges that may negatively affect their everyday activities. In addition, some individuals are aging with lifelong impairments (e.g., visual, auditory, mobility). When individuals' support needs are not adequately met due to impairments, we often refer those individuals as "aging with a disability". A World Health Survey was administered to provide statistical information about global disability prevalence [9]. In the survey, disability levels range from 0 (no disability) to 100 (complete disability); a threshold of 40 was set to indicate significant difficulties in daily life. An average disability prevalence rate for the threshold of 40 and above among people aged 60+ was 38.1%; [9]. According to the U.S. Census Bureau, among older adults 15.7 million have reported having one or more disability, which comprised 38.7% of the older population [10].

For older adults, the need to sustain health and wellness while simultaneously aging-in-place independently is crucial. Age-related limitations and/or impairment (e.g., mobility impairment; decline of vision/hearing) sometimes prevent older adults from participating in social events, doing physical activities, and using facilities in the community - all of which promote healthy aging [11] and being more socially active. Social connectedness "occurs when a person is actively involved with another person, object, group or environment, and that involvement promotes a sense of comfort, well-being, and anxiety reduction" [12]. According to this definition, being socially connected is an important component for older adults' well-being. However, aging related physical changes might prevent this population to be involved in social activities. Thus, the need for socially-enhancing technology interventions, such as telepresence, to support this population are greatly needed [13].

1.2 TELEPRESENCE FOR OLDER ADULTS: ATTITUDIONAL ACCEPTANCE

Assistive technology available for the home setting is dramatically increasing [11], and as discussed above, assistive technology, such as telepresence, that enhances social connectivity has great potential to aid persons aging independently while maintaining their well-being.

According to [15], the definition of physical presence was "the sense of being physically located somewhere" while social presence was defined as feeling of being together and communicating with someone. Thus, telepresence has the potential to facilitate communication both physically and socially. However, whether this technology meets the intended population's (older adults) needs is a first logical step of the investigation.

A range of previous studies have explored the attitudinal acceptance of telepresence by older adults and participants' overall reaction towards telepresence technology was positive. Beer and Takayama conducted a user needs assessment study on a telepresence robot (n = 12; ages 63-88) [16]. In their study, each participant served as: (1) the pilot user who operated the telepresence robot and (2) the local user who interacted with a visitor operating the telepresence robot. Data showed that 66% of the mentioned opinions towards the robot were positive, 28% were mixed and only 6% were negative [16], which indicated that overall, the older adults' attitudes on telepresence were positive.

Seelye et al. [17] interviewed older adults (N=8) and their family and friends' attitudes and preferences towards the robot VGo, which was placed in the homes of the 8 participants. The results of the study showed that overall, older adults and their family/friends had positive attitudes toward the robot.

In [18, 19], caregivers/healthcare workers and older adults evaluated telepresence robots via tutorials, focus group, and interviews, designed to assess the participants perceived advantages and disadvantages of the robot. The results from both healthcare workers as well as older adults showed that both user groups had positive reactions toward the robot.

Similarly, Mitzner and colleagues [20] conducted a study with 14 older adults aging with mobility impairments (50-70 years of age). This study aimed at investigating participants' attitudes towards televideo technology. Overall the participants were open to accepting the technology for social engagement, healthcare provider access, and physical activities colleagues [20]. Benefits such as feeling being present and being able to view facial expression were expressed colleagues [20]. Privacy/security, and difficulty to learn to use the technology were perceived as concerns colleagues [20].

In 2014, I conducted a needs assessment of telepresence for older adults with disability (n = 9; ages 54 - 78) [21]. In this study, I investigated three televideo systems: Skype, Kubi, and Beam (Figure 1.2). Results of this study showed that participants overall had positive reactions towards televideo technology, indicating they could imagine using the technology to contact family, friends and healthcare providers. Benefits such as visualization, a "sense of presence" were identified by participants. However, concerns towards the technology were also stated by the participants. The most mentioned concern was perceived difficulty of use, indicating that participants would like a system that is easy to operate. Specifically, participants were concerned with the complexity and learnability of each technology's hardware and software. Concerns about security and privacy were also discussed, particularly misuse of technology to gain sensitive information, cause embarrassing exposure, or incur harm.

Skype Kubi Beam

Figure 1.2: Examples of televideo used Wu et al. 2014

These needs assessments identified potential benefits of telepresence, which included visualization, remote monitoring, time efficiency, reducing isolation, mobility, feeling of "being there", convenience, and health diagnosis [11, 16, 17, 18, 21]. However, these studies also revealed trends in older adults' concerns about using this technology. Importantly, participants repeatedly expressed concern about (1) usability [16, 17, 21] and (2) privacy issues [11, 16, 17, 18, 21]. In the following sections, I will discuss each of these concerns in detail.

1.3 USABILITY OF TELEPRESENCE

As discussed above, studies have investigated the potentially beneficial aspects of telepresence; however, such benefits can only be met if the target population is willing and able to actually use the technology. Although telepresence is traditionally designed for individuals who are not older adults and do not experience disability (i.e., telepresence was originally designed for office use [52]), some more recent HRI/HCI studies have investigated telepresence usability with a variety of user groups. First, Boissy and colleagues evaluated the learnability and controls of telepresence with rehabilitation professionals (n = 10, ages 23-52). The participants of this study were trained in a laboratory environment and the evaluation was conducted in a home setting. The result of this study indicated that the professionals were able to operate the robot after 4 training sessions (4 hours in total). However, navigation task in this study was simple with no interactions with the simulated patient. The time taken to complete the tasks in this study suggest that teleoperate a telepresence system in an unknown home environment is much more complex for novice users. Thus, efficiency and memorability of the robot should be improved by providing the users a better-designed user interface [22].

Another study investigated the use case with older adults that have mobility or cognitive impairment on a modified telepresence robot. Tsui and colleagues utilized a user-centered approach to design an augmented reality user interface to understand how people with cognitive and/or motor impairments operate a customized interface VGo to explore an art gallery with 5 exhibits [23]. In the case study, 4 people (from a participant base of ages raging widely from 7 to 75) with cognitive or/and mobility impairments were recruited. All 4 participants succeeded in operating the VGo to explore the gallery: when participants came back for a second study session 7-10 days later, two participants needed little to no training while the other two required only marginally more time to practice. Participants' ease of learning of the interface indicated that, by utilizing the design heuristic principles, the system successfully provided its status, simple control, and feedback. This study was conducted in a gallery that the researchers built, an environment that is static, the authors stressed that the interface needs to be able to scale to homes, schools, or museums and the users should be able to customize the interface [23], thus, taking into consideration the users' special needs and capabilities [23].

I investigated the usability of telepresence by conducting a heuristic evaluation with an emphasis on identifying design issues for older adults aging with a mobility impairment [24]. Heuristic evaluation is one of the most efficient usability/-engineering methodologies for finding usability problems in an interface design [14, 57]. Conducting a heuristic evaluation requires a small set of research evaluators to judge the interface using a standard set of usability heuristics. Three different telepresence systems were evaluated (Double, Vgo and BeamPro) by 3 trained researchers. Some general themes from heuristic evaluation related to usability issues with the systems' hardware and software were revealed. Specifically, hardware limitations related to the size of telepresence systems and stability of the systems were noted. These hardware considerations were important for use in home settings, where homes may not be particularly accessible; clutter is often a challenge in older adult homes [25]. Also, adjustable height was recommended, particularly for users with mobility impairment, who may be using the telepresence systems in seated positions (i.e., in a wheelchair). Furthermore, issues regarding the UI, ease of system navigation were found, as well as privacy and network concerns.

This heuristic evaluation provided insight on the usability of telepresence systems for older adults with mobility impairment; however, further user testing will provide insight of the systems from our target users' perspective. Thus, following the heuristic evaluation, I conducted a user testing on telepresence systems. Five participants (N = 5) with mobility impairment were recruited and each of them tested telepresence systems individually in a home-like lab setting (ages 50-70). Based on participant comments, as well as observations of their operating performance, there was a learning curve to become comfortable with the telepresence controls. Participants commented "getting used to operate would be a little difficult," or that the system's ease of use increased only after practice. Participants liked the mobile capability of the robot, but the high mobility also caused concerns, such as compromising privacy. Participants commented "it can follow me around the house, it's a little creepy". Overall, results of the user testing suggested that participants prefer an intuitive user interface with an emphasize of maintaining privacy.

1.4 PRIVACY AND TECHNOLOGY DESIGN

Besides difficulty of use [16, 21], privacy was one other most mentioned concern users expressed about telepresence technology [16, 21]. The ability for telepresence systems to move around the environment (i.e., mobility) provides users the benefit to explore the local environment [16, 20, 21]. However, privacy concerns caused by telepresence mobility were also mentioned by participants [16, 20, 21]. Privacy and security are considered major barriers for the continued growth of adopting technologies [36] and "central to the concerns of HCI" [37]. As such, for older adults to fully accept and adopt telepresence technology, privacy preserving designs were greatly needed and should be taken into account at the beginning of the design process.

Previous research typically categorized information into different "privateness" levels, ranging from "not very private" to "very private" [36]. For example, location of an individual [38], personal information (e.g., phone number, salary) [39] are considered very private information. Information such as gender, first name and education level are considered less private [36].

In addition to the privateness level of information, perceived privacy also depends on the relationship between the receiver and discloser [40, 41]. For example, a spouse was associated with the least number of privacy concerns, while a supervisor was associated with the most [41]. Furthermore, location is also an important consideration in users' perceptions of privacy. For instance, bathroom might be an intimate area that normally people do not want cameras or sensing devices [53] – thus this could be an area of the home where telepresence is restricted. However, the bathroom is identified as the most common location for fall injuries in the home [42]. If an emergency occurs, certain users (e.g., caregivers, first responders) should ideally be able to override restrictions on remotely accessing cameras or telepresence in this room. This example can be referred as access control.

It is also important to provide the users: *what* data is collected, *how* the data is transmitted, and *who* the data will be shared with [43]. Information should be displayed in an intuitive way by using words that are simple for older adults to understand. Providing visual cues can help with privacy challenges [44]. Visual vocabulary for privacy includes text, images, icons, or a combination of them [45]. For example, icons that illustrate video and audio data will be collected during a telepresence session should be displayed; the location of the data will be processed or stored can also be illustrated by certain visual cues. Figure 1.3 below demonstrates examples of icons illustrating privacy.

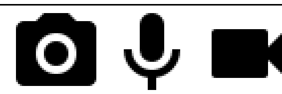
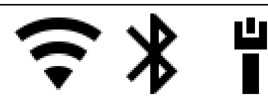
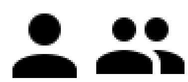
Data collection	
Data transmission	
Data sharing	
Data collection on/off	

Figure 1.3. Examples of visual cues illustrating privacy

Telepresence has much potential to help people that have special capabilities and needs. However, currently telepresence is typically not designed for use by aging population. Usability issues caused by the interface or lack of privacy preserve features can create barriers for older adults to adopt telepresence technology successfully. When designing telepresence for older adults, it is important to take considerations of their age related physical/cognitive changes as well as their perceived privacy related concerns (as older adults might perceive privacy different from younger generation). Designing the technology with older adults' capabilities, limitations and needs in mind and applying privacy preserving design considerations may ease users' concerns of adopting and using telepresence technology.

1.5 CATEGORIZATION OF USABILITY AND PRIVACY ISSUES

In summary, the use of telepresence technology to facilitate social connectedness among the aging population holds much potential. However, a list of design issues was identified via previous research – particularly related to usability and privacy. Based on previous heuristic evaluation [24] and user testing on telepresence for older adults [47], I categorized and described common telepresence usability problems and missing privacy settings in Table 1.4 and Table 1.5 below.

The identified usability problems and privacy issues served as a framework for this dissertation. These two tables facilitated the user-centered design process as the information in these tables guided the research goals and purpose.

Table 1.1 List of usability problems

Problems	Description
Color contrast	Low color contrast
Feedback and notification of the system	Lack of proper feedback and notification

Font size	Small font size
Log in	Lack of "Show password" option
Obstacle detection	Lack of obstacle detection feature
Obstacle avoidance	Lack of obstacle avoidance feature
Settings of the system	Locations of settings are not consistent

Table 1.2 List of missing privacy settings

Problems	**Description**
Accept/decline calls	Some system does not provide decline call option
Accessible control	User can initiate a call and drive to any area in the local environment once permission is granted
Notification of screen shots	Some systems provide pilot user the ability to take screenshot, however, no notification is provided to the local user
Visual vocabulary for privacy	No visual cues to inform the user that telepresence is a 2-way audio and video system

CHAPTER 2

RESEARCH GOALS

The goal of this research was to design, develop, and evaluate a usable and privacy-enhanced telepresence system for aging population on a virtual reality environment. The scope of this project considered the user experience from both the telepresence pilot and local operator perspective. When designing the interface, this research focused the scenario in which older adult takes the active role of operating the telepresence system. Previous studies suggested that older adults prefer to operate the system (as pilot user) rather than to be visited by someone else operating the system [16]. The active role (pilot user) and passive role (local user) are depicted in Figure 1.1.

To date, most telepresence systems are designed for office settings instead of utilized by older adults in a home setting. This research used HCI/HRI concepts and focused on addressing the following research questions:

RQ1: What are the essential usability and privacy-enhanced features needed to inform the design and development of a new telepresence UI for aging population?

Most commercial telepresence systems are being sold for office environment as mobile video conferencing tool [52]. When telepresence is applied in a home-setting for use by older adults, some features of the system may not be suitable for target population. Additional features may be required to accommodate intended users' physical limitations and special needs. In this study, I identified and evaluated the essential design features that a telepresence system requires to be considered user-friendly and private by older adults.

RQ2: Is the new telepresence UI perceived as more usable and private by older users compared to traditional telepresence UI design?

The usability of InTouch (the new UI) remains unknown without user testing. User testing of InTouch and Presence was conducted with 30 older adults. I evaluated older adults' accuracy in operating the telepresence UI (usability). Their perceptions of each UI (emphasized on privacy, usability of each UI) were assessed via questionnaires and semi-structured interviews.

CHAPTER 3

METHODOLOGY

3.1 USER INTERFACE DEVELOPMENT

My previous usability evaluations (heuristic evaluation and user testing) revealed usability issues and privacy concerns [47]. Thus, in this study, the development of the UI (*InTouch*) focused on usability and privacy enhancement. Instead of choosing one specific telepresence system, implementing modifications on that system and conducting user testing in real a home-environment, in this study, I developed a simulated virtual driving environment via Unity. Two UIs were developed: *Presence* (control condition) and *InTouch (the customized UI).* Both UIs were intergraded in the simulation individually and a usability evaluation was conducted to compare each UI with 30 older adults. Using a simulation was beneficial for a number of methodological reasons: (1) the testing environment was strictly controlled for each individual participant; (2) proposed a privacy and usability enhanced design framework for all telepresence system.

3.1.1 Development of the Generic UI: Presence

The purpose of the interface *Presence* was to represent design features commonly found in commercially available telepresence systems and to expose users to telepresence functionality representative of the current commercial state-of-the-art. As a first step, I drove 5 different popular telepresence systems on the market (Beam, BeamPro, Double, VGo, and MantaroBot (Table 3.1)). Among all the tested systems, the BeamPro had the most features and functionalities, and the usable design (thus, considered to be the state-of-the-art). Thus, the *Presence* interface's design was primarily based on the BeamPro.

Table 3.1. Specifications of 5 tested telepresence systems

	Beam	Beam Pro	Double	MantaroBot	VGo
					
Battery life	Up to 8 hours	Up to 8 hours	Up to 8 hours	Up to 8 hours	Up to 6 hours
Cameras	2	2	1 via iPad	1 via tablet	1
Camera tilt	No	No	No	+85/-45 degrees	180 degrees
Charging	Dock; cord	Dock	Dock; cord	Dock; cord	Dock; cord
Height	52.9’’	62’’	67’’ to 60’’	67’’ to 60’’	48’’
Local volume control	No	No	Yes	Yes	Yes
Microphone	4	6	iPad	iPad	4
Screen size	10’’ LCD	17’’ LCD	iPad	Tablet size	6’’
Speakers	1 front	1 front	1 via iPad	1 via iPad	2
Weight	39 lbs	120 lbs	15 lbs	15 lbs	19 lbs

3.1.2 Development of the custom UI: InTouch

Table 3.2 specified features I included in *InTouch*. In the following sections, I will discuss my design choices in more detail, particularly as it relates to design for older adults. These design features were organized as usability- and privacy-enhanced design.

3.1.2.1 Aging and technology design considerations

Table 3.2. Features that were included in ***Presence*** and ***InTouch***

	Beam Pro	Beam	Double	VGo	MantaroBot	**Presence**	**InTouch**
Adjustable height			✓			No	Yes
Adjustable speed	✓	✓	✓	✓	✓	Yes	Yes
Auto park	✓					No	Yes
Camera activation before a call						No	Yes
Dual cameras	✓	✓		✓		Yes	Yes
Log in show password						No	Yes
Obstacle detection				✓	✓	No	Yes
Obstacle avoidance	✓					Yes	Yes
Rotate the system	✓	✓	✓	✓	✓	Yes	Yes
Side obstacle detection						No	Yes
Staircase/back obstacle detection						No	Yes
Zoom in feature	✓	✓	✓	✓		Yes	Yes
Wifi notification	✓			✓		No	Yes

The assumption that aging population wishes to avoid adopting new technology is a fallacy [26]. Older adults do use technology on a daily basis [54]. However, a new technology must be carefully designed to be usable by older adults. As people age, functional changes are normal and expected [27]. When interacting with a new technology, functional changes of the user (older adult) may hinder the performance of accomplishing tasks. Thus, technology interventions for older adults must be designed with older adults' functional changes in mind.

Perceptual - Vision impairment among the older population is a major functional change [29] – there were a number of design recommendations I took into account when designing *InTouch.* As people age, the size of the pupil becomes smaller and less light can enter the eyes [27, 30]. Increasing screen illumination can help older adults read comfortably. Further, increasing color contrast and size of vision details will result in improved performance [31]. Warm colors were chosen over cool tone as the color perception of older adults diminishes [27]. Lastly, the ability to discriminate between colors decreases with age, particularly for colors in the blue-green range [32]. Thus, using colors within that range was avoided.

Cognitive – Cognitive changes are a normal process of aging [34]. Age-related cognition decline includes changes in memory, attention, and language comprehension [27, 34, 35]. Memory loss is a common complaint among aging population. Memory can be categorized into various forms. Working memory (short-term memory) is defined as active memory of the information just been perceived [35]. The capacity of working memory decrease as people aging: fewer pieces of information can be processed in a given time. Procedural memory is one aspect of long-term memory: knowledge of how to perform certain tasks. Older adults can learn new skills, but it may require more time [35 p18]. To accommodate memory changes, recognizable and simple icons were utilized in *InTouch*. Memory-support features such as Show Password were added to minimize working memory load.

The capacity of focusing and processing information is referred as attention. As the results of changes in attention, older adults generally perform multi-task less-well than younger adults [35 p23]. Thus, *InTouch* was designed to avoid complex displays, visual clutter and concurrent actions (e.g., pressing multiple keys to perform one command).

Lastly, older adults may experience more difficulty when comprehending language when inferences are required [35, p23]. To compensate this change, familiar terms, labels and icons were used when designing *InTouch*.

Physical/Ergonomic – Physical and motoric changes can reflect on changes of body size (e.g., height and weight loss), strength, mobility and balance [28]. Adjustable height was included as some older adults experienced mobility impairment and use a wheelchair or feel more comfortable while seating [24].

Comprehensive design guidelines for older adults are applicable [26, 27, 28, 35]. Principles used in this study are summarized in Table 3.3, Table 3.4, Table 3.5, Table 3.6.

3.1.2.2 Usability enhanced design

Log in- A log in feature was included in all tested systems. However, none of the commercial systems provided the user a "show password" option. According to participants in previous user studies [47], this feature was desired. Older adults' working memory decline with age [35]. Thus, the show password feature can inform the users what they typed (i.e., opposed to viewing dots) instead of requiring them to recall the information.

Table 3.3. General design guidelines

Category	Variable	Design choices
Vision presentation guidelines	*Color*	Warm color is preferred
	Color contrast	High color contrast
	Color discrimination	Avoid using colors in blue-green or colors of the same hue
	Font size	Minimum acceptable font size is 12; adjustable font and graphic size
	Font case	Avoid using uppercase for long text; only use uppercase on short text that draws user's attention
	Illumination	Increase the level of illumination
	Simple visual presentation	Avoid visual clutter
Auditory presentation guideline	*Volume*	Adjustable volume: e.g., user can increase the volume of warning signals
Design guidelines for cognitive decline	*Icons*	Use icons that are easy to recognize; provide description to each icon
	Instructions	Use simple and short instructions
	System feedback	Simple, short and clear feedback
Design guidelines for physical/motoric decline	*Height*	Adjustable height of the system

Menu options – The menu of the UI should be self-explanatory and easy to find. Using simple and familiar icons will help participants understand the interface [47]. One older adult stated, "it is easy to understand the icons because they are [icons] somewhat familiar to me". When testing BeamPro, participants had difficulty adjusting driving speed: the adjustable speed slide bar was not located with other icons (Figure 3.1). The icons locations should follow the principle of grouping, also known as Gestalt laws of grouping: the tendency of grouping things if they are nearby (the Gestalt law of proximity); if they share similar features (the law of similarity), or they are smooth and continuous (the law of good continuation) [56].

