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Usability Testing of a Mobile Robotic System for In-Home Telerehabilitation

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***Abstract*—Mobile robots designed to enhance telepresence in the support of telehealth services are being considered for numerous applications. TELEROBOT is a teleoperated mobile robotic platform equipped with videoconferencingcapabilities and designed to be used in a home environment to . In this study, learnability of the system's teleoperation interface and controls was evaluated with ten rehabilitation professionals during four training sessions in a laboratory environment and in an unknown home environment while performing the execution of a standardized evaluation protocol typically used in home care. Results show that the novice teleoperators' performances on two of the four metrics used (number of command and total time) improved significantly across training sessions (ANOVAS, p<0.05) and that performance in these metrics in the last training session reflected teleoperation abilities seen in the unknown home environment during navigation tasks (r=0,77 and 0,60). With only 4 hours of training, rehabilitation professionals were able learn to teleoperate successfully TELEROBOT. However teleoperation performances remained significantly less efficient then those of an expert. Under the home task condition (navigating the home environment from one point to the other as fast as possible) this translated to completion time between 350 seconds (best performance) and 850 seconds (worse performance). Improvements in other usability aspects of the system will be needed to meet the requirements of in-home telerehabilitation.**

I. Introduction

In-home telerehabilitation (e.g., the delivery of rehabilitation services at an individual's home over telecommunication networks) has been identified as a promising avenue to support healthcare service delivery by reducing costs, increase geographic accessibility, or act as a mechanism to extend limited resources [1]. In-home telerehabilitation, services can be varied and cover a continuum of activities ranging from the evaluation of the patient's functional abilities in his/her environment to specific supervised therapy or exercises. It has been used successfully for home assessments as well as to improve task performance in activities of daily living in occupational therapy [2] and can be effective in physical therapy contexts such as post surgery knee rehabilitation[3, 4].

Most in-home telerehabilitation activities rely on establishing, for the rehabilitation professional, a telepresence in the home. Existing approaches for in-home telepresence are typically based on bidirectional video and audio from videoconferencing equipment connected through a high-speed Internet connection. While static videoconferencing currently used for in telerehabilitation can create a telepresence experience, the information and interactions are constrained by the location and field of view offered by the camera system used for videoconferecing. Considering that clinical interactions during in-home telerehabilitation are not limited to one area in the home and can involve multiple individuals (e.g., caregiver, patient) across multiple areas, finding ways to expand and enhance in-home telepresence in telerehabilitation is necessary.

Proof of concepts for mobile teleoperated robots designed to enhance telepresence in the support of in hospital telehealth services have been proposed [5] and several commercial telepresence robots exist (e.g., Toshiba's, ApriAlpha, Hitachi's Emiew, Mitsubishi's Wakamura, and WowWee's Robio). However, because of size and locomotion limitations, these telepresence systems are often not appropriate for use in in-home telerehabilitation and their usability is often not adapted to the complexities of the operating conditions found in this context or the skill levels and needs of the targeted applications.

This paper presents results on usability testing of a mobile telepresence robotic system called TELEROBOT for use in the context of in-home telerehabilitation. Specifically, as this system will be used with novice teleoperators who will have received limited training, learnability of the system's teleoperation interface and controls was explored.

II. TELEROBOT

TELEROBOT is a teleoperated mobile robotic platform equipped with videoconferencing capabilities (H264 Codec with PTZ camera). Figure 1a shows TELEROBOT in a

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home environment. The user interface for the robot teleoperation is illustrated in Figure 1b. Conceived by a team of roboticists and clinical experts at Université de Sherbrooke, the development of TELEROBOT followed a series of preliminary studies. A pilot study with existing telerobotic systems in two home environments was performed to identify requirements for safety and operating conditions and teleoperation interface [6]. Focus groups were conducted with healthcare professionals involved in geriatric care and potential clients (elderly people) to establish a preliminary needs assessment, identify potential target applications, and identify check list items needed for the development of a prototype that could be used in pilot testing of these applications [7]. Interviews with system users were conducted to model the health information architecture to identify needs from the clinical perspective[8]. Based on the knowledge acquired in these preliminary studies, a prototype, using hardware modules of a previous mobile robot (AZIMUT-3 robot [9]) was built. Technical details on TELEROBOT's locomotion system, perceptual, processing, and control architecture are described elsewhere [10].