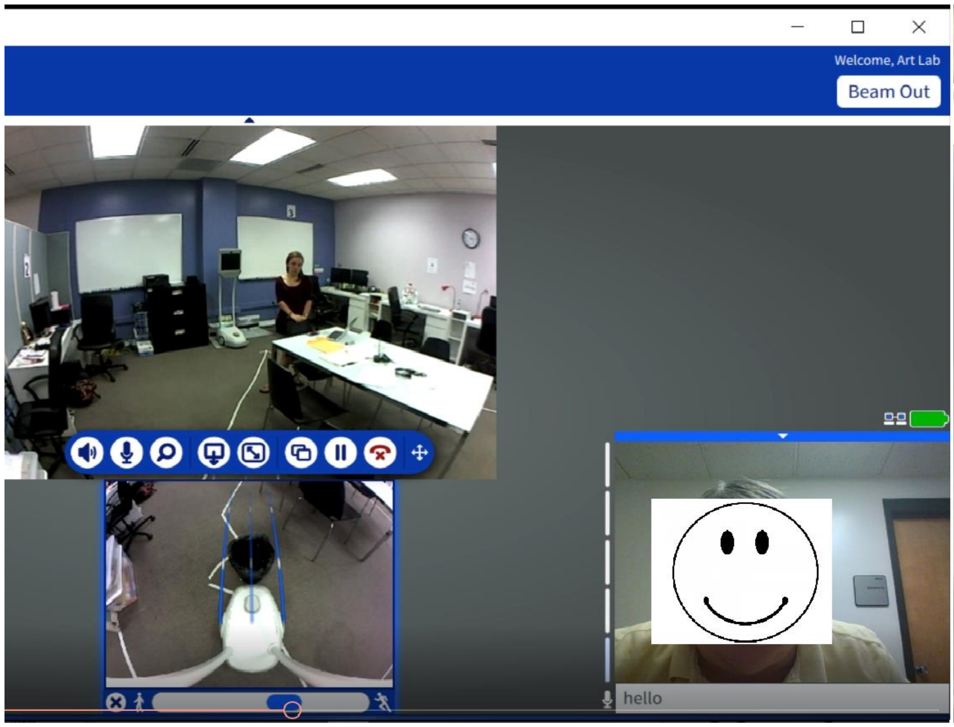


Figure 3.1 A screen shot of BeamPro UI

Font size – Small font size was mentioned as an issue in previous user testing [47]. A minimum of font size 14 was applied in *InTouch* based on findings from [65].

Color contrast – Low color contrast can cause difficulty for older adults to use the system [47]. Thus, a high color contrast, warm color theme was applied to *InTouch*.

Feedback and notifications – One major complaint in previous user testing [47] was lack of feedback and notification of the systems. For instance, when wifi connection is not ideal, proper notification should be provided to the users [47]. In *InTouch*, notifications/feedbacks were provided (e.g., the user changed a setting or encountered an obstacle while driving).

Obstacle detection – Obstacle detection was perceived to be beneficial by older participants [16, 24, 47]. Some telepresence systems have an obstacle detection feature (e.g., MantanroBot, VGo), however, when an obstacle was detected, the systems either did not provide proper notification, or provided no notification at all. For examples, MantanroBot had a red block to represent an object without informing users the red blocks represent obstacles. VGo simply displayed the word "Bump" on the screen when the system detected an obstacle (Figure 3.2), but did not specify what the telepresence actually ran into.

To improve this feature, *InTouch* highlighted nearby obstacles, and provided a notification box (Figure 3.3) to inform the user the current state of the system. According to previous study [47], lack of notification and feedbacks were identified as usability problems.

Obstacle avoidance – BeamPro provided obstacle avoidance: when an object was detected, the system slowed down automatically to avoid hitting the obstacle. This feature was identified as useful in our previous user testing [47]. Thus, obstacle avoidance was included in *InTouch*. To inform the user when obstacle avoidance was activated, a notification that explains why the robot was slowing down was also provided in *InTouch* – this was a feature not provided in any of the tested robots. The obstacle avoidance feature should be desigend to provide proper feedback to ensure that the users recognize the current status of the system and what to do next [64].

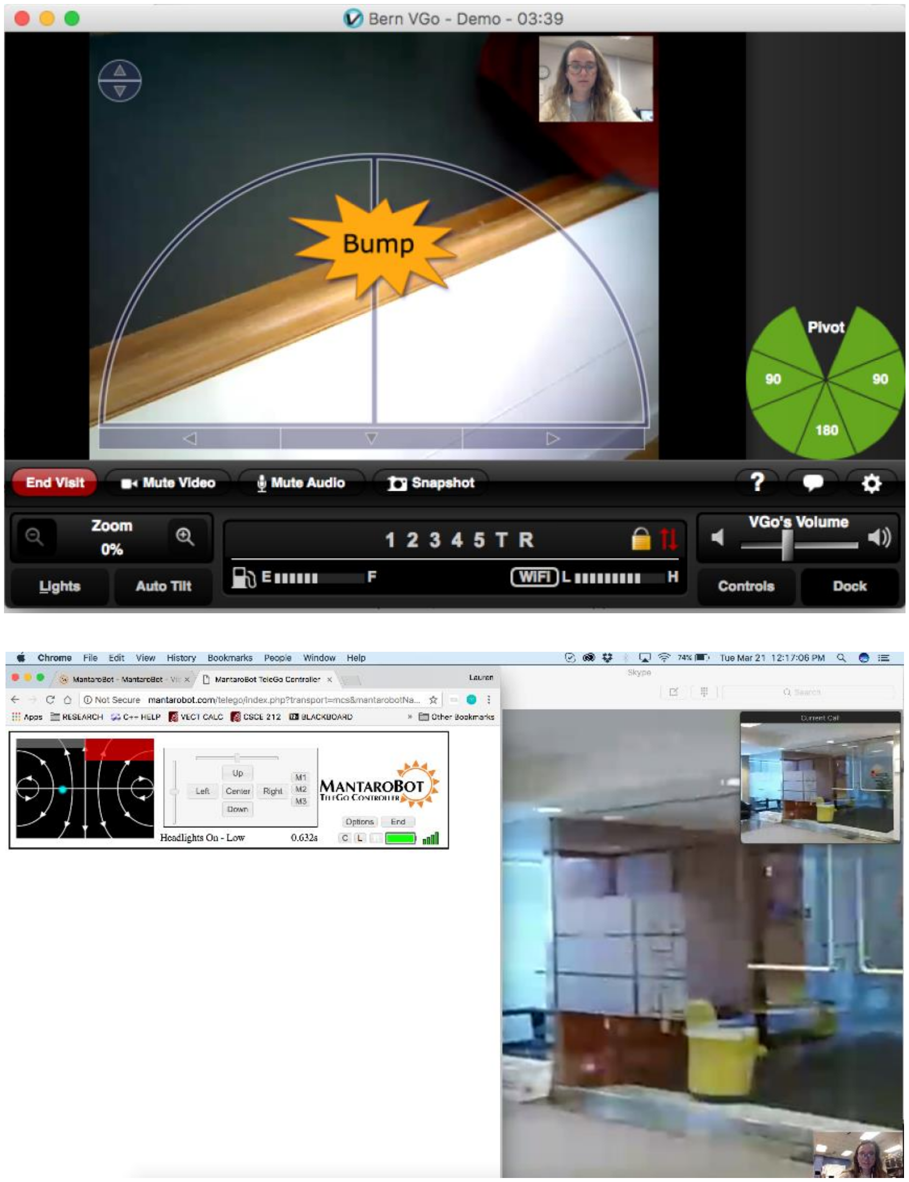


Figure 3.2. Examples of obstacle detection of VGo and MantanRobot

Figure 3.3. Examples of obstacle detection and notification of *InTouch*

Table 3.4 Summary of usability enhanced features

Features	Description
Color contrast	• High color contrast • Warm color range
Feedback and notifications	• Simple and precise feedback
Log in	• Show password option
Menu	• Use simple and familiar icons • Provide description to each menu option/icon • Avoid scattered icons
Obstacle detection	• Provide obstacle detection • Proper notification for obstacle detection
Obstacle avoidance	• Slow down when device is close to an obstacle • Notification that explains the slow down motion

3.1.2.3 Privacy enhanced design

Accessible control – As discussed in Chapter 1, under different scenarios, people's reactions or attitudes towards privacy disclosure might be different. Normally an older adult might not want other people drive telepresence system to bathroom or bedroom area [47]. Thus, constrains for pilot users to explore those areas (e.g., bedroom) was included in *InTouch* (Figure 3.4). The screenshot displayed that the user was blocked from entering the bedroom area, with a notification box indicated the user that the bedroom was a restricted area.

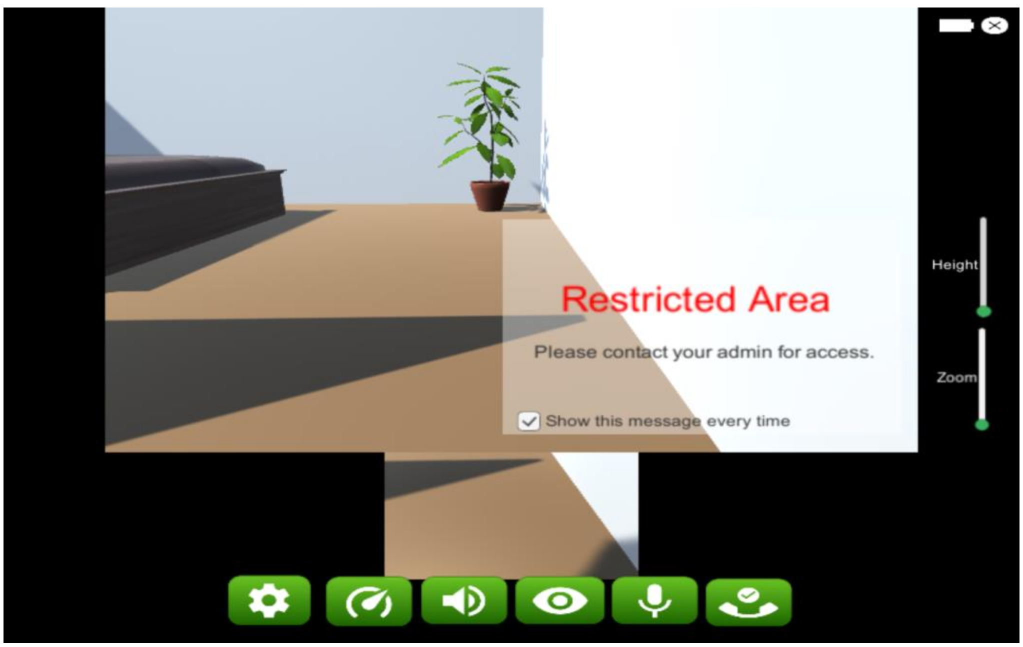


Figure 3.4. Examples of room accessible control of InTouch

Camera activation before call - Before a call was initiated, the local user would see themselves and the background environment first.

Table 3.5 Summary of proposed privacy-enhanced features

Features	Description
Accessible control	• Set constrains to certain area (e.g., bathroom, bedroom) • Caregiver or close family members can override the system
Camera activation before call	• Activate camera for local user to see themselves and their environment before a call is initiated

3.2 SIMULATION DEVELOPMENT

Unity was utilized to develop the virtual driving simulation for user testing. Unity is a game engine and integrated development environment (IDE) for developing interactive settings and media [58]. Unity was used along with graphics and drawings created with asset-creation tools, such as SketchUp, a development tool used for 3-dimensional modeling. I used Unity Personal, which is considered the best in terms of affordability and flexibility to design 3-dimensional environments to conduct studies.

Unity was chosen for this project due to the ease of use and the object-oriented programming capabilities. Because Unity was created for game design, the manipulation of objects, seen as potential obstacles for our purposes, was simple and straightforward. The ability to design the interaction between the user driving the robot remotely and the robot's environment through hierarchy and the physics engine, OpenGL, was useful [59]. All physics engines integrated into game engines, known as "middleware," were capable of simple obstacle detection in order to simulate the real-world experience of moving through an environment.

The design of the environment in the simulation was similar to that of my previous studies [21], which took place in real-world environments, in that there will be several desks and tables enclosed in four walls, Figure 3.3 show an example of the simulated virtual environment. This simulated environment was specifically designed to closely mimic a real home environment that included a bedroom (private room), open living spaces, and a staircase.

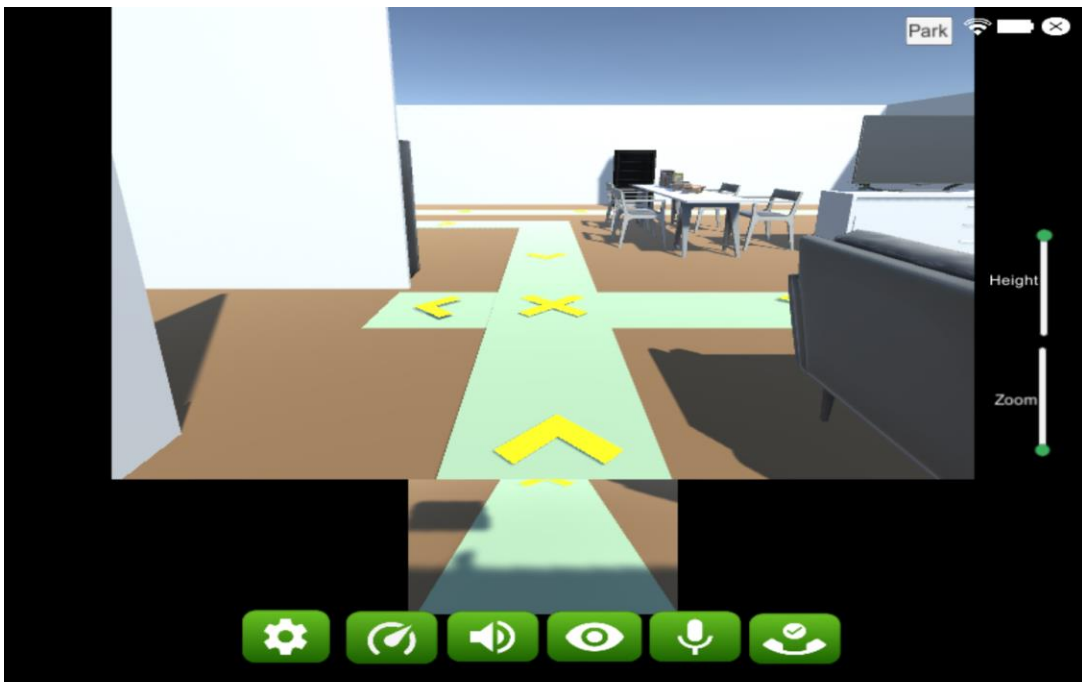


Figure 3.5 Example of the virtual driving environment

Unity Technologies requires specifications for both the development and running of projects made with Unity. The proposed simulation was built on a Dell XPS Windows 10 desktop with Intel Core i7-4790 3.6 GHz and an x64-based processor and a Mac OS X Sierra 10.12.3 MacBook Pro with Intel Core i5 2.9 GHz with 8 GB of memory and Intel Iris Graphics 6100 1536 MB. The running of a Unity project is possible on a larger variety of platforms. For the purpose of this project, I only implemented the application on a laptop computer. The simulation represented a home-like scenario, each participant experienced the same driving environment.

3.3 HCI ELAVUATION

To evaluate the usability of *InTouch*, a within-subjects study was conducted, with two conditions integrated into the virtual driving environment: 1) *Presence* and 2) *InTouch*. Users tested each UI by performing a list of tasks. Interviews were conducted during the test session and questionnaires were administrated pre and post each study.

3.3.1 Participants

Thirty older adults, aged from 61 to 84 (M = 71.00, SD = 5.50), were recruited to participate in this study. Gender was not split evenly, with 9 males and 22 females; however, this distribution is representative of the population, with more women living into older age. The older adults were compensated with a $30 gift card for their participation in the 2-hour study. All participants were recruited from Columbia, SC and Athens, GA, via Assistive Robotics Technology Laboratory participant database, local senior centers, and retirement communities. Flyers and emails of this study were distributed to senior communities in Columbia, SC and Athens, GA. All participants volunteered to participate this study.

Participant demographic and health information was obtained from the Demographic and Health Questionnaire [46] (see appendix A). Participants varied in their education background, as depicted in Table 3.6. One participant was multi-racial, 1 was black/African American, 28 were white. Participants were widowed (16.7%), married (60%), single (13.4%), divorced (6.7%) or living with partner (3.4%). Twenty-three (76.7%) participants reported that they lived in a single-family home while the rest (23.4%) lived in an apartment or condominium. One participant reported that his/her community was specifically designed for seniors. Most participants (96.7%) reported that they could drive themselves as the primary mode of transportation while 1 older adult (3.3%) used public transportation. Household income of participants also varied. (Table 3.7)

Table 3.6 Participants highest education level

Highest Education Level				
High school graduate/GED	**Some or in-progress college/Associate's degree**	**Bachelor's degree**	**Master's degree**	**Doctoral degree**
6.7%	10%))	23.4%)	36.7%	23.4%

Table 3.7 Participants household income

Household Income				
< $25,000	**$25,000 - $49,999**	**$50,000 - $74,999**	**> $75,000**	**Do not wish to answer**
6.7%	20%	16.7%	53.4%	6.7%

The older adults were satisfied with their health (M = 4.3, SD = 1.04; where 1 = not at all satisfied, 3 = neither satisfied nor unsatisfied, 5 = extremely satisfied). Two older adults (6.7%) were not able to walk without a walking aid.

To assess older adults' familiarity level of video conferencing technology, I administered *Video Conference Technology Usage Questionnaire,* which included 30 different types of video conferencing systems. For each video conference technology, participants checked if they have used those technologies in the last 12 months (see appendix C). One older adult (3.4%) reported did not use any video conferencing technology within the last 12 months while 29 (96.6%) reported used the such technology at least one. The top 3 mentioned video conferencing systems were Google Hangouts, Facebook video and Facetime. Overall, participants in this study were familiar with video conferencing technology. Detailed video conferencing usage is depicted in Figure 3.6.

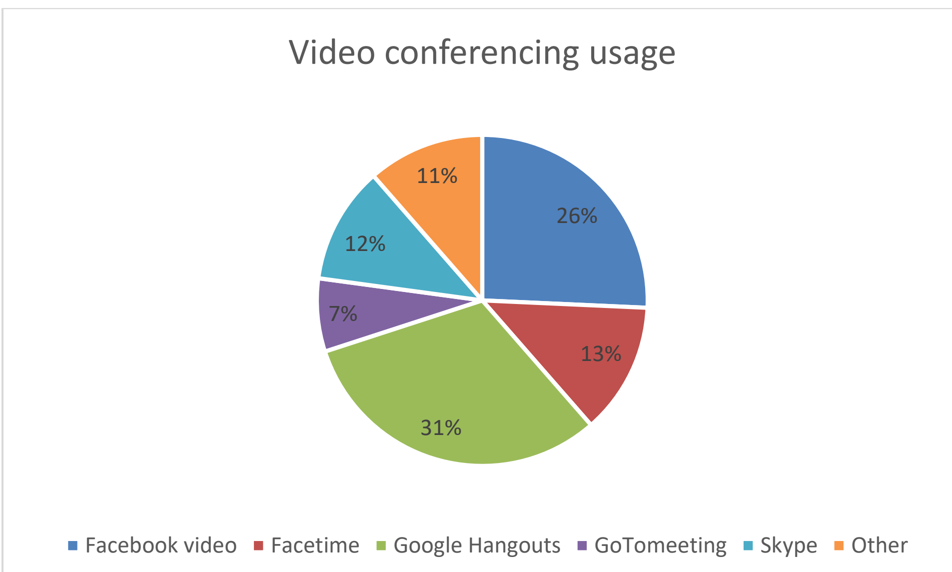


Figure 3.6 Participants video conferencing usage

3.3.2 User Testing Procedure

On arrival to the user testing session, participants were informed that the user testing session will be audio and video recorded and audio data will be transcribed for analysis. The Demographic & Health Questionnaire and Video Conferencing Usage Questionnaire were administered at the beginning of each study session to obtain participants' demographic, health, and video conference usage information. Participants were instructed to complete the materials prior to the user testing session.

The user testing followed a specific order, starting with an introduction of telepresence technology, and its capabilities. After demonstrating telepresence technology to the participant via a short video, following questions regarding usefulness of telepresence technology were discussed: 1) What are your first impressions about Telepresence robot? 2) Do you think telepresence robot can be useful? Why? and (3) briefly describe how might you use telepresence technology.

To begin with the user testing, half the participants tested *Presence* first, followed by *InTouch*. The other half drove *InTouch* first, followed by *Presence*. This counter-balance of order was to reduce the skewing of results due to practice effects. Each participant then was asked to perform a list of tasks (Table 3.9). During testing, the participant was reminded to think-out-loud [48]. This is a usability method where participants use the system while continuously verbalizing their thoughts as they move through the user interface [49]. This method enables researchers to discover what users really think about a design of a system. During the user testing, hints were provided if the participant could not perform that task or if they explicitly asked for help. After one test session, questionnaires regarding the tested UI were administered and the older adults were interviewed about their opinions of the UI. After a short break, half the participants who tested *Presence* were then presented with the *InTouch*, or via versa. Each participant performed the same list of tasks with the same testing protocol. After this test session, the same questionnaires and interview questions were administered.

Table 3.8 User testing tasks

1. Log into the system with provided username and password
2. Initiate a video call
3. Mute the microphone
4. Unmute the microphone
5. Change the speaker sound level
6. Using the arrows on the keyboard, drive to the first intersection marked as "X" follow the green line. When arrive at "X", please turn right.
7. Adjust the driving speed
8. Using the arrows on your keyboard, drive the system follow the yellow arrow. Drive to the next "X" then turn right to face the wall with a painting on (Question: how many people are in the painting)
9. Please zoom in
10. Please zoom out and turn left.
11. Follow the green path and stop at the next "X", turn right to face the book shelf (Question: what is on the lowest level of the shelf)
12. Use change the height feature to lower the system (this task was only assigned when testing *InTouch*)
13. Turn left, drive forward to the stairs
14. Drive towards the trash can as close as to hit it. You should notice automatically decreases in speed as you approach the bin
15. Drive to the bedroom.
16. Drive back to the charging dock
17. End the call

3.3.3 Usability Measurements

3.3.3.1 Navigation Measures

Tracking each participant's driving path in the virtual environment was vital to this project. Similar to a case study conducted by Tsui et al. in 2015 in which they had participants remotely visit an art gallery, allowing participants to "form and execute movement strategies for viewing the exhibits," my plan was to have an outline of the preferred path but allow users to navigate the virtual environment freely [23]. Unity has extensions available for path finding, which tracked the accuracy of remote driver's navigation. The path finding system generates a NavMesh, which displays the constraints for an object's movement in the environment. The NavMesh also calculates the path of the game objects at run-time [62]. I incorporated path finding into the simulation to measure the system's movement trajectories [23]. This granted us the ability to use the exact course of the user and measure the differences and deviations among the varying routes [62]. This quantified the participant's success in driving the system, in terms of efficiency and accuracy. The time each participant spends on finishing tasks on each interface was also measured.

3.3.3.2 Error Analysis

Errors happen and they are common during a user testing session [50]. It is important to measure what mistakes users made during testing, how often each mistake happened, and why each mistake happened. During each testing session, I observed each participant's driving performance and took note. Each session was also video recorded. Errors made by each participant were evaluated, counted, and categorized. However, it is important to state that errors can cause by slips, mistakes, interface problems and scenario errors [50]. In this study I mainly focused on analyzing errors caused by user interface issues. Participants' think-out-loud data provided insight into *why* mistakes happened.