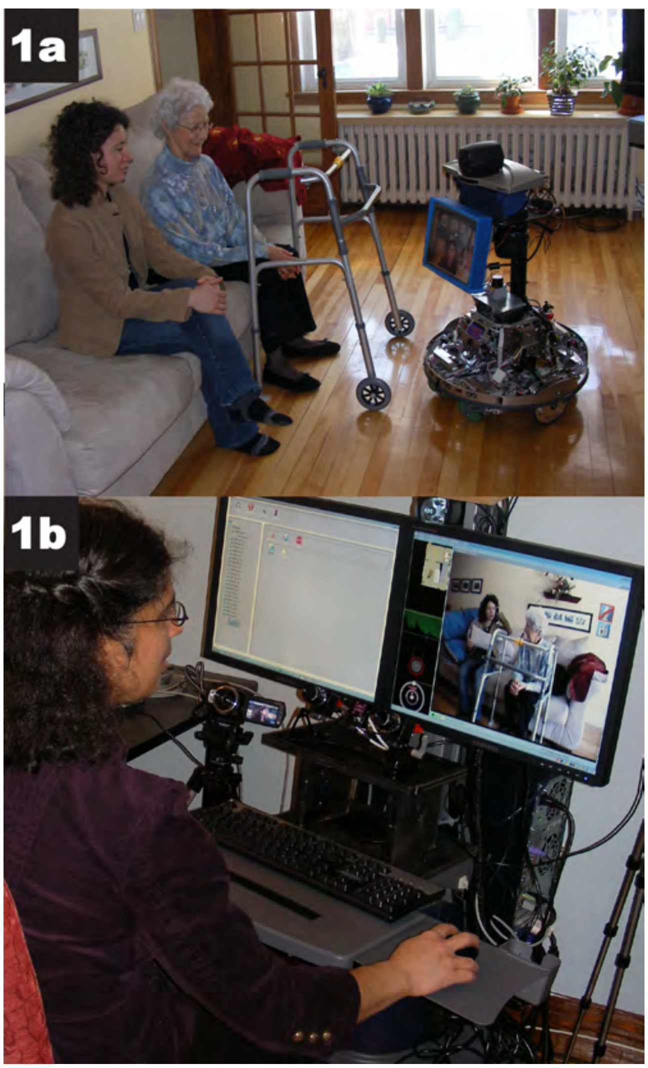

Figure 1. Overview of TELEROBOT and teleoperation station and interface.

The teleoperation interface of TELEROBOT is shown in Figure 1b. It consists of a Map window, a Radar window with a mouse control to activate and control the robot locomotion and direction; and a large visualization screen and control of the PTZ camera mounted on top of the mobile robot. The mobile robot base is 0.29 mhigh and the height of the videoconferencing equipment can be manually adjusted from 0.65 to 0.95 m. The videoconferencing equipment consists of a 1024 _ 768 touch screen display, a 20W sound amplifier connected on a pair of 4 X speakers, a Tandberg 550 MXP codec (H.264) providing a SIF resolution (352 _ 240) over a 384 kbps Internet connection, a pantilt- zoom camera with a 10X optical zoom and a wide-angle lens, and an omnidirectional microphone. The remote operator can continuously see the robot's position using the two-dimensional map window. The map window illustrates the main obstacles (walls, stairs, doors and furniture), and pre-defined observation points (colored dots) can be placed on the map to guide the user to where specific tasks must be conducted. The Radar window displays the laser range finder data and is used to evaluate distances between the robot and nearby obstacles. A horizontal grey line is displayed at 1 m from the robot and the two vertical grey lines on the side of the robot help the operator navigate through narrow spaces (e.g., doorways). The red circle around the robot illustrates the security zone: as the robot moves closer to obstacles.

III. METHODS

Usability is defined in ISO 9241 as the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments. Usability is also a quality attribute [11] that assesses how easy user interfaces are to use and can be evaluated on 5 quality components (learnability, efficiency: memorability, errors, satisfaction). In this study, learnability of the system's teleoperation interface and controls (how easy is it for users to accomplish basic tasks the first time they encounter teleoperation interface and controls) was evaluated with rehabilitation professionals during four training session in a laboratory environment and in an unknown home environment. Training sessions consisted in the execution of three tasks (e.g., entering and exiting rooms through door frames, navigating and moving the robot in open spaces or tight environments, scanning the environment with the camera to identity specific objects) with increasing levels of difficulty to familiarize the user with the controls and teleoperation of the robot. The physical layout and architectural details of the training environment and home environment and tasks performed used in the usability test scenarios appears in Figure 2.