3.3.3.3 Questionnaires

Usability questionnaires were administered with a variety of goals. Participants completed a Perceived Usefulness Questionnaire (Appendix C), an Ease of Use Questionnaire (Appendix D), System Usability Scale Questionnaire (Appendix E) and NASA Task Load Index (Appendix F) after testing each UI. The Perceived Usefulness Questionnaire measured the degree that the participants perceived that the UI would meet their needs [51], whereas the Ease of Use Questionnaire refers to the degree to participants that using a system would be free of effort [51]. System Usability Scale (SUS) was used for measuring the usability of a system (e.g., software, hardware). NASA-TLX [66] was used to evaluate participants' perceived workload on 6 subscales.

After participants completed both testing sessions, Privacy Attitudes Questionnaire (Appendix G) and Telepresence Features Questionnaire (Appendix H) were administered. These questionnaires were custom made, and the purpose of Privacy Attitudes Questionnaire was to understand participants' privacy attitude. The Telepresence Features Questionnaire included 6 design features, participants checked if each feature was important to them on a 7 point Likert scale (Appendix H).

3.3.3.4 Interviews

Open-ended questions were discussed at the end of each testing session to assess the user's perceived usefulness and privacy of each interface (Appendix I).

CHAPTER 4

RESULTS

4.1 RESULTS FROM QUESTIONNAIRES

4.1.1 System Usability Scale (SUS) Results

SUS was originally created in 1986 by John Brooke [67]. This questionnaire is widely used for measuring the usability of a vast variety of products (e.g., software, hardware), and has become an industry standard. The original SUS is a 10-statement Likert scale – half worded positively and the other half worded negatively. Each question uses a 5-point scale of strength of agreement (with anchors for strongly agree and strongly disagree). To interpret the data, the participants' score for each question was converted into a new number by implementing the following: (1) for odd number questions, I subtracted 1 from the users' response; for even number statements, subtracted the users' response from 5; (2) I summed the converted responses for each participant and (3) multiplied the total by 2.5 to convert the response from each user to 0-100.

A paired samples t-test was conducted to compare the System Usability Scale (SUS) scores between conditions. The *InTouch* condition yielded a significantly ($t(29) = 2.87$, $p<.05$) higher SUS score ($M = 82.08$, $SD = 12.21$), compared to the control *Presence* condition ($M = 76.33$, $SD = 14.79$). *Presence* and *InTouch* conditions (Figure 4.1) yielded a SUS score that is higher than 68, indicating that both interfaces are easy to use. However, the significant higher *InTouch* SUS score suggests that it was perceived by participants to be more user friendly than *Presence*.

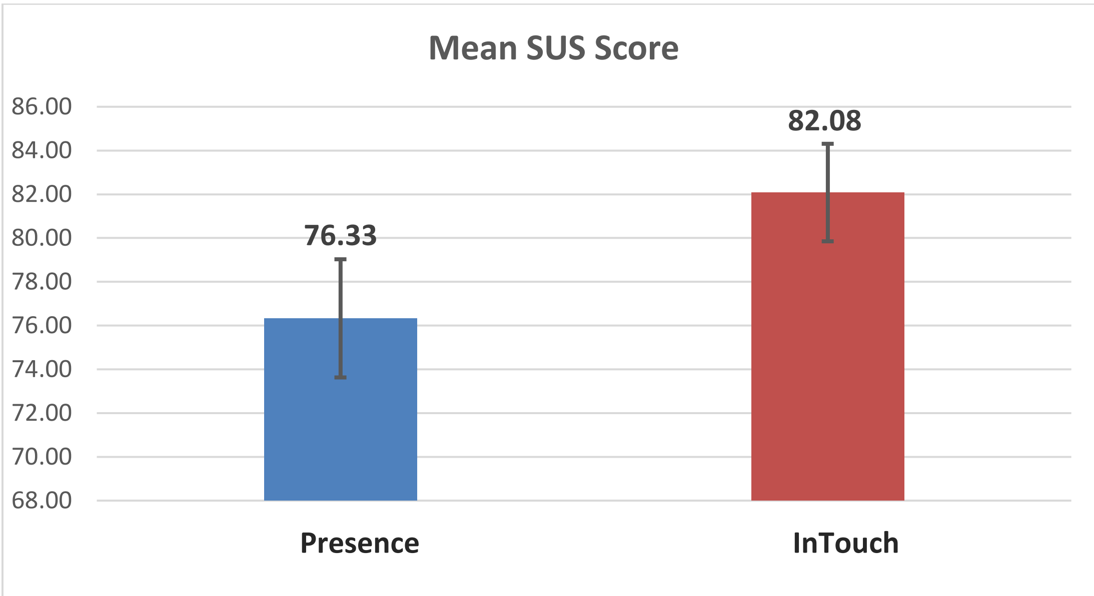


Figure 4.1 Mean SUS score

4.1.2 Technology Acceptance Model (TAM) Questionnaire Results

The TAM questionnaire was administered to assess the user's perceived usefulness and ease of use toward the tested interfaces. The TAM questionnaire is split into two parts: 6 questions pertain to Perceived Usefulness (PU, Appendix C) and 6 questions pertain to Perceived Ease of Use (PEU, Appendix D).

Paired samples t-tests were conducted to compare the average PU and PEU between conditions. The average perceived usefulness score did not yield a significant difference between conditions. As shown in Figure 4.2, both user interfaces were perceived as useful by the participants.

There was a marginally significant difference in the perceived ease of use scores ($t(29)=1.89$, $p=.07$), with *InTouch* having a higher average score than *Presence*. This finding supports the SUS scores (section 4.1.1). Specifically, *InTouch* yielded higher scores for 4/6 of the perceived ease of use questionnaire items. These questionnaire items are depicted in Figure 4.3 and Table 4.1.

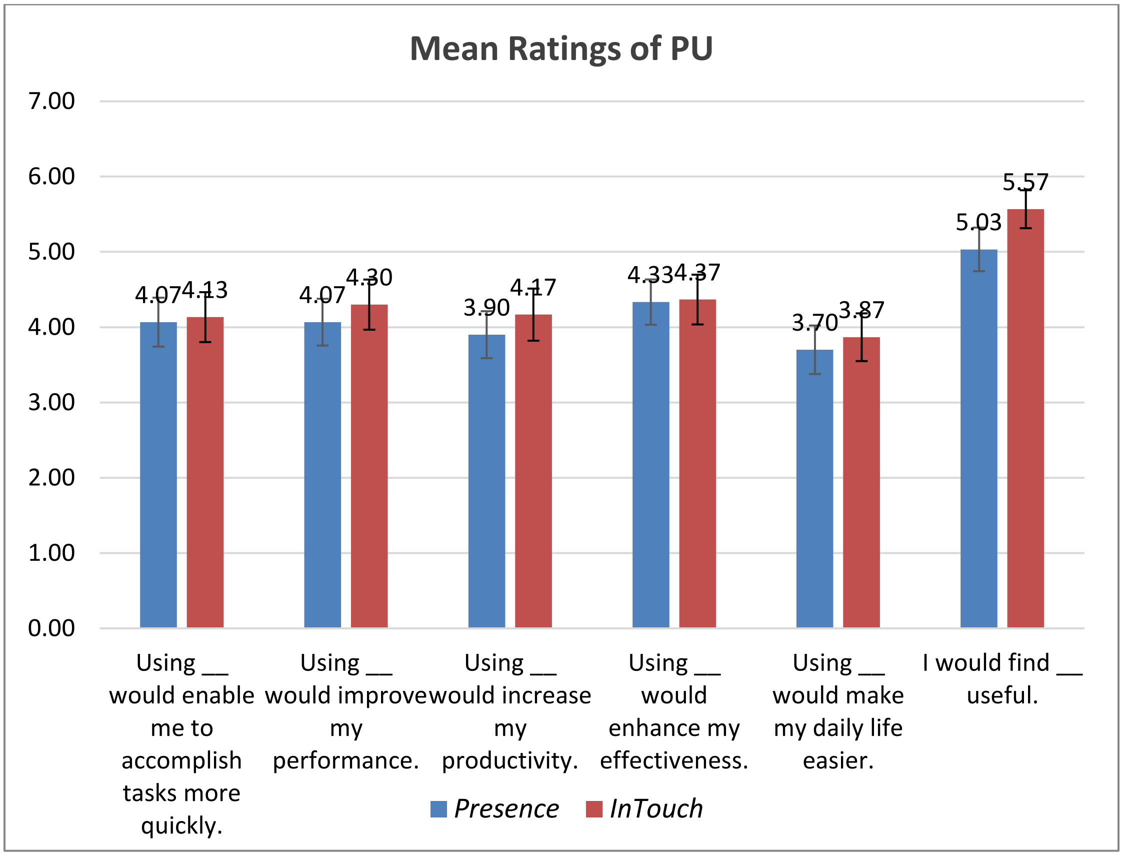


Figure 4.2 Mean ratings of PU of *Presence* and *InTouch*

4.1.3 Senior Technology Acceptance Model (STAM) Questionnaire Result

The Senior Technology Acceptance Model (STAM) adopted from [69] was administered to further measure the participant's acceptance of *Presence* and *InTouch*.

STAM (Figure 4.4) was an extension of TAM but for older adults [69]. Compared with TAM, the STAM questionnaire assessed 8 more dimensions (Table 4.2). Paired sample t-tests indicated that *InTouch* and *Presence* statistically differed on 3 questionnaire items [Table 4.3]. These 3 items belong to 3 measure dimensions: perceived ease of use, gerontechnology self-efficacy and facilitating conditions. Based on the theoretical model showed in Figure 4.4, all 3 dimensions relate to perceived usefulness, usage behavior and attitudes towards use.

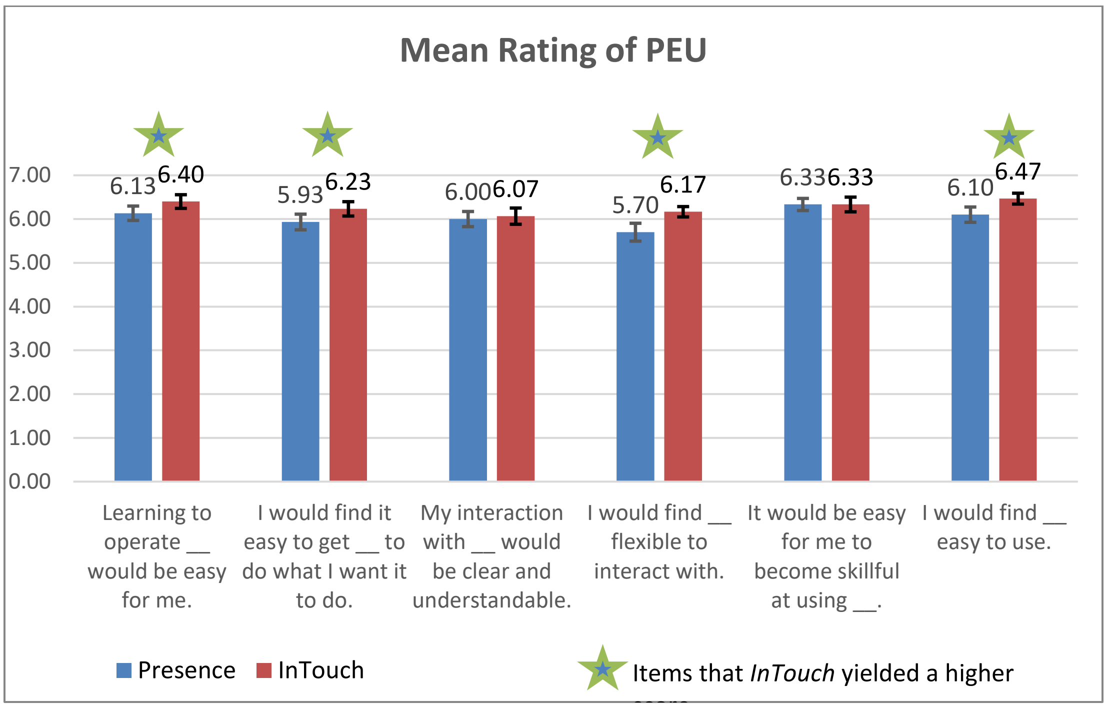


Figure 4.3 Mean ratings of PEU of *Presence* and *InTouch*. * Indicates statistically significant difference.

Table 4.1 List of PEU items that *InTouch* yielded statistically significant higher ratings

Questionnaire Item	*InTouch M*	*InTouch SD*	*Presence M*	*Presence SD*	t-value	*p*
Learning to operate ____ would be easy for me	6.40	.86	6.13	.90	2.11	.043
I would find it easy to get ____ to do what I want it to do	6.23	.90	5.93	.98	2.19	.037
I would find ____ flexible to interact with	6.17	.65	5.79	1.12	2.09	.046
I would find ____ easy to use	6.47	.68	6.10	.96	2.63	.014

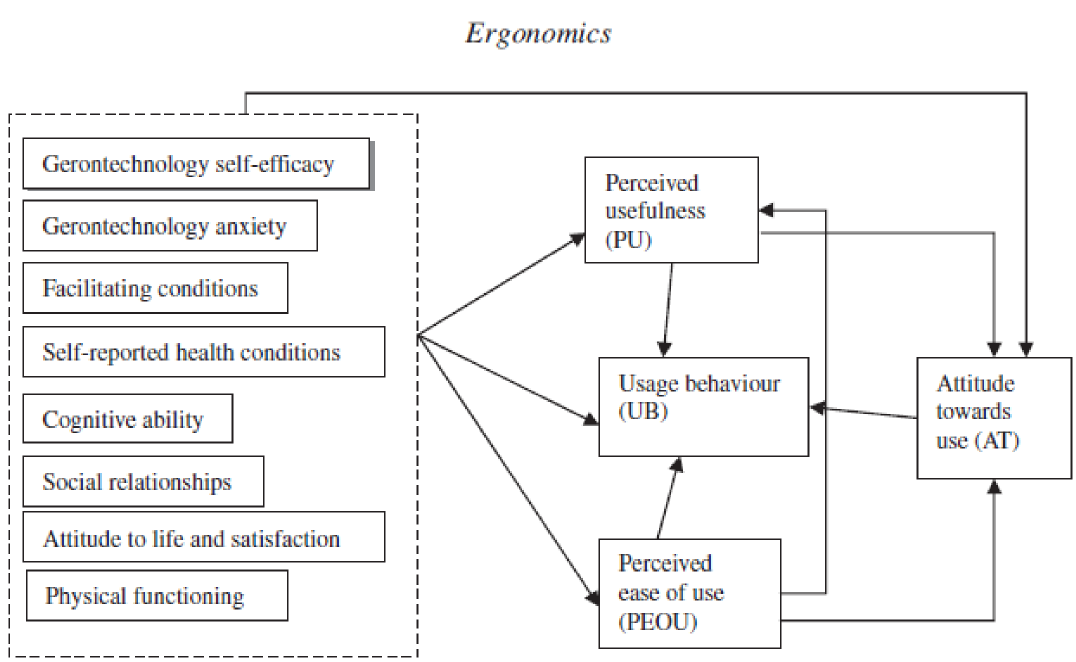


Figure 4.4 Senior technology acceptance model [69]

Table 4.2 Additional items in STAM

Gerontechnology self-efficacy	You could complete a task using technology if there is someone to demonstrate how You could complete a task using technology if you have just the instruction manual for assistance
Gerontechnology anxiety	You feel apprehensive about using the technology You hesitate to use the technology for fear of making mistakes you cannot correct
Facilitating conditions	You have the knowledge necessary to use the system A specific person (or group) is available for assistance with technology difficulties Your financial status does not limit your activities in using technology When you want or need to use technologies, they are accessible for you Your family and friends think/support that you should use technology
Self-reported health conditions	How are your general health conditions How are your health conditions compared with the same-age groups? How good is your hearing How well can you see How well are you able to move around
Cognitive ability	How would you rate your memory How satisfied are you with your ability to learn new information How well are you able to concentrate How satisfied are you with your ability to make decisions
Social relationships	How satisfied are you with your personal relationships How satisfied are you with the support you get from your friends and family Do you participate in social or community activities
Psychological function	Do you feel that as you get older you are less useful How satisfied are you with your quality of life
Physical function	Ability to use telephone Grocery shopping Food preparation Doing housework or handyman work Laundry Getting to places beyond walking distance Taking medications Managing money

Table 4.3 STAM items that *InTouch* yielded a statistically significant higher rating

Questionnaire Item	*Question Category*	*InTouch Mean*	*InTouch SD*	*Presence Mean*	*Presence SD*	*t-value*	*p*
I can be skillful at using ____	*Perceived ease of use*	9.13	1.01	8.67	1.47	2.25	.032
I could complete a task using ____ if there is someone to demonstrate how	*Gerontechnology self-efficacy*	8.70	2.35	7.87	2.93	2.41	.023
I think my family & friends will support that I use ____	*Facilitating conditions*	8.10	2.18	7.33	2.44	2.39	.023

4.1.4 NASA Task Load Index (NASA-TLX) Questionnaire Result

The NASA Task Load Index questionnaire was administered after each testing session to assess users' perceived workload after finishing a list of tasks. No statistically significant differences were found in the NASA TLX score between conditions. Both groups scored relatively low on the NASA TLX [Figure 4.5], suggesting that both UIs required minimal amounts of workload.

4.1.5 Privacy Attitudes Questionnaire Result

The privacy attitudes questionnaire was adopted from [71] to assess older adults' general privacy attitudes. Results of the questionnaire (Figure 4.6) show older adults concerned about online identity theft, their online privacy (e.g., being hacked) and privacy in everyday life (e.g., check credit card bill regularly). Participants also expressed their concerns of how companies handle their personal information (Figure 4. 6). In addition, it was unlikely that older adults would read the privacy policy. Overall older adults had concerns regarding privacy, such as being hacked.

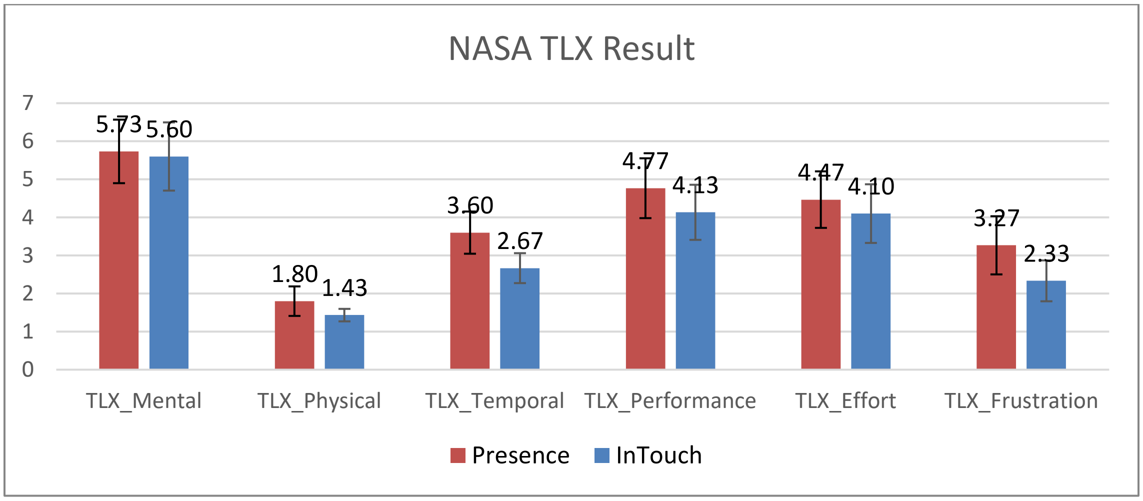


Figure 4.5 NASA TLX result

4.1.6 Telepresence Features Questionnaire Result

This questionnaire was designed to assess older adult's attitudes towards the additional usability and privacy enhanced features included in *InTouch*. Participants rated each item from 1 being not at all important and 7 being extremely important. Results of the questionnaire indicate that participants perceived the additional features to be important for telepresence technology (Figure 4.7). In particular, stair detection, obstacle detection and room accessible control were recognized as very important by the participants.

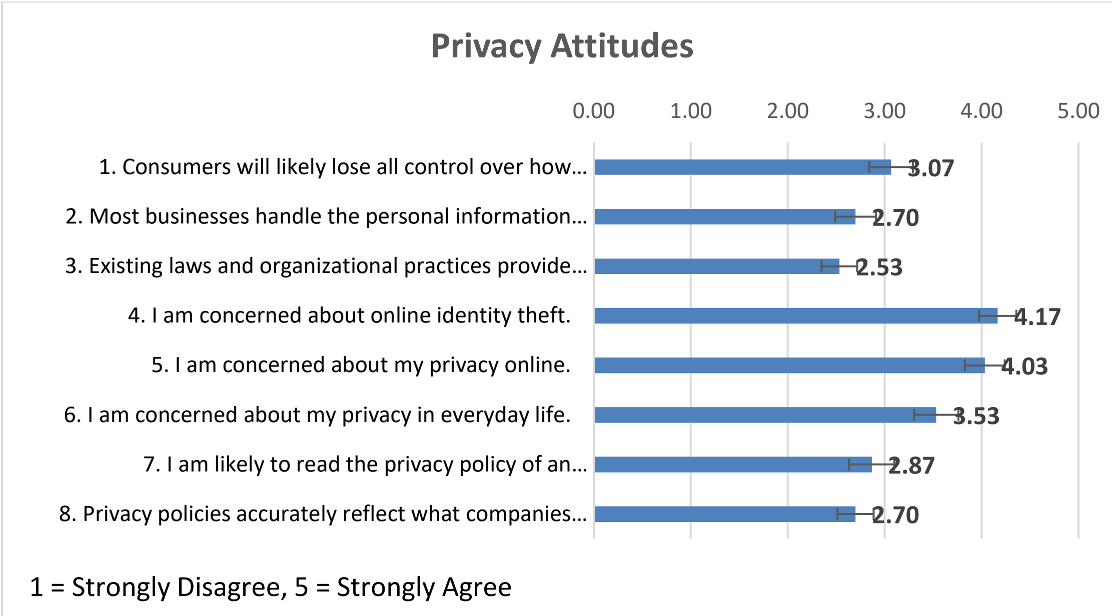


Figure 4.6 Privacy questionnaire results

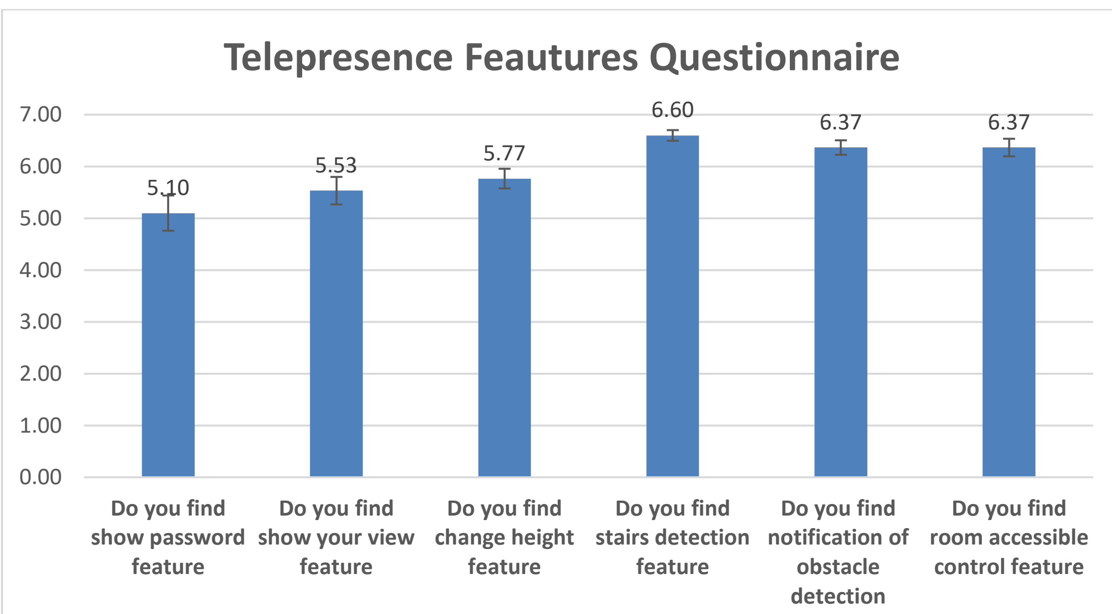


Figure 4.7 Telepresence features questionnaire results

4.2 RESULTS FROM INTERVIEW

4.2.1 Segmentation and Coding Scheme Development

The interview data was analyzed according to a coding scheme to identify the patters and themes from the discussions. To do so, first, all 30 audio recordings were transcribed verbatim with the participant's personal information omitted. Next, transcriptions were divided into segments to analysis. A segment is defined as a participant's statement that described their feeling, thought, or opinion regarding the specific question that was discussed. For instance, when asked "What was your first impression of the Telepresence robot", a participant's response "I think it was really easy to drive" was identified as the segment for this question. Detailed interview structure attached at Appendix J.

Next, a well-defined coding scheme was developed. A coding scheme is an organized categorization of information retrieved from the interviews. In this study, the coding scheme was the format followed the interview structure and it was based on the nature of participant's comments and currently existing literature. The coding scheme included themes that were already identified to be related to perceived usefulness and perceived ease of use. To ensure each segment is grouped naturally by its label(s), an iterative generation strategy was applied. In this approach, a segment was coded either to a category that was already included in the coding scheme, or a new category label was assigned determined by the researcher that described the general idea of that segment.

Two raters coded same 3 randomly selected transcripts independently. Percent agreement was calculated as the percentage at which different coders agreed and remained consistent with their assignment of particular codes to particular data. The reliability resulted in 84.6% agreement between the two raters. There is no standard or base percentage of agreement among qualitative researchers, but ~85% is considered to be an acceptable benchmark [70]. The primary and secondary raters then reviewed disparate codings and modified the coding scheme for clarification. The remaining interviews were analyzed by the primary rater only.

4.2.2 Opinions of Telepresence Robot

In this section, participants indicated their first impression of telepresence robots, whether they perceive this technology to be useful, and how might they want to use this technology. These interview questions were asked after the participants watched a short video introducing them to telepresence robots in general (i.e., to introduce this technology concept to them), but before they demoed *InTouch* or *Presence*. Participants' first reaction of telepresence technology was mostly positive (86.7%), some were mixed (3.4 %) and a few of them expressed a negative first impression (6.7%) (see Figure 4.8). All participants (100%) perceived telepresence robots to be useful in general. Participants were also asked how might they use telepresence robot. Participants most commonly mentioned they would use the technology to stay in touch with family and friends, overall results are presented in Figure 4.9.

4.2.3 Opinions of Presence and InTouch

In this section of the interview, participants reported their first reaction, their perceived usefulness, perceived ease of use, and perceived privacy level of *Presence* and *InTouch*. These interview questions were administered after each UI demonstration.

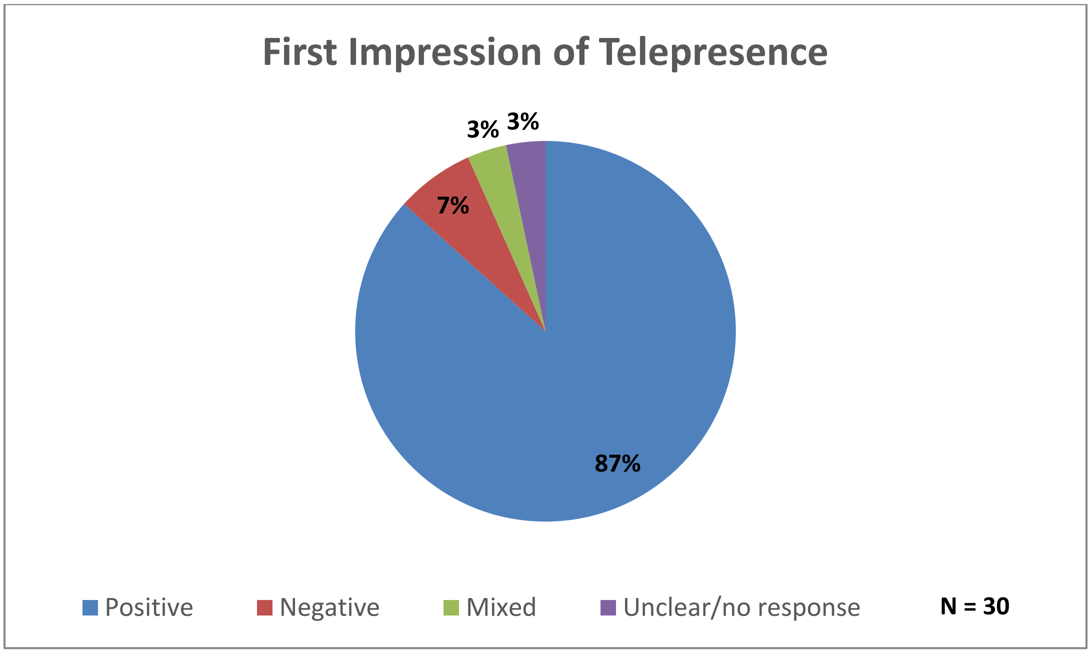


Figure 4.8 First impression of Telepresence robot

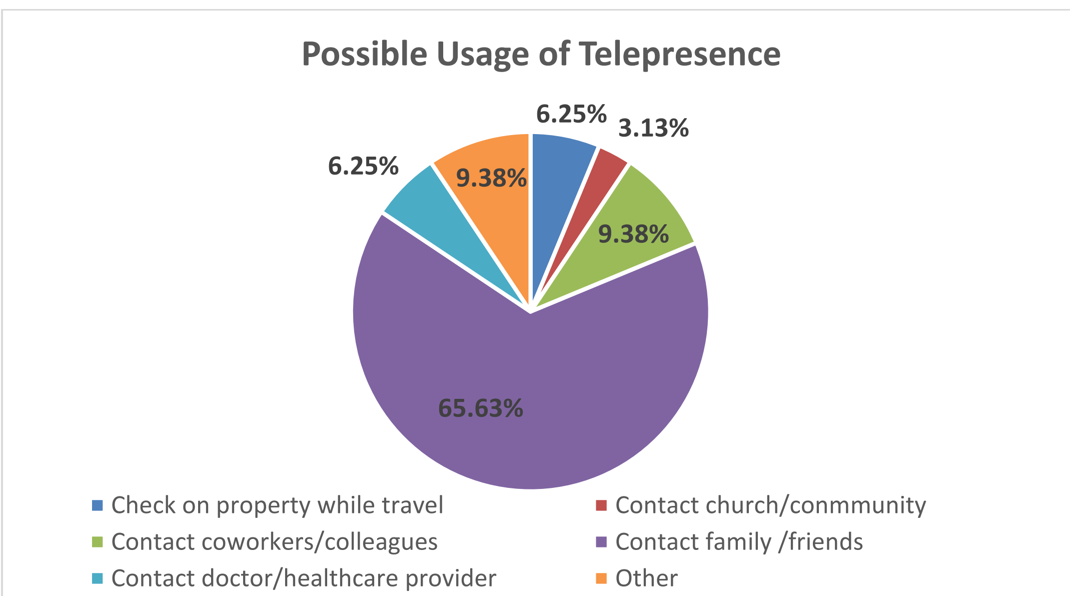


Figure 4.9 Identified possible usage of Telepresence

Perceived Usefulness.

Over half (63.4%) participants had positive first impression of *Presence*. Two had mixed (6.7%) feeling (e.g., can be helpful but a little confusing). A few older adults (20%) held a negative reaction towards *Presence*. Three participants responses were unclear (Figure 4.10) how they felt about *Presence*. It is important to note that all 6 participants who had negative impressions towards *Presence* tested *InTouch* prior to *Presence* and expressed a preference for *InTouch*. In addition, "missing features" was the most commonly mentioned reason participants provided when asked why they had negative impression of *Presence* (i.e., missing design features compared to *InTouch*).

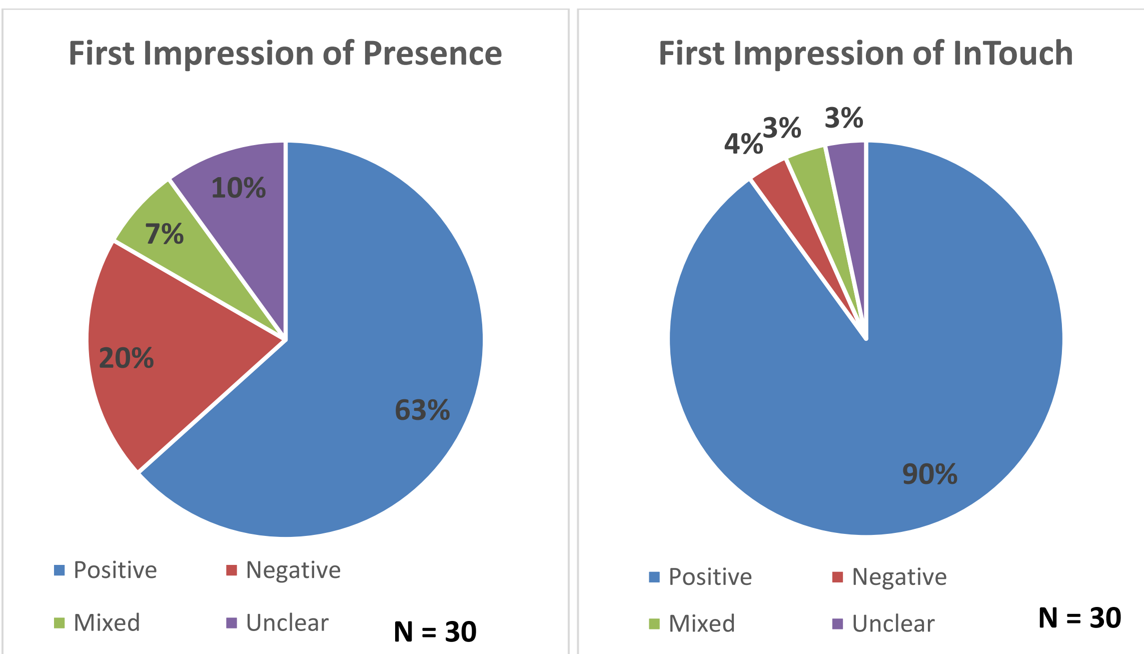


Figure 4.10 First Impression of *Presence* and *InTouch*

Ninety percent participants had positive first impression of *InTouch*. One participant stated "It was very cool. It was easy to use, it was fun." For participants who tested

Presence prior to *InTouch*, some of them expressed their preference on *InTouch* over *Presence* as one mentioned "I liked it better… I think it's easier to use". The one participants who expressed negative first impression tested InTouch first and stated, "It was confusing as to what to do next". One older adult had mixed feelings of *InTouch* and stated that that although the additional features were helpful but they also cluttered the testing experience as he stated, "I think the additional features, even though I liked them, it just cluttered the experience a little bit."

In addition to their first impressions, participants were also asked if they could imagine *Presence* and *InTouch* being useful for them. Half participants (Figure 4.11) perceived *Presence* to be useful (53.4%), 7 participants (23.4%) considered *Presence* not useful (note: 5 of them tested *InTouch* prior to *Presence*), 5 older adults (16,7%) indicated their perceived usefulness of *Presence* depended on their own needs (e.g., health status, or social engagement).

When asked to assign usefulness rating on a 1 to 5 scale (with 1 as not useful at all, 5 to be very useful), participants on average rated *Presence* as M = 3.38, SD = .90 (Figure 4.12), which was close to neutral. As for why participants assigned that usefulness rating, 33.4% of participants reported that their current life style (e.g., relatives lived close) or current living environment (e.g., space limitation) limited their perceived usefulness of *Presence*. 20% reported that missing feature (e.g., notification, room control) was the main contribution to the lower usefulness rating. A few participants (6%) stated *Presence* was not easy to use, thus a low usefulness score was assigned (see Figure 4.13). Twenty-five participants (83.4%) indicated *Presence* has the potential to help then stay social connected while 5 (16.7%) stated *Presence* would not help with connecting family and friends (Figure 4.14).

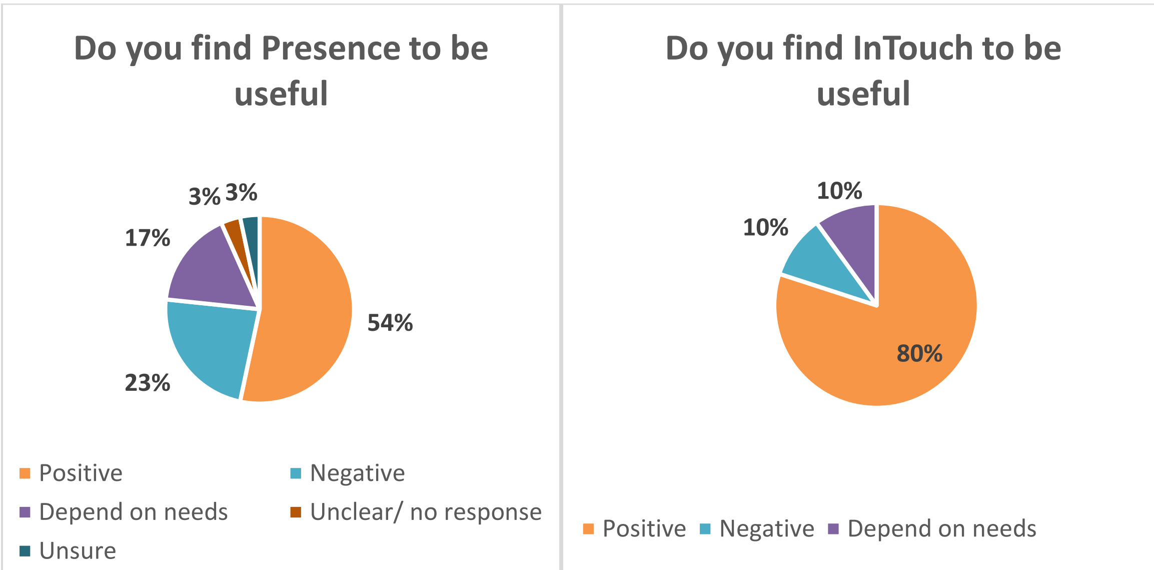


Figure 4.11 Usefulness of *Presence* and *InTouch*

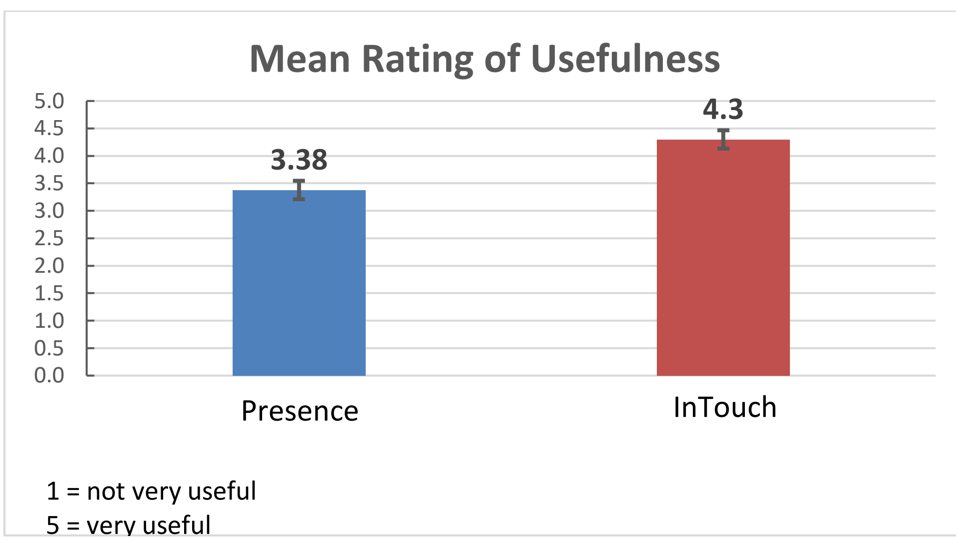


Figure 4.12 Mean rating of perceived usefulness

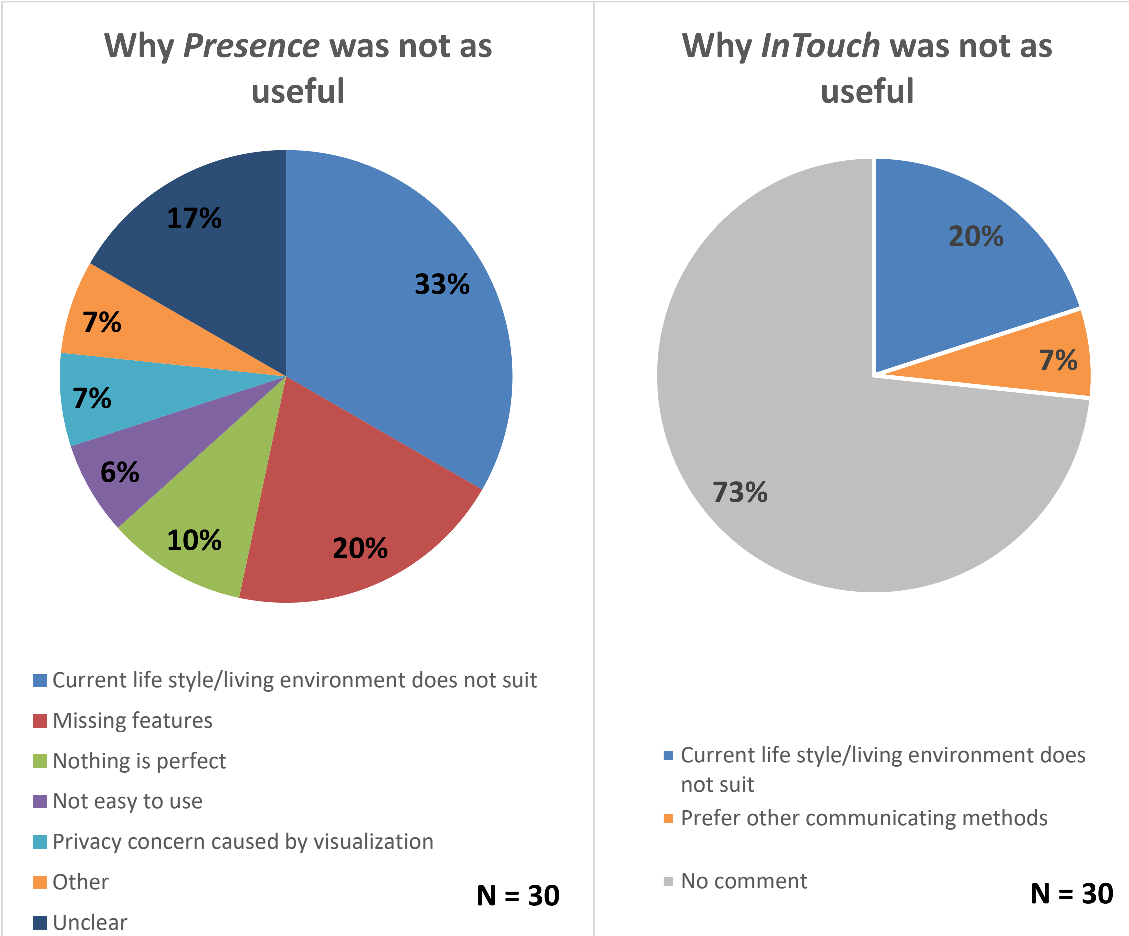


Figure 4.13 Why *Presence*/*InTouch* was not as useful

Overall, participants perceived *InTouch* as more useful than *Presence*. More participants (80%) perceived *InTouch* to be useful (Figure 4.11) compared to *Presence* (54%). When asked if *InTouch* was useful, one participant responded, “I think it was very useful, it would connect, be able to connect with family.” Ten percent older adults stated that the usefulness of *InTouch* would depend on their needs (Figure 4.11). For the rest 10% (3) who did not perceived *InTouch* as useful, 2 participants preferred emails over other communication methods, and the other one older adult stated, “it's not useful. But, like I said, other people with large families and kids, the parents, grandparents can all be there with them. And I think that would be very useful." Participants also discussed the usefulness of *InTouch* on a scale of 1 to 5 (1 = not useful at all, 5 = very useful). Results from this question indicated that participants perceived *InTouch* to be more useful (*M*=4.3, *SD*=.92, Figure 4.0). Results from other questions from the perceived usefulness interview section were depicted in Figure 4.15. Overall, both UIs were perceived as enjoyable, help users stay connected. In addition, participants also expressed their willingness to use it if they had access to it.