Teleoperation performances on four metrics: number of commands on the interface during the performance of the scenario; total time to complete the scenario; % of total time when the robot was in motion, % of total time when the AVOID controls were in use (reduction of the velocity of the robot when an obstacle is between 20 cm and 10 cm stopping the robot completely at 10 cm) in the training environment and the unknown home environment were compared to an expert. The expert had more than 50 hours of training on the functioning of the robot and was familiar with the home environment. The expert operator performed five trials and the best score on each of the six variables measured determined the best trial to keep as the gold standard to normalize the performances of the novice operators.

To simplify the experimental set up (keeping the participants and the research personnel in one place) and in order to eliminate the potential effects of communications problems cause by an unstable Internet connection, the usability test scenario is performed using a local Wi-Fi network, with the teleoperators being guided blindfolded in a closed room located on the second floor of the house.

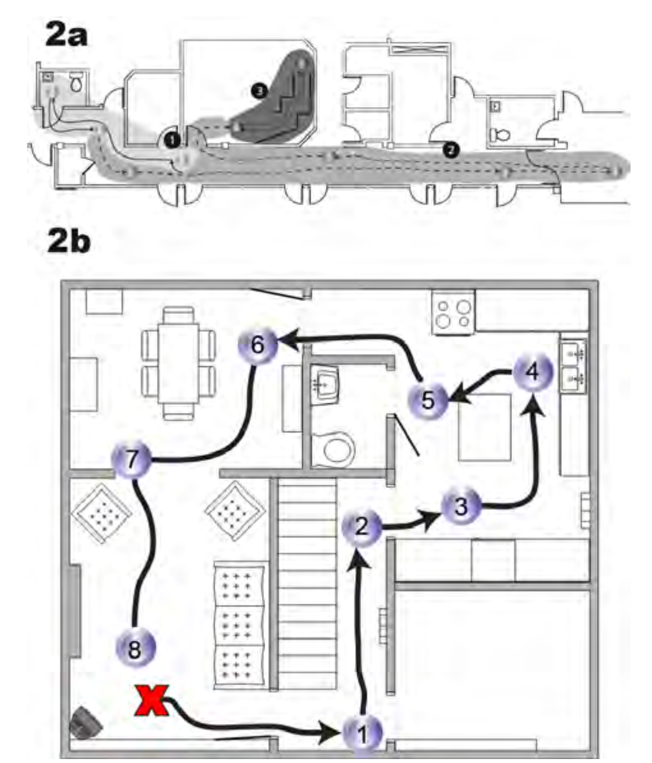

Figure 2. Usability test scenarios. a) Overview of tasks and physical environments used for training sessions. Where 1 is navigating the mobile robot in a corridor, entering a bathroom and operating the PTZ camera on the videoconferencing system to identify information located on a wall, 2 is using the locomotion system across a corridor with different surface and a door step and 3 is maneuvering the robot in a tight environment with obstacles at different distance form the robot. b) Overview of physical environment and navigation tasks performed by novice teleoperators in unknown home environment. The first task consisted in navigating the home environment from one point to the other as fast as possible.

IV. Results

Ten participants (5 physiotherapists, 5 occupational therapists) were recruited from a pool of rehabilitation professionals affiliated with the Sherbrooke Geriatric University Institute (SGUI) or with private clinics. The project was approved by the institutional review board of the CSSS-IUGS and all participants gave their informed consent. All participants were currently involved as part of their work in the provision of homecare services.

Participants (2 men, 8 women) were aged between 23 and 52 (35.3 average with standard deviation of 9.5) and had an average of 8.5 years of clinical experience (min of 1 year, max of 21). Eight out of ten participants reported spending less than 3 hours per day on computers for work and/or leisure. Computer use was mostly associated with word processing, email and web surfing. None of the participants were active or past video game users.

Results (Figure 3) show that the novice teleoperators' performances on two of the four metrics used (number of command and total time) improved significantly across training sessions (ANOVAS, $p<0.05$).