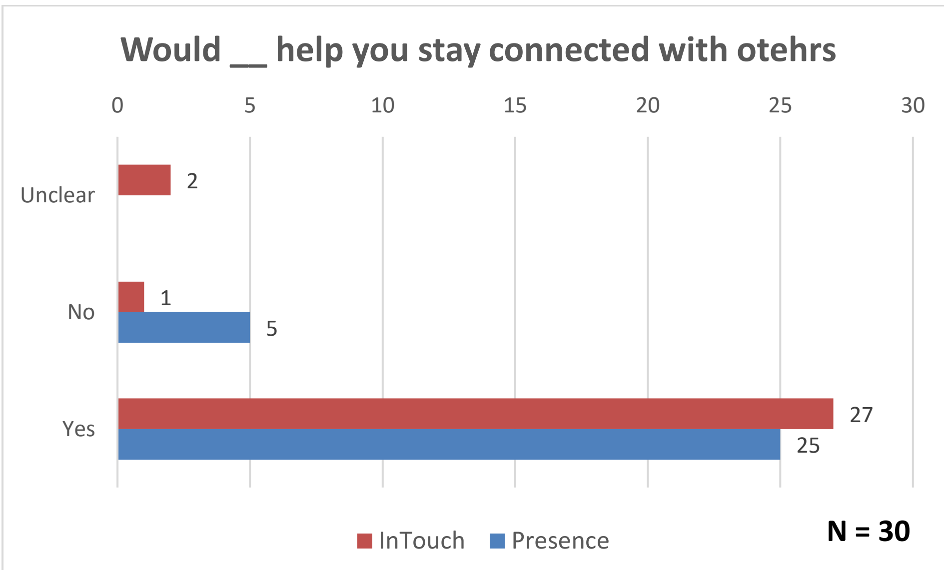


Figure 4.14 Would *Presence*/*InTouch* help with social connectedness

<u>Presence Ease of use</u>

Regarding the ease of use of each interface, participants first assigned a value from 1 to 5 (1 = not easy to use, 5 = very easy to use). The mean values of *Presence* and *InTouch* were depicted in Figure 4.16 (*Presence M* = 4.00, *SD* = .87; *InTouch M* = 4.50, *SD* = .57.

Participants reasoning for these ratings of *Presence* and *InTouch* are presented Figure 4.17 below. *InTouch* yielded a slightly higher ease of use rating. These results indicated that overall both *Presence* and *InTouch* were identified as easy to use by older adults.

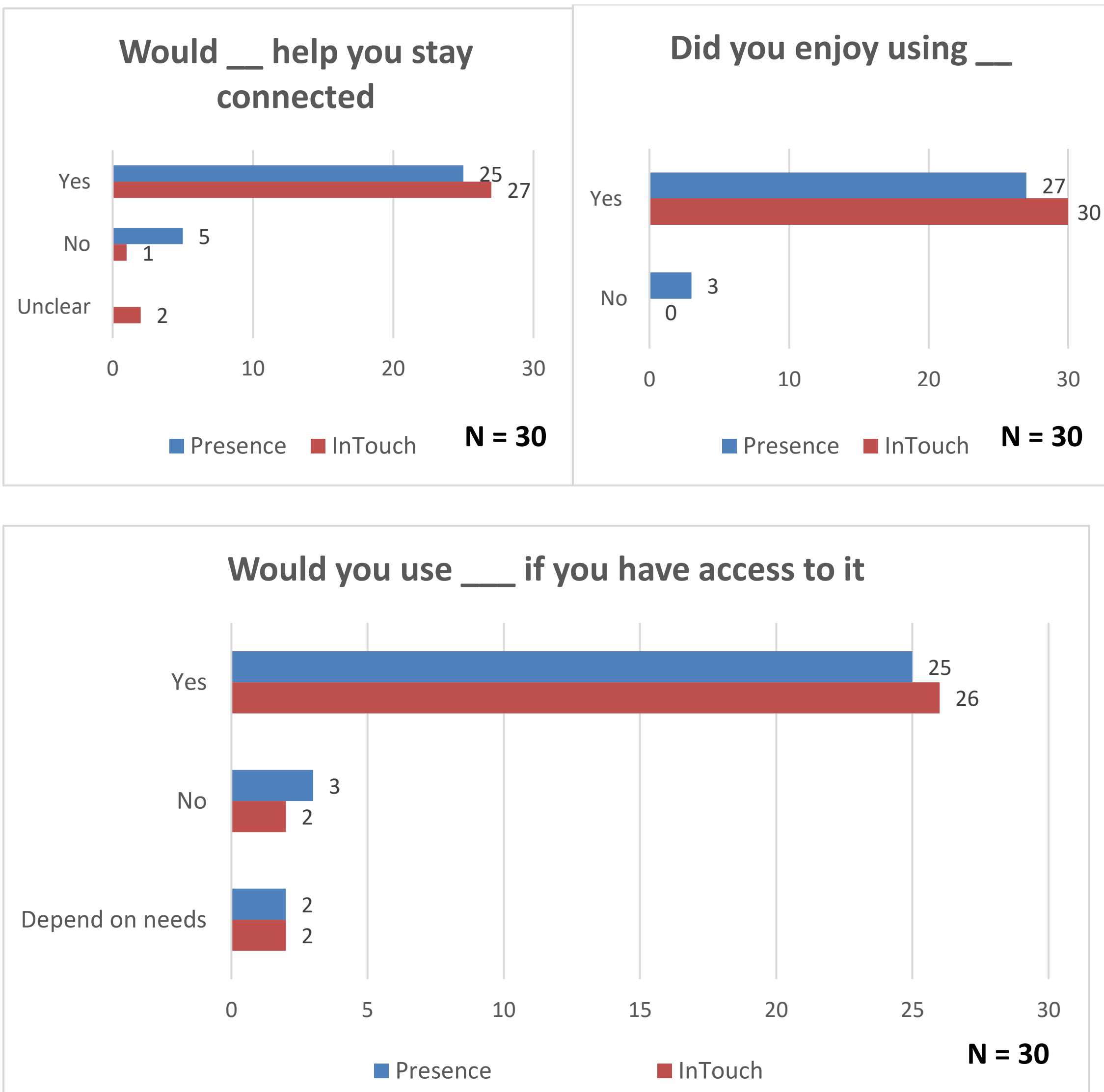


Figure 4.15 Additional questions regarding usefulness, numbers report frequencies

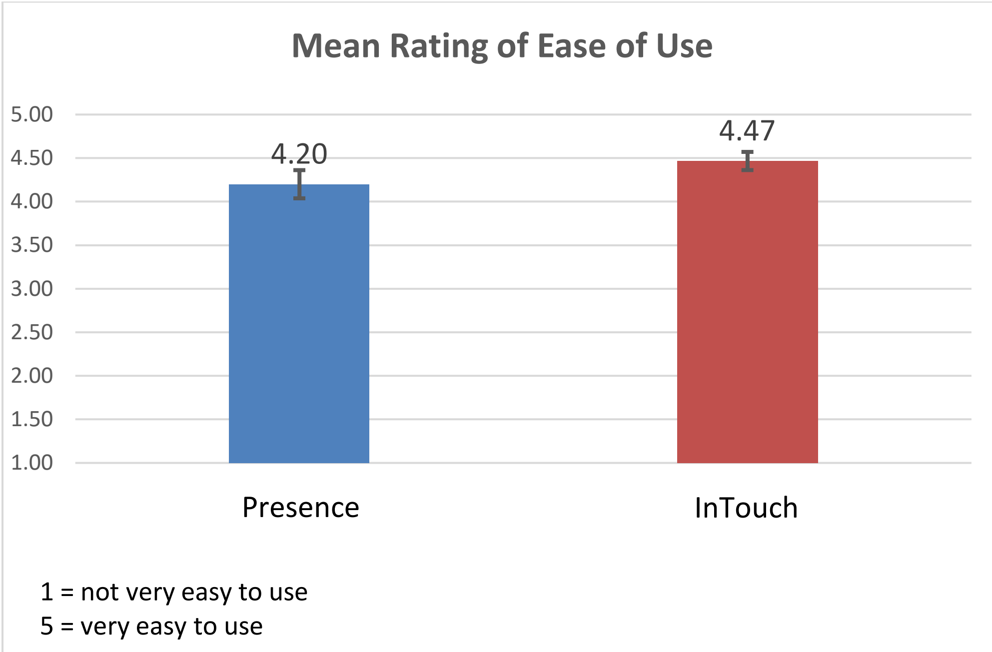


Figure 4.16 Mean Rating of Ease of Use (error bar represents standard error)

To further investigate why certain ease of use ratings were assigned, participants also discussed: 1) what did they find easy to use (Figure 4.17) 2) what did they find hard to use (Figure 4.18). For the *Presence* condition, participants made significantly (X^2 = 13.89, p<.001) more comments related to features they found easy to use (i.e., 35 mentions of features they found easy to use), compared to only 10 features they found difficult to use. Similarly, for *InTouch* significantly (X^2 = 24.38, p<.001) more mentions of features that were easy to use (37) were made compared to features that were difficult (5).

Under *Presence* condition, "Control and moving around" was the most frequently mentioned feature that was easy to use (72.22%). Menu icons were intuitive to use was the second mentioned aspect (22.22%). Participants particularly pointed that volume icon to change the volume and magnifier icon to zoom in a spot were easy to recognize. When asked “Do you remember what was easy to use in Presence”, one participant stated “Oh sure. The search feature which zoomed in, the sound.” Participants also reported autonomous features, such as obstacle avoidance, made Presence easier to use (5.56%). As one participant state “I like the docking thing. And I like that it wouldn't run over the trash can”.

For *InTouch (*Figure 4.17*)*, “Control and move around” was still the most mentioned easy to use aspect (63.89%). Similar to *Presence*, menu and icons were easy to use was mentioned 22.22%. Additional features (e.g., notification, stair detection) helped with the ease of use was mentioned 13.89% of times.

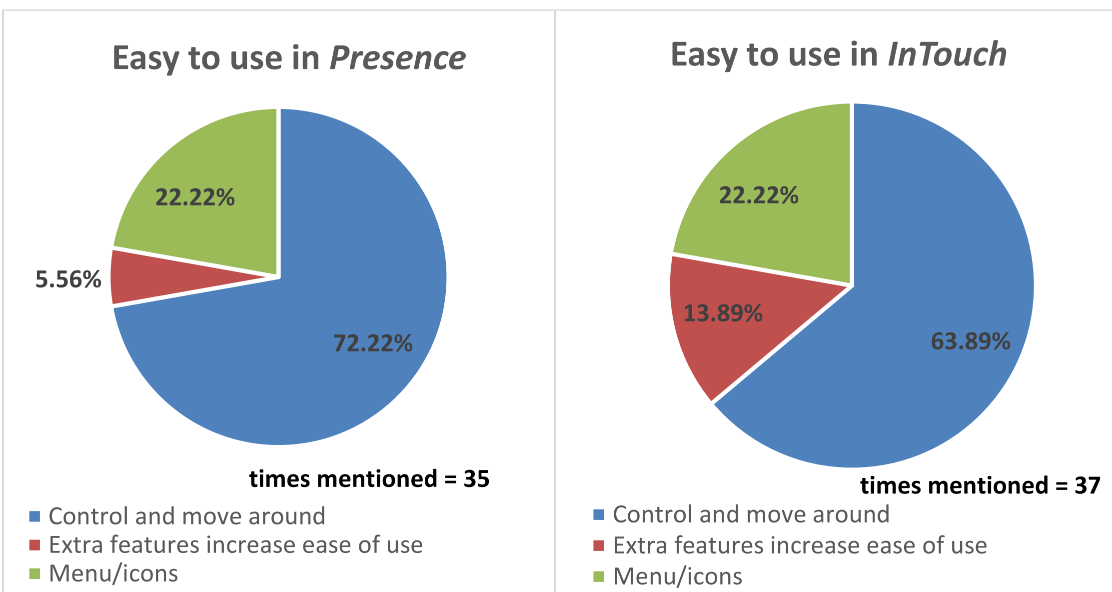


Figure 4.17 Items identified easy to use

Features identified as difficult to use were listed in Figure 4.18 with the frequency of comments. For *Presence*, lack of familiarity of the laptop/driving environment was mentioned the most (50%). Unintuitive icon was mentioned (30%) as zoom icon was identified to be confusing. Missing autonomous features (e.g., obstacle avoidance) was mentioned (20%) as another factor that increase the difficulty of use.

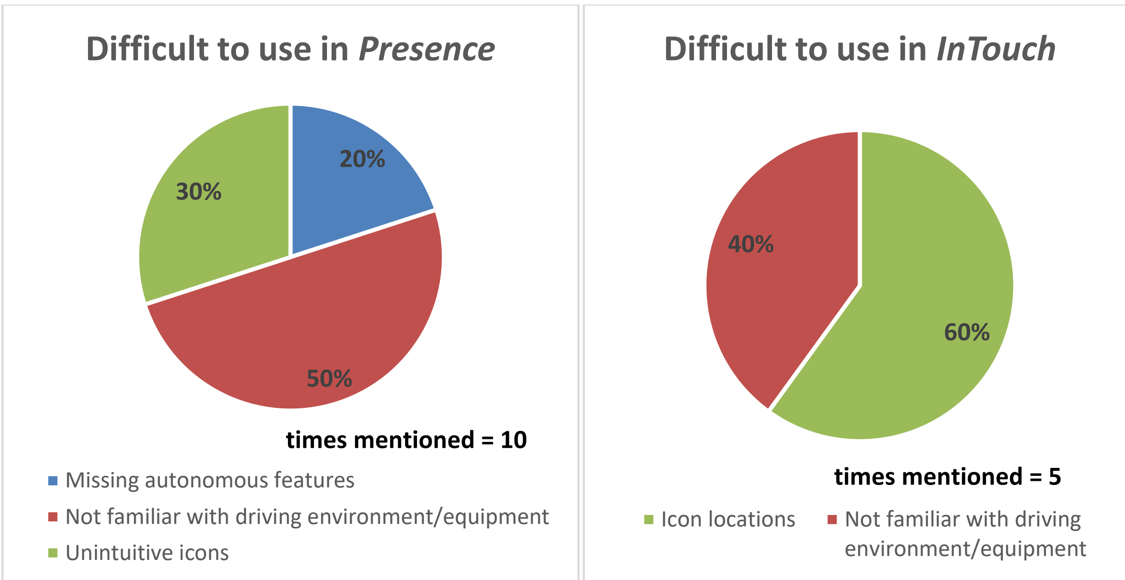


Figure 4.18 Items identified as difficult to use.

<u>Perceived Privacy</u>

To measure participant's perceived privacy of each UI, researcher asked each participant a list of questions regarding privacy (Appendix I). Participants perceived privacy level for *Presence* and *InTouch* are presented below. First, as a pilot user (the user who remotely controls the robot), on a scale of 1 to 5 (1 = not private at all, 5 = very private), Figure 4.19 depicted that participants perceived *Presence* and *InTouch* as private. (*Presence* M = 3.83, SD = 1.51, *InTouch* M = 4.50, SD = .94). Within people (50% of participants) who perceived Presence as very private (private rating = 5) as pilot user, all participants assigned the rating due to "pilot user was in control. Privacy concerns as pilot user are depicted in Figure 4.20. Although previous studies [16, 21, 23] showed that visualization was one of the major perceived benefits of Telepresence, the two-way video mechanism of Telepresence increased older adults' privacy concern at some level as a pilot user. As one participant stated, "I still don't think it's very private (being a pilot user) because I can see, they can see my surrounding, I can see theirs." Another participant explained why they were concerned about privacy as a pilot user "Because I would be showing my face in order to communicate or they would want to know why I wasn't there."

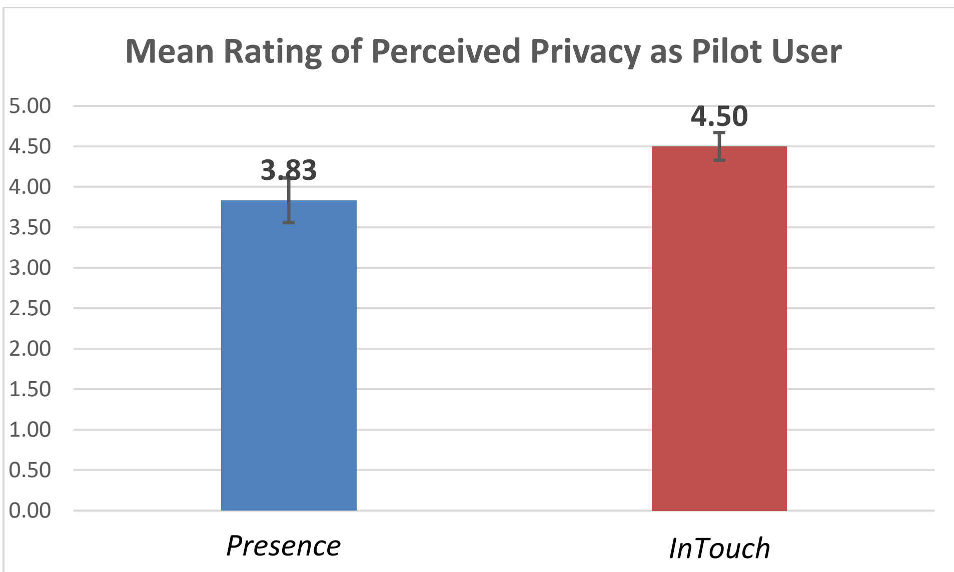


Figure 4.19 Mean rating of perceived privacy: pilot user

When asked to consider the privacy level of each UI from a local user perspective, older adults perceived *Presence* to be not very private (M = 2.07, SD = 1.31, Figure 4.21) compared to *InTouch*'s higher score (M = 3.80, SD = 1.35, Figure 4. 21). For *Presence*, the most mentioned concern was lack of control as a local user (38%, Figure 4.22) (e.g., such as setting private areas of the home). Participants who tested *InTouch* prior to *Presence* also stated that for *Presence*, missing room accessible control was a major privacy concern as a local user (28%). Visualization was again identified as privacy concern for both UIs (Figure 4.22). Lastly, under both conditions, participants expressed (Figure 4.22) their concern regarding security of telepresence robot (e.g., being hacked/monitored).

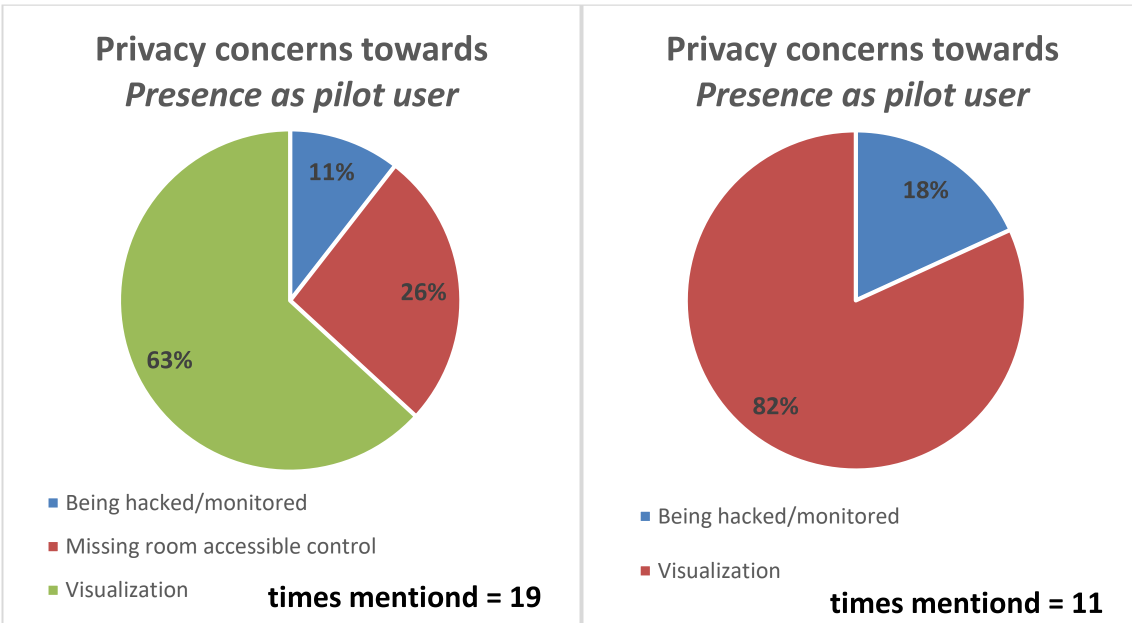


Figure 4.20 Privacy concerns as pilot user

<u>Closing questions.</u>

This section reflected participant's general opinions of *Presence* and *InTouch*. In this section, I first showed participants screenshots of both UIs, then participants were asked to compare their experience on both *Presence* and *InTouch*. Most older adults preferred *InTouch* (97%) over *Presence* (0%), while 3% had no preference on either UI (Figure 4.23). One participant stated, "I prefer *InTouch* better, because it was easier to find what I want.” Another older adult indicated that “I like InTouch better because it doesn’t have the thing (menu bar) on the way”. To further discuss what factors influenced older adults’ preferences, participants were encouraged to explain why *InTouch* was preferred over *Presence (*Figure 4.24*)*. Most participants perceived *InTouch* to be easier to use over *Presence (*Figure 4.25*)*. Additional features of *InTouch* were identified (68%, Figure 4.28) as why *InTouch* was easier to use compare to *Presence* (such as privacy features). Clearer menu was another major factor (32%, Figure 4.28) that increased the ease of use of *InTouch*. Compared with *InTouch* (Figure 4.27), the *Presence* (Figure 4.26) menu bar was located in the middle of the screen, between the front camera view and path view. Participants prefer the menu location of *InTouch* over *Presence* as one stated “I like that the icons are at the bottom. I felt like they were blocking my view here (in *Presence*)…”

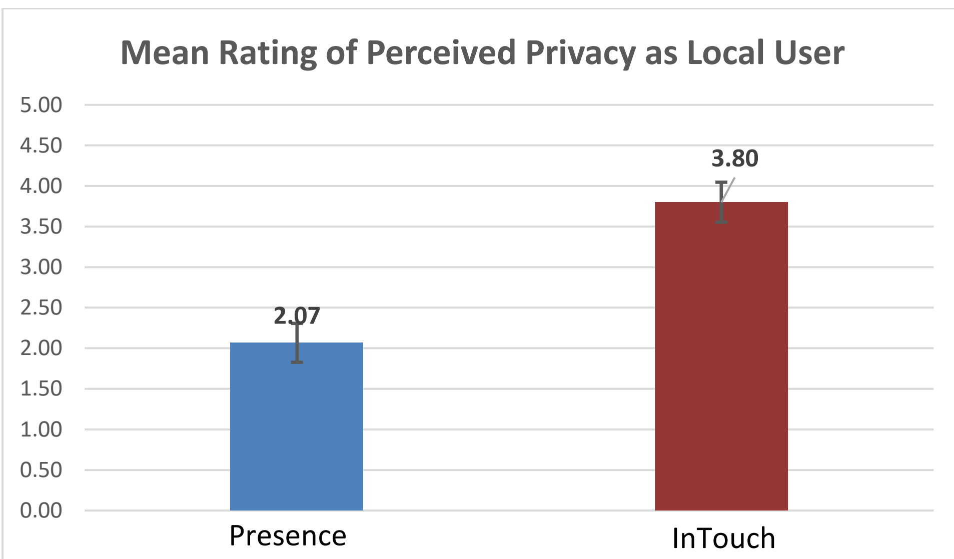


Figure 4.21 Mean rating of perceived privacy: local user

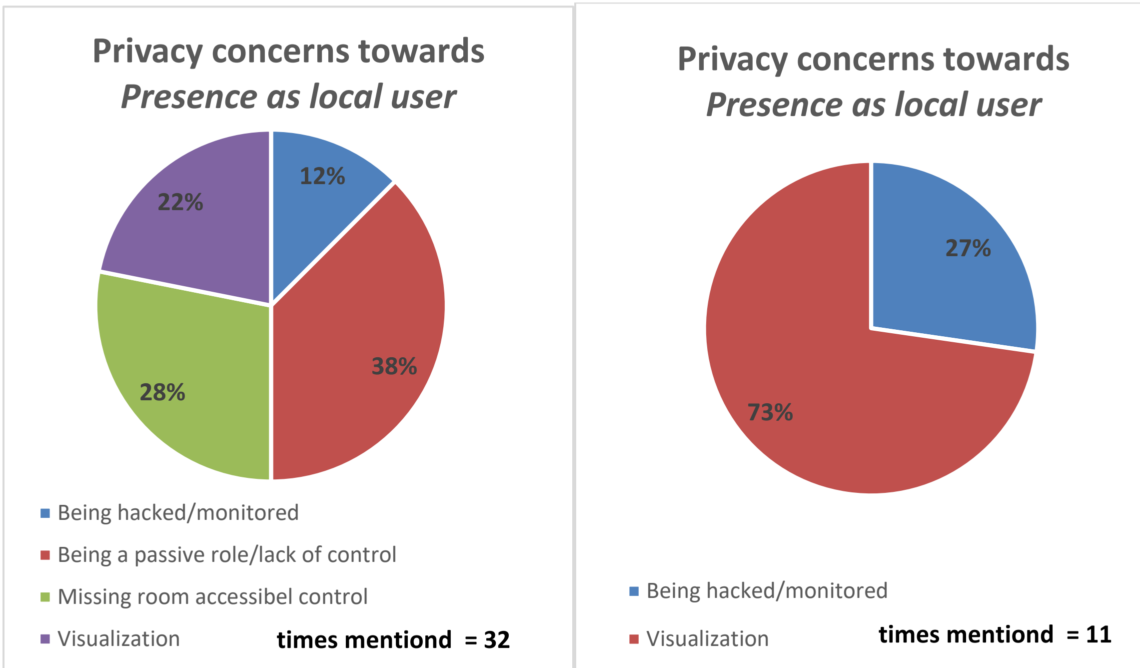


Figure 4.22 Privacy concerns as local user

Participant's perceived privacy level was also compared within both UIs. Most older adults (90%, Figure 4.29) considered *InTouch* have more privacy enhanced features, with room accessible control (89%) and camera activation before call (11%).

Lastly, 97% of older adults (Figure 4.31) in this study would choose *InTouch* over *Presence* for their house due to the additional features (45%), enhanced privacy level (37%), enhanced ease of use (10%) and enhanced safety (8%, Figure 4.32).

4.3 Driving Performance

Under each condition, Unity output a pair of robot location coordinates every 10 frames. Within each testing, the number of pairs of coordinates that were not within the ideal driving path range divided by total amount of coordinates is the error rate of that participant's driving performance.

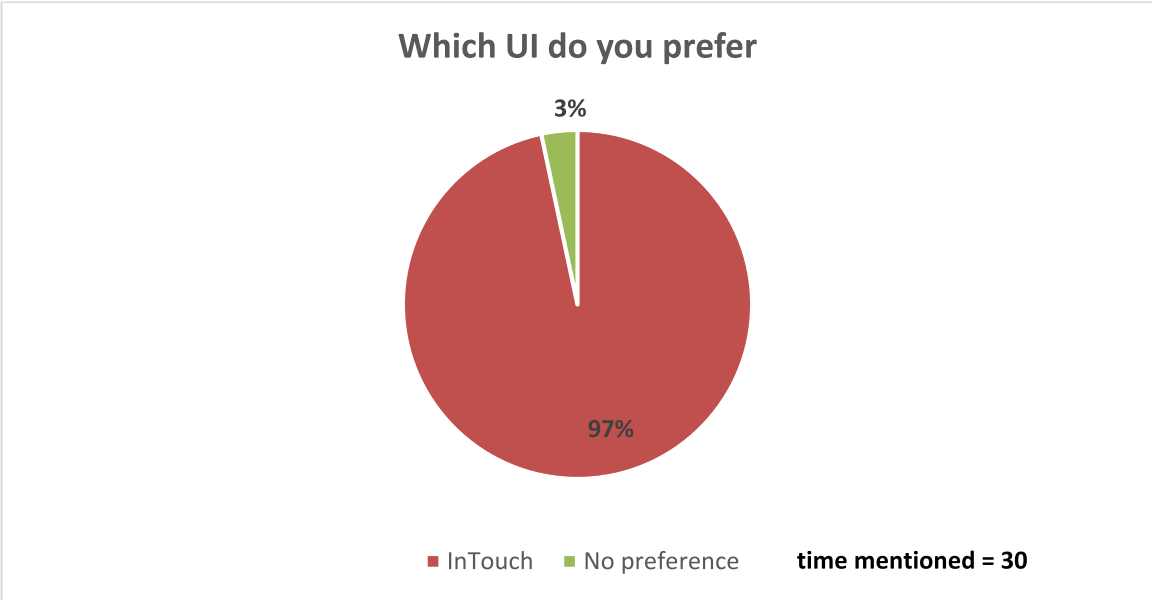


Figure 4.23 Preference on *Presence* and *InTouch*

A paired samples t-test was conducted to compare performance data between the two conditions. Participants performed significantly better (i.e., more accurate) ($t(29) = 3.30$, $p<.01$) in the *InTouch* (M = 0.13; SD = .09) condition compared to the *Presence* condition (M = 0.22; SD = .11). Participants deviated, on average, from the path only 13% of the time during the *InTouch* testing, compared to 22% in the *Presence* condition. Therefore, while participants performed well in both conditions, the *InTouch* UI yielded statistically significant more accurate navigation.

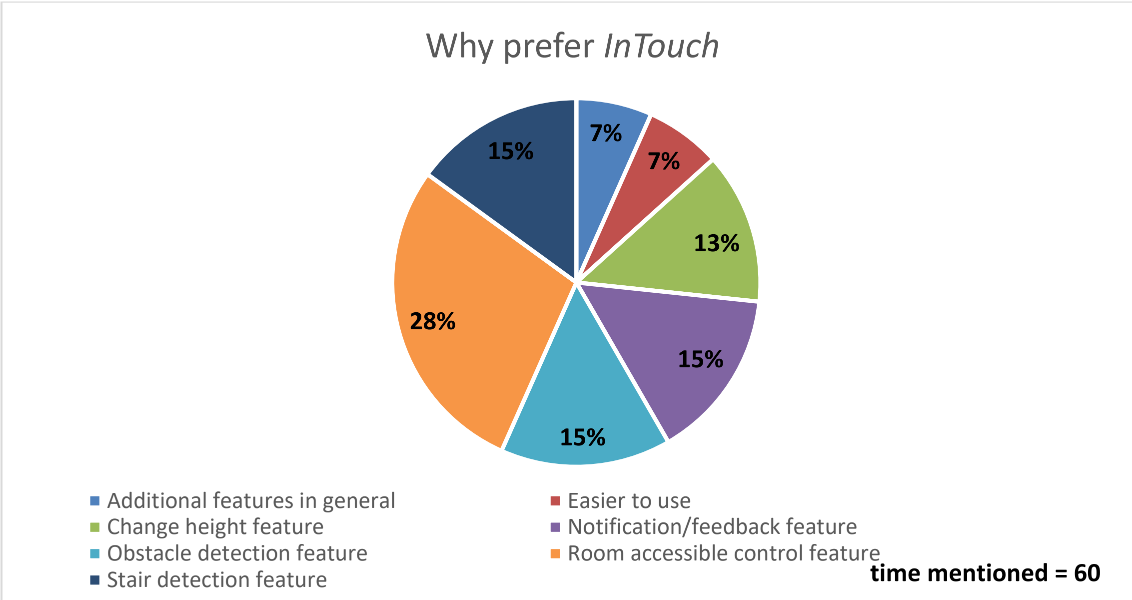


Figure 4.24 Why prefer InTouch

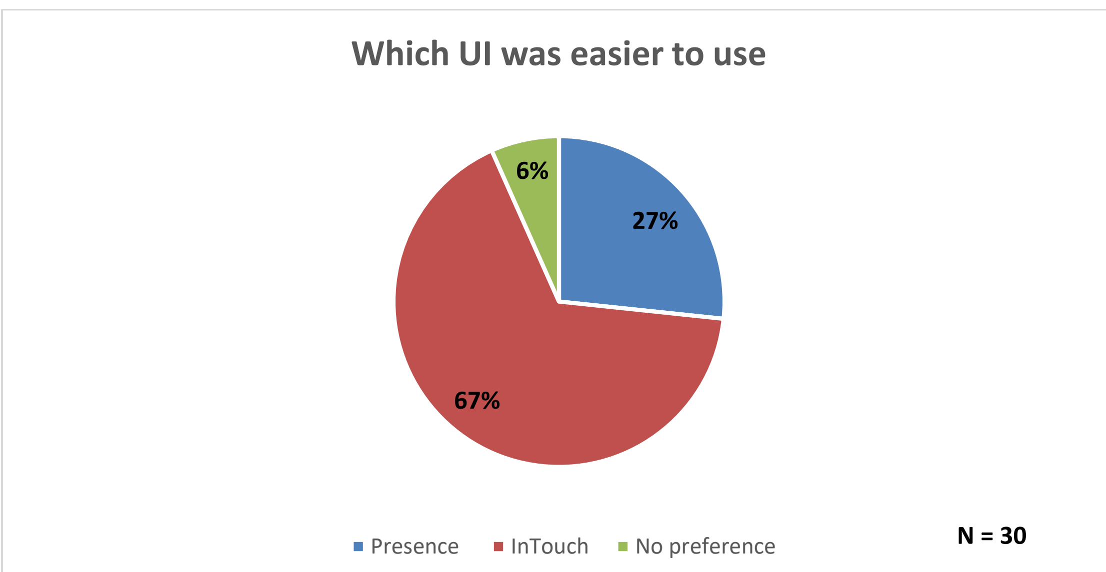


Figure 4.25 Perceived easier to use

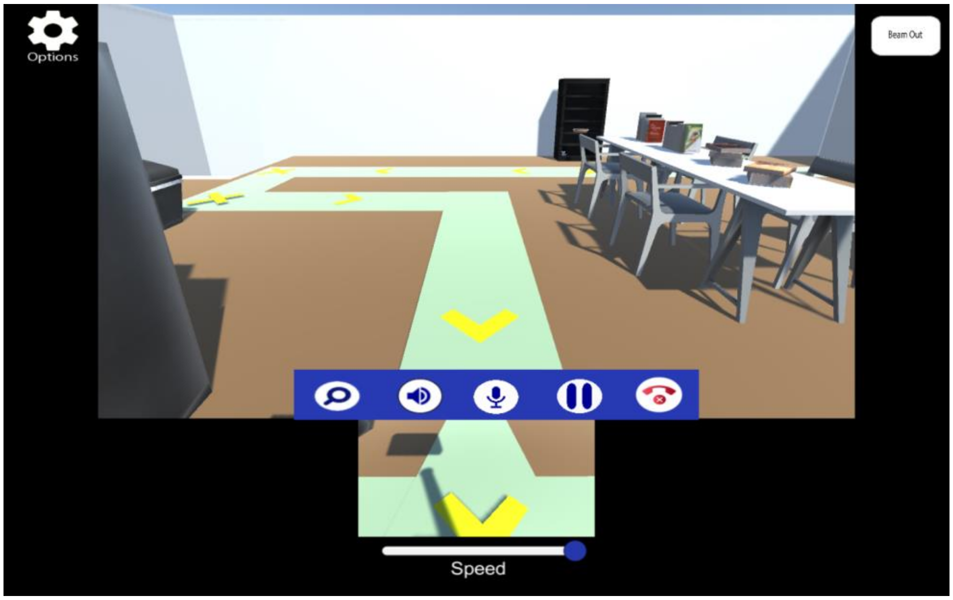


Figure 4.26 Screenshot of *Presence* UI

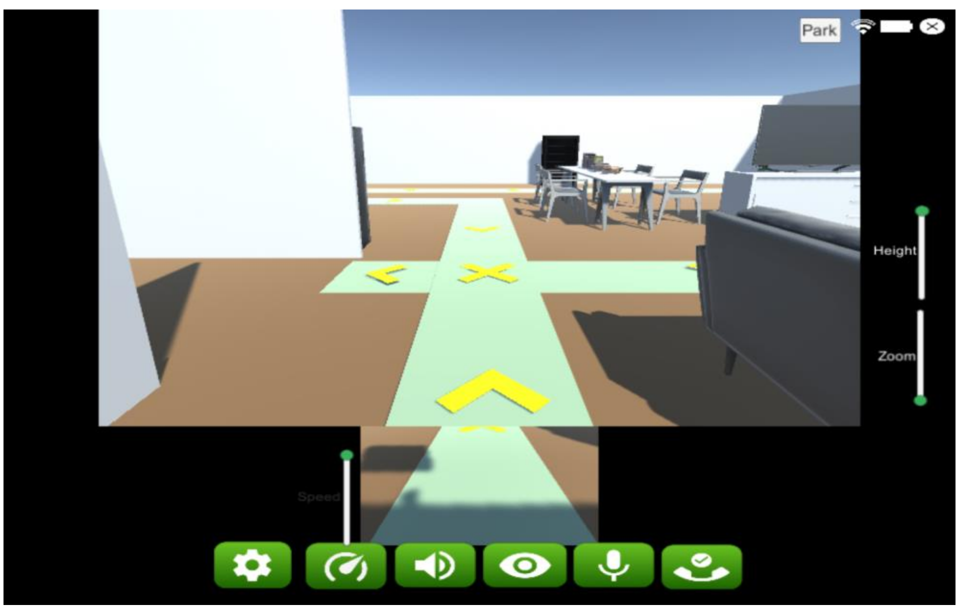


Figure 4.27 Screenshot of *InTouch* UI

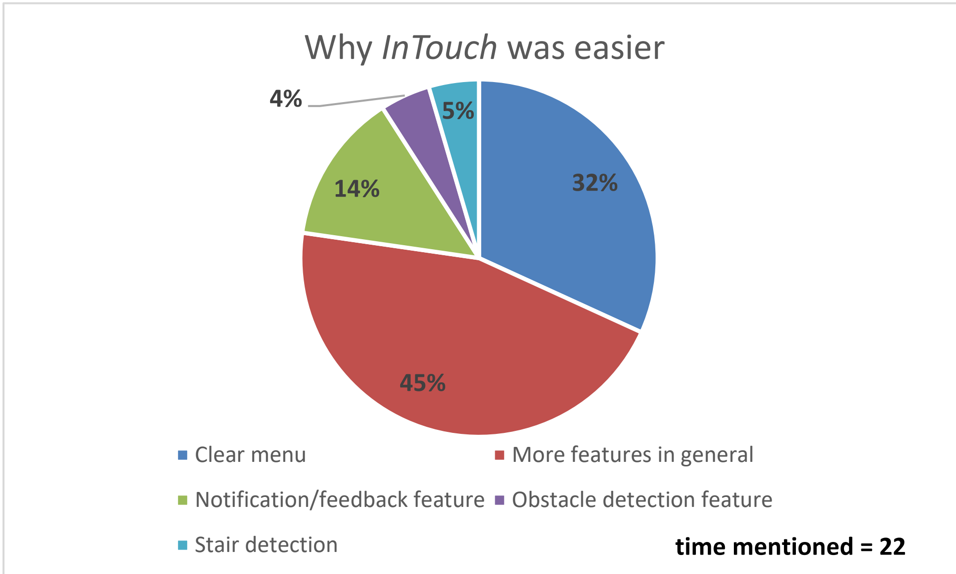


Figure 4.28 Why InTouch was easier to use

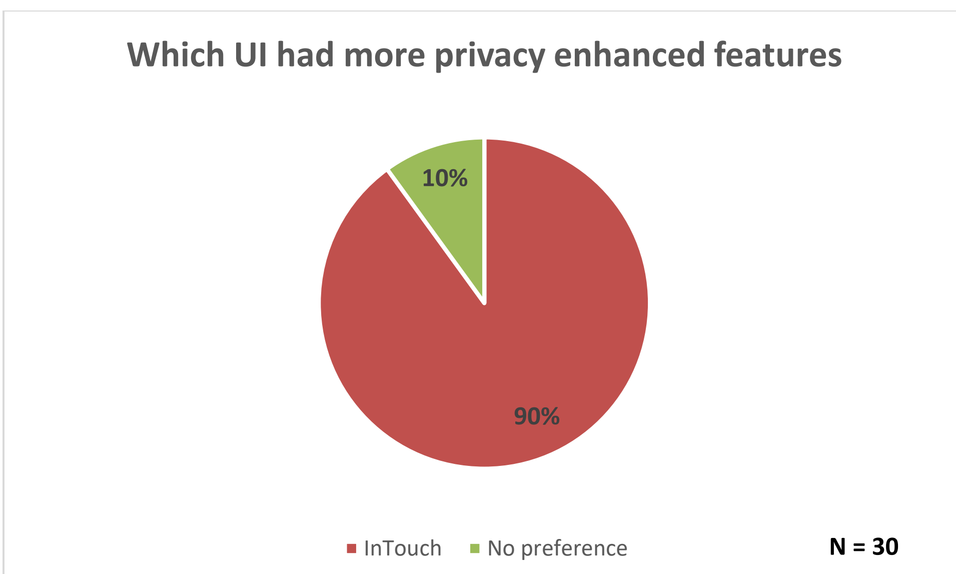


Figure 4.29 Perceived privacy enhanced features

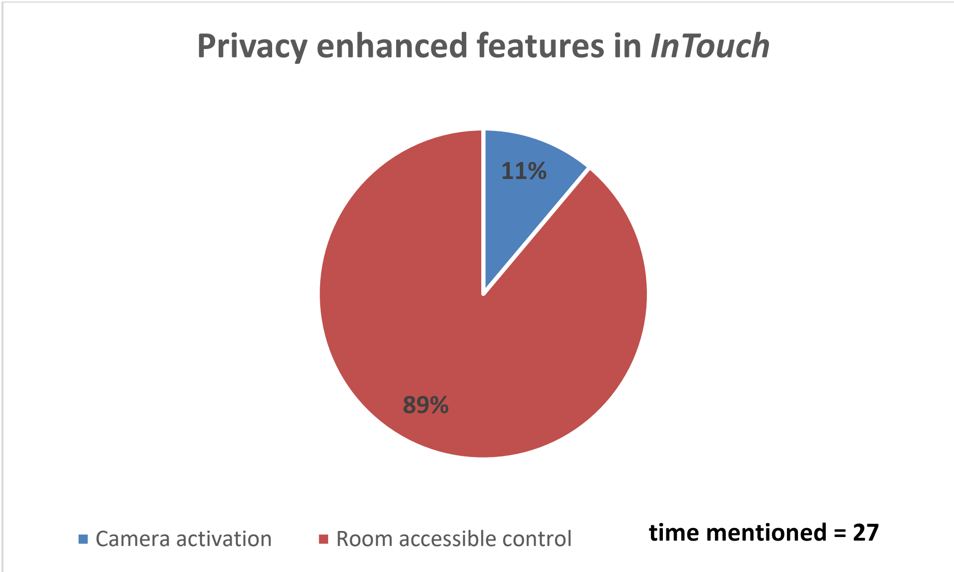


Figure 4.30 Perceived privacy enhanced features in *InTouch*

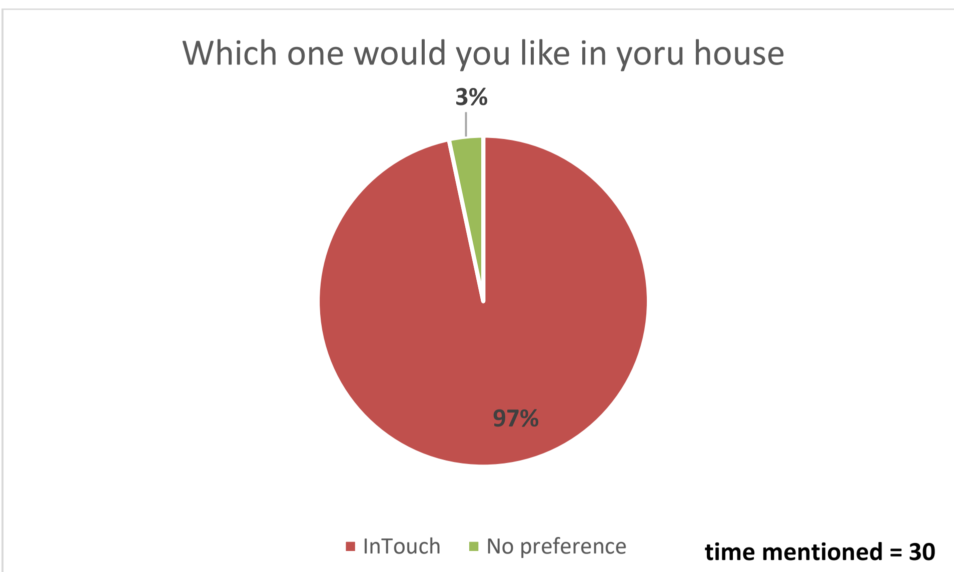


Figure 4.31 Responses to which system to choose in their house

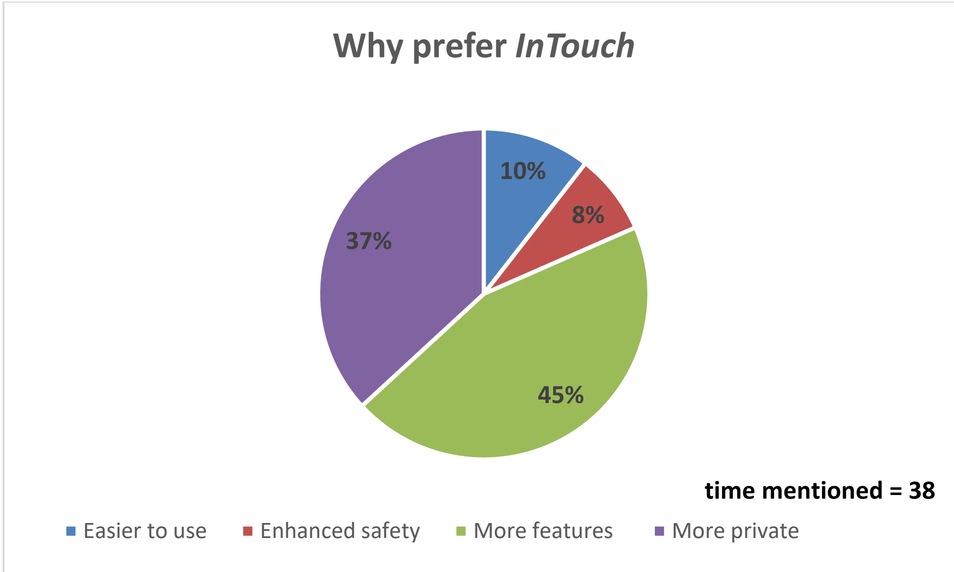


Figure 4.32 Why prefer *InTouch* in their house

CHAPTER 5

GENERAL DISCUSSIONS

5.1 SUMMARY OF FINDINGS

As the older population is rapidly growing worldwide [1], technology that allows this group to sustain wellness and health while aging-in-place independently is greatly needed [13]. Telepresence technology holds great potential to help the aging population stay socially connected. Previous studies indicate that the aging population overall held positive attitudes towards telepresence technology [16, 17, 18, 19, 21] and expressed their willingness to use this technology to contact family, friends, caregivers [16, 21] as well as attending community event (e.g., visiting church) [21, 47]. However, usability issues and privacy concerns were identified [16, 20, 21, 24, 47] as barriers that could potentially prevent older adults from adopting telepresence technology.