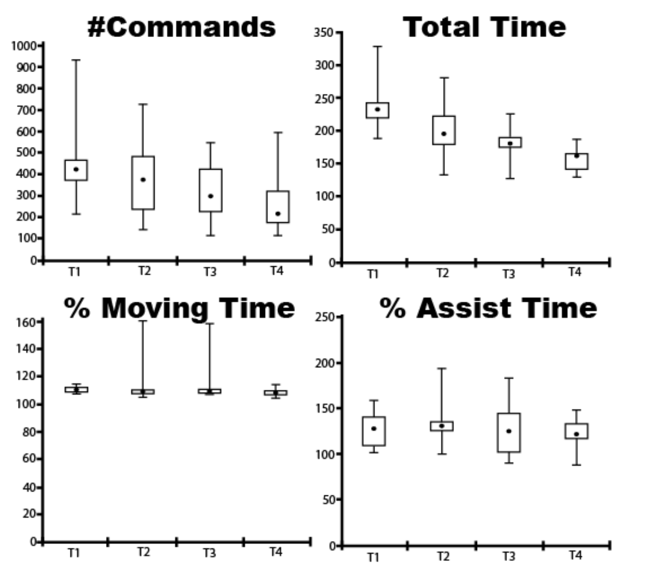

Figure 3. Teleoperation performance of rehabilitation professionals (n=10) compared to expert during training sessions (T1,T2,T3,T4) on 4 metrics (# commands, total time, % moving time, % assist time). Results are computed from the average performance across the three tasks performed in each training session.

Performance in these metrics (Figure 4) in the last training session (T4) reflected teleoperation abilities seen in the unknown home environment (H) during navigation tasks (Spearman Rank correlation r=0,77 and 0,60). Where the worst operators under training conditions performed the worst in the unknown environment. Teleoperation performances in terms of the total number of commands and the total time to accomplished the tasks in the training environment or home environment remained however significantly less efficient then those of an expert (average of 296%-401% of the expert performances in the home task). Under the home task condition (navigating the home environment from one point to the other as fast as possible) this translated to completion time between 350 seconds (best performance) and 850 seconds (worse performance). As this was a simple navigation task with no interactions with the simulated patient, the time taken to complete the tasks suggest that teleoperation of TELEROBOT in an unknown home environment is a complex task for novice teleoperators.

	Number of commmands	
	T	H
Mean	261%	401%
Std	143%	128%
Min	113%	221%
Max	593%	586%
Corr.	0,77	

	Total Time	
	T	H
Mean	157%	296%
Std	20%	075%
Min	129%	190%
Max	188%	476%
Corr.	0,60	

	%Moving Time	
	T	H
Mean	107%	102%
Std	2%	2%
Min	103%	98%
Max	112%	104%
Corr.	0,24	

	%Assist Time	
	T	H
Mean	123%	132%
Std	16%	23%
Min	88%	105%
Max	148%	177%
Corr.	0,62	

Figure 4. Teleoperation performances (mean, sdt, min and max) of rehabilitation professionals (n=10) in last training sessions (T4) and during navigation of an unknown home environment compared to expert.

V. CONCLUSION

Teleoperated from a distant location, TELEROBOT has the potential to enhance the telepresence experience in in-home telerehabilitation beneficial tool in health applications. Potential applications for robotic telepresence include: monitoring the loss of autonomy and the patient's abilities by means of an analysis of tasks in the actual situation and in the natural environment; supervision or rapid access to a professional when patients return home from the hospital; remote tele-surveillance (i.e., guardian angel) of the older person so the family caregiver can leave the house; remote training (e-learning) of natural caregivers in the provision of medical care and the operation of specialized equipment.

However, design and usability issues related to such systems are still broad and mostly unexplored. Results from our usability test scenario with TELEROBOT demonstrate that rehabilitation professionals were able to learn to teleoperate such a robot in an unknown home environment with 4 training sessions totaling 4 hours.

Improvements in other usability aspect of the system, namely efficiency and memorability will have to be achieved in the near future to consider the use of mobile robots in a home environment with rehabilitation professionals. Efficiency could be gained by providing, through a better teleoperation user interface, increased situation awareness (SA) to the teleoperator (i.e., the perception of the robot's location, surroundings and status, the comprehension of their meaning, and the projection of how the robot will behave in the near future). On going work is focused on establishing and implementing the specifications of a complete, efficient and usable in-home telerehabilitation mobile robotic system with a second generation TELEROBOT.

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