This study was proposed to address the identified usability and privacy issues by designing and developing a more usable and private telepresence UI, *InTouch*. To evaluate older adult's attitudes towards *InTouch*, a user study was conducted with 30 aging adults. The study results can be categorized into 3 parts: questionnaire results, interview results and driving performance.

A SUS questionnaire was administered to measure the usability of the *Presence* and *InTouch* interfaces. *InTouch* held a significantly higher SUS score (M = 82.02, SD=12.21)

Compared to the Presence condition (M = 76.33, SD = 14.79). However, the higher SUS rating of *InTouch* suggests that participants perceived *InTouch* to be more usable than *Presence*.

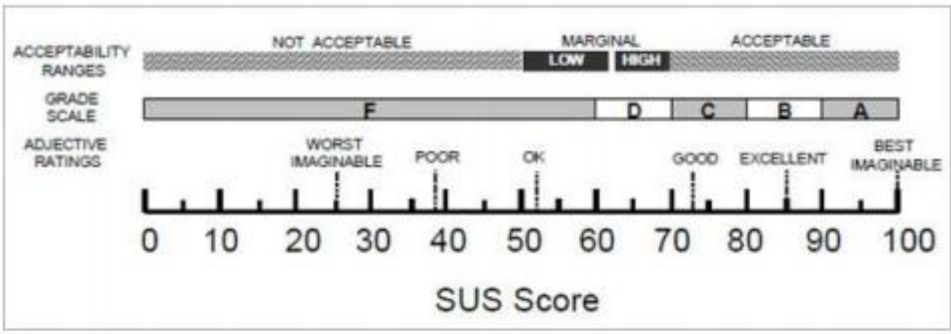


Figure 5.1 Grade ranking of SUS scores [72]

TAM and STAM were used to investigate older adults' acceptance, attitudes and usage behavior towards both UIs. The results show that there was no significant difference in perceived usefulness between the two UIs. This was not surprising since previous work [21, 24] shows that participants find telepresence useful overall. As for ease of use, the *InTouch* condition yielded a marginal, yet statistically significant, difference over *Presence*. Specifically, *InTouch* received higher scores on four out of six items related to ease of use.

To investigate mental work load of each UI, the NASA-TLX was administered after each participant tested each UI. Both UIs received relatively low scores, indicating neither UI required a high work load.

Results from the Telepresence Features Questionnaire show older adults' positive attitudes towards the additional features in the *InTouch* condition. Particularly, participants perceived 'obstacle detection', 'stair detection' and 'room accessible' control as very important features.

To analyze the interview data, all thirty recoded audios were transcribed verbatim with participants' personal information omitted. Transcripts were segmented based on the interview structure. Two raters individually coded three randomly selected transcripts. After reaching 85% agreement [70], the primary rater coded the rest of transcripts.

Similar to previous studies [16, 21, 24], findings from the interview indicate participants overall held a positive reaction towards telepresence technology and they would use such technology to contact family, friends, caregivers or colleagues. However, older adults' first impression of each UI was noticeably different between two conditions: 90% of the participants held positive impressions towards *InTouch* while only 63% commented on *Presence* positively.

Although questionnaire data shows participants' perceived usefulness of both UIs was similar, interview data suggests otherwise with 80% of the older adults finding *InTouch* to be useful and only 54% holding the same opinion towards *Presence*. For people who found neither *Presence* nor *InTouch* to be useful, the most reported reason was that telepresence does not suit their current life style or living environment (*Presence*: 33%, *InTouch*: 20%), though they can imagine themselves using this technology later. The second most mentioned reason for not perceiving *Presence* to be useful was missing features (20%) such as ‘obstacle detection’, ‘notifications’ and ‘room accessible controls’ (these participants tested *InTouch* prior to *Presence*).

Both UIs were perceived as easy to use (1 = not easy at all, 5 = very easy; *Presence* *M* = 4.20, *SD* = .89, *InTouch M* = 4.47, *SD* = .57), particularly regarding the easy controlling and driving of the robot in the simulation (*Presence* 72.22%, *InTouch* 63.89%). For people who identified menu and icons in *Presence* as easy to use (22.22%), their main argument was *Presence* had less features, and thus less icons for them to choose from. In the *InTouch* condition, ‘menu/icons’ was the second most commented (22.22%) reason for the ease of use, particularly how the (*InTouch*) menu bar was located at the bottom of the screen. The third factor that most facilitated ease of use of *InTouch* was ‘additional features’ (13.89%). This again verified older adults’ positive attitudes toward the additional features included in *InTouch*. Regarding what was hard to use in each UI, lack of familiarity with the driving environment and the laptop used in the study was identified under both conditions (*Presence* 50%, *InTouch* 40%). The second most mentioned was ‘unintuitive icons’, specifically the icon for the zoom feature (Figure 5.1). Participants reported that this icon means search not zoom. This finding was similar to a previous study [47]. The zoom feature in *InTouch* was redesigned as in Figure 5.2. However, 60% of the comments mentioned that the redesign was still hard to use.

Perceived privacy was discussed from the perspective of both the pilot and local user. Older adults perceived acting as the pilot user to be private (1 = not private at all, 5 = very private; *Presence M* = 3.83, *SD* = 1.51, *InTouch M* = 4.50, *SD* = .94). When asked to consider themselves as the local user, participants held a higher perceived privacy rating in the *InTouch* condition (*M* = 3.80, *SD* = 1.35) compared to *Presence (M* = 2.07, *SD* =

1.31*)*. ‘Room accessible control’ in *InTouch* was identified as a feature to enhance privacy for both the local and pilot user. Overall, participants preferred *InTouch* over *Presence* and perceived *InTouch* to be easier and more private.

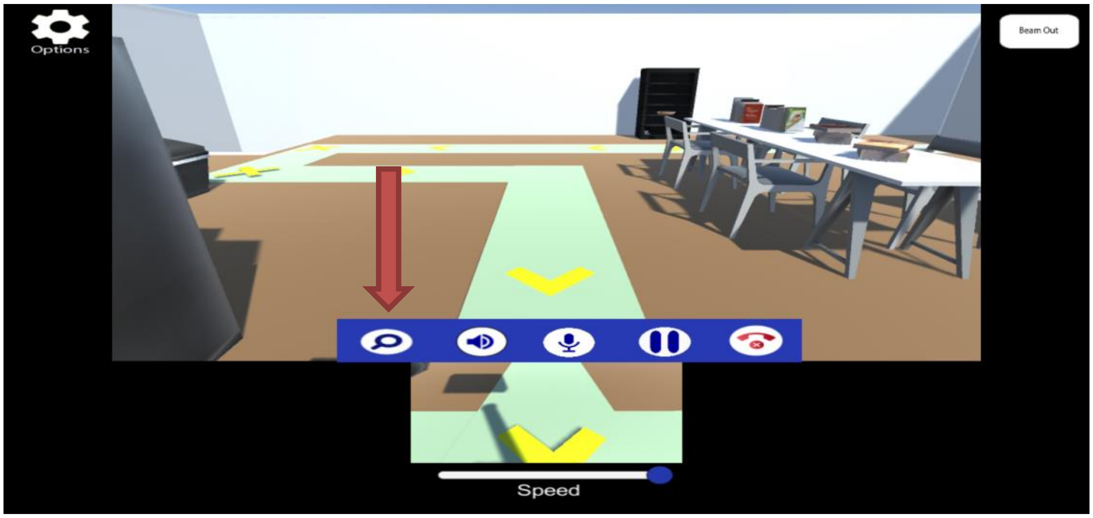


Figure 5.2 Zoom feature in *Presence*

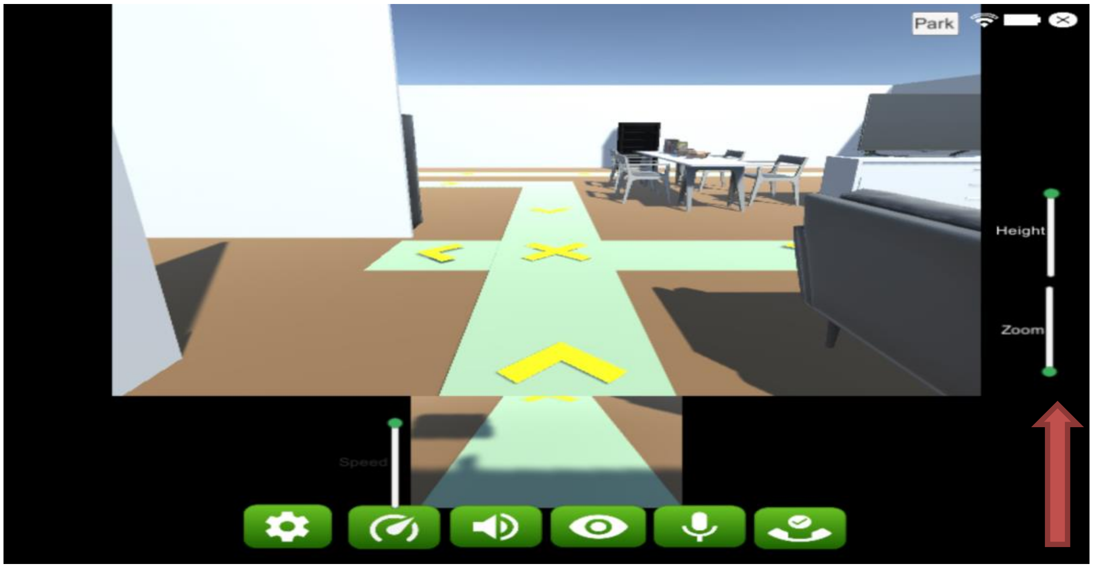


Figure 5.3 Zoom feature in *InTouch*

Driving performance in each UI was determined by the deviation from the ideal path. Participants performed significantly better ($t(29) = 3.30$, $p<.01$) in the *InTouch* (M = 0.13; SD = .09) condition compared to the *Presence* condition (M = 0.22; SD = .11). While participants performed well in both conditions, the *InTouch* UI yielded a statistically significant improvement in navigation accuracy.

5.2 DISCUSSIONS

In this study, I investigated the usability and privacy of telepresence for older adults and addressed the following research questions:

RQ1: What are the essential usability and privacy-enhanced features needed to inform the design and development of a new telepresence UI for the aging population?

Findings from this study provided design suggestions that can enhance the usability and privacy levels of telepresence for the aging population. First, older adults were more likely to have positive attitudes toward a system that provides more autonomous features (e.g. stair detection or obstacle detection), for ensuring safety. In addition, autonomous features can facilitate the driving experience to be more accurate. Older adults held positive attitudes towards using the arrow keys to navigate, as the they claimed "driving around was easy". This study also verified that for older adults, designing intuitive and self-explanatory icons is a crucial factor that may influence a user's usefulness and ease of use perceptions of telepresence. For instance, under the *Presence* condition, multiple older adults specified their negative opinion of the Zoom feature in the *Presence* UI (Figure 5.1); as one participant stated "it's a search icon to me. That means looking for something, not zoom.”. In addition, older adults also held a higher preference for placing the menu bar at the bottom of the interface, since placement of the menu bar can affect the visual cluster level of the interface. Lastly, proper feedback and notification can inform users about the status of the system. Table 5.1 lists design suggestions for usability.

The zoom feature in *InTouch* was identified as difficult due to the location of the icon. The placement of the zoom feature violates Gestalt Principles – “We tend to see things that are close together or look, sound, or feel the same as belonging together.” [75] Future refinements should include a redesign the zoom icon and group it with the rest of icons. Contrary to expectations, users did not identify ‘show password feature’ as useful. One participant commented, “I use password manager now, I don’t need to see it.”

Table 5.1 Recommended design features that enhances usability

Usability	Autonomous features	*Auto park*
		Obstacle detection
		Obstacle avoidance
		Stair detection
	Controlling method	*Arrow keys*
	Icons	*Intuitive*
	Menu	*Place at the bottom instead of in the middle*
	Notification/feedbacks	*Provide notification and feedbacks*

‘Privacy concern’ was the other most commented upon concern regarding telepresence technology [16, 21, 47] and can potentially prevent older adults from adopting such technologies [36, 37]. Although in this study participants primarily focused on experiencing each UI as a pilot user, the results of the study provide privacy recommendations (Table 5.2) for both the pilot and local user. 'Lack of control' was a primary theme when participants discussed their perceived privacy level during the testing sessions. One participant indicated that they did not feel the local user was private at all due to "…it wasn't even an option…There was no option for privacy, I don't have any control over [it]". For local users, being able to accept and decline a call is a crucial feature for them in order to accept telepresence.

Another identified feature that enhanced privacy for both the pilot and local user was 'room accessible control': a local user can pre-determine areas that cannot be visited unless the pilot user logs in as an administrator. This feature can 1) restrain access of private areas (e.g. a bedroom or bathroom) 2) grant access to people that are considered administrators. This feature was also identified as important when acting as a pilot user (i.e. when the older adults would drive the telepresence in another person's home). One participant said "I might see whatever I don't want to see. Unintentionally. My daughter has a very messy house." Another feature participants mentioned was to show a caller ID for the local user before each incoming call. This feature allows users to decide whether to accept or decline. Camera activation was also reported as an important feature. One participant commented "I would want to make sure my hair is combed before a call".

Table 5.2 Features that enhance privacy level

Privacy	Provide users more controls	*Accept/decline a call*
		Room accessible control
	Camera activation before call	
	Show caller ID/image	

RQ2: Is the new telepresence UI perceived as more usable and private by older users compared to traditional telepresence UI design?

The second question addressed by this research was if *InTouch* was perceived as more usable and private by aging adults. Questionnaire items from SUS, TAM and STAM indicated that overall both UIs were easy and enjoyable to use. However, *InTouch* yielded higher ease of use scores, confirming that the new UI was perceived to be more usable. In addition, the qualitative data of this study suggest that during the interview participants would make comparisons between the two UIs, and the data indicate that *InTouch* was perceived as more useful, easier to use and more private than *Presence*.

In this study, both qualitative and quantitative data suggest older adults perceived *InTouch* to be more useful and easier to use. According to the TAM [73, figure 5.3], PU and PEU are the two variables which predict a user's behavioral intention, which in turn predict the future usage of technology.

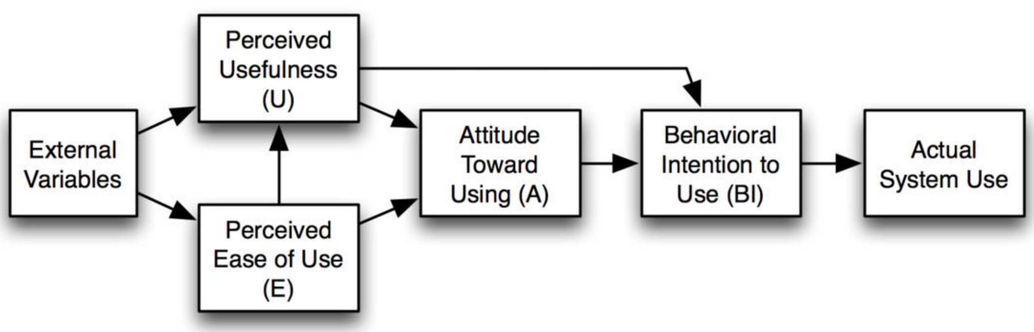


Figure 5.4 Technology Acceptance Model [73]

While the original TAM does not include privacy as one variable that might affect users' attitude toward using, this study indicates that the older adults preferred *InTouch* over *Presence* also due to the privacy-enhanced feature in *InTouch*. Although currently there is no study add privacy as a variable to TAM to assess Telepresence technology, one study has investigated an augmented TAM that includes privacy as well as some other variables such as security and compatibility [78] to measure people's attitudes toward online shopping. In that study privacy was found not to be significant predictor of attitude towards online shopping. In the future, similar approach could be taken to assess the acceptance of Telepresence by adding privacy related items.

5.3 SCOPE, LIMITATIONS AND FUTRUE DIRECTIONS

While this study advances our knowledge of the usability and privacy features of telepresence technology for the aging population, it is critical to recognize the scope, limitations and future directions of this area of research.

For this study I had hoped to recruit an equal number of participants within two gender groups; however, due to the size and geography of the cities where the study was conducted, I was only able to recruit 9 males (30%, N = 30). Second, participants' reported highest education level and their household income were not representative of the general population. A study with a larger sample size, and a sample with a range of socioeconomic and gender demographics should be conducted in the future to investigate whether the perceived usefulness, ease of use and privacy level of this technology will change with the demographic background of the participants'.

In this study, only one participant used walking-aid occasionally, overall the older adults were satisfied with their current health condition and did not have impairments nor disabilities. Many older adults experience sensory, cognitive, and physical challenges that may negatively affect their everyday activities. In addition, some individuals are aging with lifelong impairments (e.g., visual, auditory, mobility). These older adults are often referred to as "aging with a disability;" According to the U.S. Census Bureau, among older adults 15.7 million have reported having one or more disability, which comprised 38.7% of older population [76]. Future design of Telepresence robots should also include features that are usable for people with disabilities. "Getting on my way" was a concern revealed by wheelchair users, due to the size of the robot [47]. Thus, a more compact, home-environment friendly Telepresence robot might suit this population better. Another design suggestion provided by wheelchair users is using a joystick to control the robot [47]. Voice control is another suggestion provided by older adults [47]. As audio technology has reached a stage of maturity [77], investigating voice control technology on Telepresence can potentially improve the usability of this technology. Design recommendations are listed in table 5.3.

The next major step is to integrate *InTouch* to an actual telepresence robot. This study was conducted in a simulated virtual environment to ensure each participant experienced the same driving environment. It is critical to conduct similar user testing study but utilize real robots, as the interaction with a robot is drastically different from operating in a simulation.

Table 5.3 Telepresence Design recommendations for people with disabilities

Compatible size
Joystick
Voice control

In this study, each participant only had two hours to test both UIs, it is critical to conduct user study for a longer time period. Some participants mentioned "I am not sure I will use it after novelty runs off". One study placed 3 Telepresence robots in 3 users' homes for 12-18 months [78]. Over all the older adults yielded positive feedback on the tested robot. However, usability and privacy concerns were again, revealed in this long-term study. For example, the size of the tested robot was considered inconvenience for small and clustered houses. In addition, as local user, unable to know caller's identity was identified as a privacy concern [78].

Participants in this study also mentioned they would want to use Telepresence to check on their parents. One said, "My mother lives alone and if I have one of this [Telepresence], I could see if she's doing alright." In this study older adults tested both UIs as the pilot user, the next step is to investigate this technology for older adults as local users. Previous studies indicated that Telepresence could be beneficial for healthcare providers [21,47]. Previous study shows [78], comparing with a stationary camera, older adults performed less privacy enhancing behaviors under the mobile robot condition. However, that study was conducted in a lab setting with an imaginary scenario. It is important, in the next step to investigate target population's perceived privacy towards Telepresence when using such technology as a home monitoring device.

As mentioned previously, overall participants held a positive reaction to telepresence technology and the two UIs; they also perceived this technology to be useful. However, since each study was only 2 hours long it remains unknown whether this population will really adopt this technology after the novelty wears off. An ideal study in the future would require that participants have robots in their house over a period of time. In addition to the limited interaction time, all sessions were in a controlled environment in this study. However, a real life environment is more dynamic and complex. Thus, investigating telepresence usage in a home environment over a longer period of time is needed.

The findings from this study provide insight on what usability and privacy features are critical for the aging population to use this technology. The data suggest that for designing a usable and private UI for this population, we do not have to redesign the whole technology; instead small modifications can improve user attitudes towards the technology. While more research is needed, this study was the first to investigate the usability and perceived privacy of a telepresence UI specifically designed for older adults, compared to the industry standard. This study also utilized a simulated environment to test the UI in a controlled environment.

As telepresence technology design continues to develop, in the near future people will be able to use telepresence robots to regularly visit places and people. In [74], researchers stated that "more accessible designs are also usually easier to use by everyone all the time." By investigating the design of telepresence robots for older users, and applying those findings to design recommendations, I aim to improve the ease of use and privacy level of telepresence robots – not only for our target users, but for all users who wish to enhance their social connectedness.

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APPENDIX A – DEMOGRAPHIC AND HEALTH QUESTIONNAIRE

1. Gender: ☐1 Male ☐2 Female

2. What is your date of birth? ________________________ (mm/dd/yyyy)

3. Are you fluent in English? ☐1 Yes ☐2 No

4. What is your preferred language for communicating?

   ☐1 English

   ☐2 Spanish

   ☐3 American Sign Language

   ☐4 Other (please list)__________________

5. What is your highest level of education?

   ☐1 No formal education

   ☐2 Less than high school graduate

   ☐3 High school graduate/GED

   ☐4 Vocational training

   ☐5 Some or in-progress college/Associate's degree

   ☐6 Bachelor's degree (BA, BS)

   ☐7 Master's degree (or other post-graduate training)

   ☐8 Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)

☐9 Do not wish to answer

6. Current marital status (Check **one**)

☐1 Single

☐2 Married

☐3 Separated

☐4 Divorced

☐5 Widowed

☐6 Other (please specify) _________________

☐7 Do not wish to answer

7. Do you consider yourself Hispanic or Latino?

☐1 Yes ☐2 No ☐3 Do not wish to answer

8. How would you describe your primary racial group?

☐1 American Indian/Alaska Native

☐2 Asian

☐3 Native Hawaiian or Other Pacific Islander

☐4 Black or African American

☐5 White

☐6 More than one race

☐7 Other (please specify) ______________________

☐8 Do not wish to answer

9. In which type of housing do you live?

☐1 Single family home

☐2 Apartment or Condominium

☐3 Assisted living residence

☐4 Nursing home residence

☐5 Other (please specify) ________________

☐6 Do not wish to answer

10. Is your housing or community specifically designed for seniors (i.e., 55 and older)?

☐1 Yes ☐2 No ☐3 Not sure

11. What is your primary mode of transportation? (Check **one**)

☐1 Drive myself

☐2 A friend or family member drives me

☐3 Walk

☐4 Bicycle

☐5 Taxi

☐6 Use transportation service provided by my residence

☐7 Use public transportation (e.g., bus, subway, van services)

☐8 Other (please specify) _________________

12. Which category best describes your yearly household income? Do not give the dollar amount, just check the category.

☐1 Less than $25,000

☐2 $25,000 - $49,999

☐3 $50,000 - $74,999

☐4 $75,000 or more

☐5 Do not wish to answer

☐6 Do not know for certain

Occupational Status

13. What is your primary occupational status? (Check **one**)

☐1 Employed full-time Occupation_____________

☐2 Employed part-time Occupation_____________

☐3 Student

☐4 Homemaker

☐5 Retired Former occupatiom ______________ Year retired__________

☐6 On maternity leave, on sick leave, or disabled

☐7 Unemployed or temporarily laid off

☐8 Other (please specify) ____

14. Are you currently receiving disability benefits (e.g., SSI, SSDI)?

☐1 Yes

☐2 No

Health Information

1. How satisfied are you with your present health?

☐1	☐2	☐3	☐4	☐5
Not at all satisfied	Not very nor dissatisfied	Neither satisfied satisfied	Somewhat satisfied	Extremely satisfied

2. How often do health problems stand in the way of your doing the things you want to do?

☐1	☐2	☐3	☐4	☐5
Never	Seldom	Sometimes	Often	Always

3. How many different **prescription medications** do you take each day?

____

4. How many different **over-the-counter medications/supplements** do you take each day?

____

5. Please indicate if you have ever been told by a health professional that you have any of the following conditions. Check **one** box for each condition.

Condition	Yes1	No2	Do not wish to answer/ Not sure3
a. Alzheimer's Disease			
b. Arthritis			
c. Asthma			
d. Cancer			
e. Cardiac Atrial Fibrillation/ Cardiac Arrhythmia			
f. Chronic Kidney Disease			
g. Chronic Obstructive Pulmonary Disease (COPD)			
h. Coronary Artery Disease/ Coronary Heart Disease			
i. Depression			
j. Diabetes/High Blood Sugar			
k. Heart Failure/ Congestive Heart Failure			

l. High Blood Pressure/Hypertension			
m. High Cholesterol/Hyperlipidemia			
n. Osteoporosis			
o. Overweight			
p. Stroke/Transient Ischemic Attack			
q. Other? (If yes, please list below) ____________________________ ____________________________			

Vision/Hearing/Motor Capabilities

Please describe your vision, in general, by answering the following questions.

1. Do you wear glasses or contacts to help you see things at a distance?

☐1 Yes ☐2 No

2. Do you have difficulty seeing, even when wearing glasses or contact lenses?

☐1 Yes ☐2 No

3. Do you NOW use any of the following supportive aids? (Check **all** that apply)

☐1 Audio description

☐2 Braille

☐3 Computer equipment (scanners, OCR, etc.)

☐4 GPS wayfinding device

☐5 Guide dog

☐6 Reader service

☐7 Reading magnifier

☐8 Screen reader

☐9 Telescopic lenses

☐10 White cane

☐11 Other, please specify: ______________________

☐12 Do not use any

Please describe your hearing, in general, by answering the following questions.

4. In the last month, have you used a hearing aid or other hearing device?

☐1 Yes ☐2 No

5. a. Do you have difficulty hearing, <u>even when using</u> a hearing aid or other hearing device?

☐1 Yes ☐2 No

6. Can you hear well enough to use the telephone, <u>with/without</u> wearing a hearing aid?

☐1 Yes ☐2 No

7. Can you hear well enough to carry on a spoken conversation in a quiet room, <u>with/without</u> wearing a hearing aid?

☐1 Yes ☐2 No

8. Do you NOW use any of the following supportive aids? (Check **<u>all</u>** that apply)

☐1 Assistive listening devices (e.g., personal headphones)

☐2 Assistive signaling devices (e.g., doorbell flashing light)

☐3 Closed caption television

☐4 Cochlear implant

☐5 Hearing aid

☐6 Interpreter services (e.g., sign language)

☐7 TDD, TTY, or Teletype

☐8 Telephone amplifier

☐9 Videophone

☐10 Other, please specify ____________

☐11 Do not use any

Please describe your <u>physical mobility and strength,</u> in general, by answering the following questions.

9. Are you able to walk independently <u>without</u> using a walking aid (e.g., cane, walker, crutches)?

☐1 Yes ☐2 No

10. Do you have difficulty lifting something as heavy as ten pounds, such as a full bag of groceries?

☐1 Yes ☐2 No

11. a. Do you have difficulty using your hands (e.g., writing, typing, using sign language)?

☐1 Yes ☐2 No

12. Do you NOW use any of the following lower body supportive aids? (Check **<u>all</u>** that apply)

☐1 Cane

☐2 Crutches

☐3 Power/Electric wheelchair

☐4 Grab bars

☐5 Knee walker

☐6 Lift chair

☐7 Manual wheelchair

☐8 Orthotic device (please specify) _______________

☐9 Prosthetic device (please specify) _______________

☐10 Scooter

☐11 Walker

☐12 Other (please specify) _______________

☐13 Do not use any

13. Do you NOW use any of the following upper body supportive aids? (Check **all** that apply)

☐1 Grabber/Reacher

☐2 Orthotic device (please specify) _______________

☐3 Prosthesis device (please specify) _______________

☐4 Other (please specify) _______________

☐5 Do not use any

Please place a circle in the response area that best represents your situation (we understand that there may be exceptions)

1. My general health conditions									
Very Poor									Excellent
1	2	3	4	5	6	7	8	9	10
2. How are my health conditions compared with the same-age groups									
1	2	3	4	5	6	7	8	9	10
3. How good is my hearing									
1	2	3	4	5	6	7	8	9	10
4. How well can I see									
1	2	3	4	5	6	7	8	9	10
5. How well am I able to move around									
1	2	3	4	5	6	7	8	9	10
6. How would I rate my memory									
1	2	3	4	5	6	7	8	9	10
7. How satisfied am I with my ability to learn new information									
Strongly Dissatisfied									Strongly Satisfied
1	2	3	4	5	6	7	8	9	10
8. How well am I able to concentrate									

Very Poor									Excellent
1	2	3	4	5	6	7	8	9	10
9. How satisfied am I with my ability to make decisions									
Strongly Dissatisfied									Strongly Satisfied
1	2	3	4	5	6	7	8	9	10
10. How satisfied am I with my personal relationships									
Strongly Dissatisfied									Strongly Satisfied
1	2	3	4	5	6	7	8	9	10
11. How satisfied am I with the support I get from my friends and family									
Strongly Dissatisfied									Strongly Satisfied
1	2	3	4	5	6	7	8	9	10
12. I participate social or community activities									
Not At All									Very Often
1	2	3	4	5	6	7	8	9	10
13. I feel that I get older I am less useful									
Strongly Disagree									Strongly Agree
1	2	3	4	5	6	7	8	9	10
14. How satisfied am I with my quality of life									
Strongly Dissatisfied									Strongly Satisfied

1	2	3	4	5	6	7	8	9	10
15. Ability to use telephone									
Unable to									Able to
1	2	3	4	5	6	7	8	9	10
16. Ability to grocery shopping									
1	2	3	4	5	6	7	8	9	10
17. Ability to prepare food									
1	2	3	4	5	6	7	8	9	10
18. Ability to do housework or handyman work									
1	2	3	4	5	6	7	8	9	10
19. Ability to do laundry									
1	2	3	4	5	6	7	8	9	10
20. Ability to get to places beyond walking distance									
1	2	3	4	5	6	7	8	9	10
21. Ability to take medications									
1	2	3	4	5	6	7	8	9	10

22. Ability to manage money									
1	2	3	4	5	6	7	8	9	10

APPENDIX B – VIDEO CONFERENCE TECHNOLOGY USAGE QUESTIONNAIRE

Check if you've used the following in the last 12 months

- ☐ Adobe Connect
- ☐ Anymeeting
- ☐ Beam
- ☐ Cisco WebEx Meeting Center
- ☐ Citrix GoToMeeting
- ☐ ClickMeeting
- ☐ Double
- ☐ eVoice
- ☐ Facebook Video
- ☐ Facetime
- ☐ Giraffe
- ☐ Google Hangouts
- ☐ Gotomeeting
- ☐ iMeet
- ☐ Imeet
- ☐ InterCall
- ☐ Join.me
- ☐ Kubi
- ☐ Mikogo
- ☐ Onstream Meetings
- ☐ ooVoo
- ☐ Readytalk
- ☐ Skype
- ☐ StartMeeting
- ☐ Tango
- ☐ TeamViewer
- ☐ Vgo
- ☐ Viber
- ☐ Zoom
- ☐ Other: _____

APPENDIX C – PERCEIVED USEFULNESS QUESTIONNAIRE

Please place an X in the response box that best represents your general opinion

1. Using InTouch would enable me to accomplish tasks more quickly.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

2. Using InTouch would improve my performance.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

3. Using InTouch would increase my productivity.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

4. Using InTouch would enhance my effectiveness.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

5. Using InTouch would make my daily life easier.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

6. I would find InTouch useful.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

APPENDIX D– PERCEIVED EASE OF USE QUESTIONNAIRE

Please place an X in the response box that best represents your general opinion

1. Learning to operate InTouch would be easy for me.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

2. I would find it easy to get InTouch to do what I want it to do.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

3**. My interaction with InTouch would be clear and understandable.**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

4. I would find InTouch flexible to interact with.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

5. It would be easy for me to become skillful at using InTouch.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

6. I would find InTouch easy to use.

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Extremely Unlikely	Quite Unlikely	Slightly Unlikely	Neither	Slightly Likely	Quite Likely	Extremely Likely

APPENDIX E – SYSTEM USABILITY SCALE

Instructions: For each of the following statements, mark one box that best describes your reactions to the enhanced UI

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

APPENDIX F – NASA TLX

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

APPENDIX G –PRIVACY ATTITUDES QUESTIONNAIRE

Instructions: For each of the following statements, mark one box that best describes your privacy attitudes. Privacy can be defined as the control over when, how, and to what extend your information is communicated to others.
We would like you to consider your privacy attitudes toward the telepresence robot now and in the future.

1. Consumers will likely lose all control over how personal information is collected and used by telepresence companies

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

2. Most businesses handle the personal information they collect about consumers in a proper and confidential way.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

3. Existing laws and organizational practices provide a reasonable level of protection for consumer privacy today.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

4. I am concerned about online identity theft.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

5. I am concerned about my privacy online.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

6. I am concerned about my privacy in everyday life.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

7. I am likely to read the privacy policy of an ecommerce site before buying anything.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

8. Privacy policies accurately reflect what companies do.

☐	☐	☐	☐	☐
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

APPENDIX H – TELEPRESENCE FEAUTURES QUESTIONNAIRE

Please place an X in the response box that best represents your perceived level of importance of each feature.

1. **Do you find show password feature**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important

2. **Do you find show your view feature**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important

3. **Do you find change height feature**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important

4. **Do you find stairs detection feature**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important

5. **Do you find notification of obstacle detection**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important

6. **Do you find room accessible control feature**

☐1	☐2	☐3	☐4	☐5	☐6	☐7
Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important

APPENDIX I –TELEPRESENCE INTERFACE USABILITY TESTING INTERVIEW SCRIPT

Materials

- Laptop
- Video cameras
- Digital audio recorders (2)
- Extra batteries (AAA's)
- Testing script (3 copies)
- Timer
- Note pads and pens for note taker
- Pens/pencils for participants
- Questionnaires (bring extras)
- New participant database forms (bring extras)
- USB Mouse
- Copy of Usability Testing documents

Key

- Researcher 1
- Researcher 2

Researcher 1
Conducting the interview, help when participant tests the systems.

Researcher 2
Support Researcher 1, give feedback, and help with paperwork;
Review and obtain informed consent and media release form.

Questionnaire Review
Researcher collects questionnaires and reviews for completeness. Any missing questionnaire items can be filled out prior to the introduction. If time does not allow, then complete missing items after study completion.

- *Minimum Battery* (demographics)
- *Video Conference Technology Usage Questionnaire*
- *Privacy Attitudes Questionnaire*

Introduction
Hello. I am Jen I am a Ph.D. student at the University of South Carolina. I will take notes and audio record the session.

I am here because I want to understand your opinions and attitudes about the usability and privacy toward telepresence robots. Telepresence robots can be defined as remotely controlled mobile systems that allows a person to feel or appear to be present in another location. Think of it as "skype on wheels" or "video conferencing on wheels."

Imagine you want to visit a friend who lives in California. This friend has a telepresence robot in their home. You could log into the robot, see and hear your friend through the video, and move around their home as if you were really there. In just a little bit, I will show you a video that demonstrates how these robots work.

Topic and goal

Before I show you the video, let me tell you a little bit about this study. Our goal of this study is to understand your attitudes and opinions toward telepresence robots. Your information will help us develop telepresence robots that are useful, easy to use, and private.

There will be two sessions. You will have the opportunity to test two telepresence robots' designs. These are NOT real robots, rather you will test a simulation of these robots. These two robot simulations are named: Presence and InTouch. After each testing session, I will ask you to answer some questions and fill out some questionnaires. Any questions thus far?

Procedure

Our session will take approximately 2 hours.

There is no rush during the session. There will also be a 5-minute break after we test each telepresence robot. However, if you need to take additional breaks, just let me know.

Are there any questions? Do you need to use the restroom or get water before we get started?

Pre-Use

First, before we begin to test the simulations, let me tell you more about telepresence. I am going to play a video that demonstrates a telepresence robot. I will then ask you some questions about this technology, but please hold any questions until the video is complete.

- Play Beam video demo

What you just saw in the video is one type of telepresence robot. Imagine using this robot to connect with your family or friends, communicate with your supervisor or boss, talk to your therapist or doctor, or use this robot to attend exercise class, church, and so on.

1. What are your first impressions about telepresence robot? (encourage participants to specify Why)
2. Do you think telepresence robot can be useful? Why?
3. Briefly, tell me how might you use telepresence?

When using a telepresence robot, there will be 2 users: the user who remotely controls the robot is called pilot user (show pilot user picture); user who is co-located with the robot is defined as local user (show local user picture). When a user control the robot by selecting or clicking on icons displayed on the computer screen, we refer that controlling platform as the interface of the robot.

I am investigating how a person might operate a telepresence robot. For example, I am interested in understanding how might a person drive it around, or what will the interface look like. In this study, I'm going to show you two different simulations of the interface that a person would use to drive the telepresence robot. You will use each interface, and then I will ask you some questions about your opinions. Any questions? Okay let's get started.

Presence UI User Testing

	Complete Presence UI usability testing for each individual
Now I would like to give you an opportunity to use the Presence UI. There will be a list of tasks I would like you to complete. I will give you your tasks one after another and observe your actions on each task. In this part, there will be **20 tasks**, please read each task carefully and complete it to the best of your ability. If you have major questions on one task and are unable to complete it, I will be here to assist you. Please tell me what's going on through your minds as you do the tasks, in another word, think out loud	*Start video camera* *Start timer* *Hand each task one after another to participant* *Take notes*

Now you've completed all 20 tasks using Presence, now I am going to ask you some questions about your experience driving Presence. To help you remember what the interface looked like, there is a picture of the interface <<hand them a screenshot with the name in large letters at the top>>

Opening questions (ice breaker)

- What was your first impression of Presence?

Perceived usefulness

- Did you find Presence to be useful? On a scale of 1 to 5, with 1 being less useful, and 5 being most useful, how useful do you think Presence is? Why?
- Would Presence help you stay connected with others? Why or why not?
- Can you imagine yourself using Presence? Why?
- Did you enjoy using Presence? Why?

- Assume you have access to Presence, do you think you will use it?

Perceived ease of use

- On a scale of 1 to 5, with 1 being less easy to use, and 5 being most easy to use, how easy to use do you think Presence is? Why?
- What was easy to use in Presence? Why?
    - <<encourage participant to refer to screenshot -- make sure you/participant clearly specifies what design feature they are referring to>>
- What was difficult to use in <name>? Why?
    - <<encourage participant to refer to screenshot -- make sure you/participant clearly specifies what design feature they are referring to>>

Perceived privacy

Next I have some questions about privacy. We define privacy as (Westin, 1967) the control over when, how, and to what extent your information is communicated to others. I'm going to ask you questions about privacy using two scenarios. The first scenario, imagine you are the pilot user, and the robot located in someone else's house. Imagine you are visiting a family or friend in their home by remotely control the robot in their environment

- on a scale of 1 to 5, with 1 being less private, and 5 being most private, how private do you think Presence is? Why?
- Do you have any privacy concerns about Presence? List your concerns if you have any.
    - For each concern, ask "why?"
- What your privacy concerns (if they have any), make you want to use the telepresence less often?

Next, imagine you are the local user, and the robot is located in your house. Imagine a family member or friend logs into the robot to visit you

- on a scale of 1 to 5, with 1 being less private, and 5 being most private, how private do you think Presence is? Why?
- Do you have any privacy concerns about Presence? List your concerns if you have any.
    - For each concern, ask “why?”
- What your privacy concerns (if they have any), make you want to use the telepresence less often?

Now I would like you to complete couple questionnaires.
Distribute questionnaires
Please complete the questionnaires to describe your experience using <name>.

- *Perceived Usefulness Questionnaire*
- *Perceived Ease of Use Questionnaire*
- *System Usability Scale*
- *NASA-TLX*
- *Features Comparison Questionnaire* (After each sessions)

Do you have any other comments on this interface?
Do you need to use the restroom or get water before we continue?

InTouch UI User Testing

	Complete InTouch UI usability testing for each individual

Now I would like to give you an opportunity to use the InTouch UI. There will be a list of tasks I would like you to complete. I will give you your tasks one after another and observe your actions on each task. In this part, there will be **20 tasks**, please read each task carefully and complete it to the best of your ability. If you have major questions on one task and are unable to complete it, I will be here to assist you. Please tell me what's going on through your minds as you do the tasks, in another word, think out loud.	*Start timer* *Hand each task one after another to participant* *Take notes*

Now you've completed all 16 tasks using InTouch, now I am going to ask you some questions about your experience driving InTouch. To help you remember what the interface looked like, there is a picture of the interface <<hand them a screenshot with the name in large letters at the top>>

<u>Opening questions (ice breaker)</u>

- What was your first impression of InTouch?

<u>Perceived usefulness</u>

- Did you find InTouch to be useful? On a scale of 1 to 5, with 1 being less useful, and 5 being most useful, how useful do you think InTouch is? Why?
- Would InTouch help you stay connected with others? Why or why not?
- Can you imagine yourself using InTouch? Why?
- Did you enjoy using InTouch? Why?
- Assume you have access to InTouch, do you think you will use it?

<u>Perceived ease of use</u>

- On a scale of 1 to 5, with 1 being less easy to use, and 5 being most easy to use, how easy to use do you think InTouch is? Why?
- What was easy to use in InTouch? Why?

    - <<encourage participant to refer to screenshot -- make sure you/participant clearly specifies what design feature they are referring to>>
- What was difficult to use in InTouch? Why?
    - <<encourage participant to refer to screenshot -- make sure you/participant clearly specifies what design feature they are referring to>>

<u>Perceived privacy</u>

Next I have some questions about privacy. Privacy can be defined as the control over when, how, and to what extent your information is communicated to others. I'm going to ask you questions about privacy using two scenarios.

In this first scenario, imagine you are the pilot user, and the robot located in someone else's house. Imagine you are visiting a family or friend in their home by remotely control the robot in their environment <refer to diagram>

- on a scale of 1 to 5, with 1 being less private, and 5 being most private, how private do you think InTouch is? Why?
- Do you have any privacy concerns about InTouch? List your concerns if you have any.
    - For each concern, ask "why?"
- What your privacy concerns (if they have any), make you want to use InTouch less often?

The second scenario, imagine you are the local user, and the robot is located in your house <<refer to diagram>>. Imagine a family member or friend logs into the robot to visit you

- on a scale of 1 to 5, with 1 being less private, and 5 being most private, how private do you think InTouch is? Why?
- Do you have any privacy concerns about InTouch? List your concerns if you have any.
    - For each concern, ask "why?"
- What your privacy concerns (if they have any), make you want to use InTouch less often?
- What might you do to reduce privacy concerns?

Now I would like you to complete couple questionnaires.

Distribute questionnaires
Please complete the questionnaires to describe your experience using <name>.

- *Perceived Usefulness Questionnaire*
- *Perceived Ease of Use Questionnaire*
- *System Usability Scale*
- *NASA-TLX*

Do you have any other comments on this interface?

Interview

Screenshots of each interface

1. Compare each experience, which one you prefer, give me at least 3 reasons why?
2. Okay now I will ask you some additional questions, and I would like you to compare both interfaces. Which interface was easier to use? And why? *(Encourage them to talk about all three).*
3. Which interface did you perceive has more privacy enhanced features? List some features. Why?
4. Which system would you like in your home, imagine cost is not an issue. Why? *(Encourage them to talk about all three)*

Post-Interview Questionnaire

Distribute questionnaires

- *Privacy Attitudes Questionnaire*
- *Feature Questionnaire*

Debriefing

Thank you for your time today. Your input will help us to develop a smart presence system that is more useful and easier to use for specific group. It is very important that you do not discuss this study with anyone else until the study is complete. Our efforts will be greatly compromised if participants come into this study knowing what is about and how the ideas are being tested. Thank you again for your participation!