Depth and Shared Space as Resources in Physical Telerehabilitation

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1. INTRODUCTION

In a patient's rehabilitation journey, physical therapy, commonly referred to as physiotherapy, can be an important piece of the recovery puzzle. The applications of physical therapy are broad and varied, but consider, as an example of the process, that a patient who has undergone knee surgery may need to use physical therapy to assist in reducing the amount of disability, and improving the function of the knee [6]. This type of therapy would involve assessment of function and disability by the therapist, as well as performing or guiding the patient in knee exercises that are intended to support the patient's rehabilitation. The patient would be expected to follow the recovery program created by the therapist, and is able to present any concerns around recovery and use of the knee, to which the therapist can respond. The task is one that has traditionally required colocation of the patient and the practitioner, since the interaction is fairly hands on for the therapist.

The problem is that physiotherapy services may not be easily accessible for those who may benefit from the treatment. Telerehabilitation, which is "the provision of rehabilitation services at a distance using telecommunications technology as the delivery medium", attempts to address some of these access issues [5]. Patients who must receive rehabilitation services from a therapist may be remote from the practitioner, or may be physically limited in their ability to meet in person. Even if the patient were not limited in these ways, the use of remote therapy would result in time and money saved by the patient, insurance companies, and the health care system, with added potential benefits in being able to treat a person while they are in their own living space. These are all attractive reasons to pursue telerehabilitation for physical therapy treatment.

Telerehabilitation has used various technologies, which may be broadly classified in three categories: 1) image-based, 2) sensor-based, and 3) virtual environments and virtual reality telerehabilitation [5]. Image-based telerehabilitation primarily uses videoconferencing tools in order to provide physical therapy treatment, and appears to result in outcomes that are similar to those of traditional rehabilitation services. Sensor-based services make use of "equipment such as tilt switches, accelerometers and gyroscopes to sample and quantify movement through three-dimensional space", and while these systems may be practical and effective, they are costly, and may not be economically feasible. Virtual environments have been explored as a way to allow specialists to manipulate the patient's environment, allowing the patient to learn new motor skills that apply to real world skills, through use of task repetition, feedback and motivation.

Telerehabilitation has become increasingly viable thanks to advances in communications technologies [5], but the problem with current telerehabilitation approaches is that they do not allow the therapist to work in three-dimensional space, and most systems use classic videoconferencing methods, which may not be ideal for the types of interaction required in physiotherapy. While current tools may provide outcomes that are similar to face-to-face therapy, tools that address these issues may result in a more efficient and enjoyable experience. OneSpace [3], a tool that allows multiple users to share a virtual space remotely through video, has the potential to support image-based telerehabilitation by allowing for depth relationships to be preserved during the communication (Figure 1). As it is primarily a tool for video communication, OneSpace obviously falls into the category of image-based telerehabilitation technology, but it may also be classified as sensor-based, as well as a virtual environment for therapy. Since the tool uses sensors to acquire depth information for each pixel of the image, OneSpace may be considered a sensor-based technology. OneSpace also, in a sense, virtually places the patient into the environment of the practitioner, and as such, may be viewed as a virtual environment telerehabilitation technology. The tool may also be modified in order to allow the therapist to virtually manipulate the patient's space, by using on-screen images or targets in order to aid in the therapy. As this tool could fit into any of the three classifications, it is important to evaluate it as a possible tool to support physical telerehabilitation.

Our approach to solving the problem with current telerehabilitation methods is to perform a qualitative study that will evaluate the depth and shared space afforded by OneSpace as resources in physical telerehabilitation. The steps we will take in this work include investigation into current methods used and research currently being done, possible improvements to the OneSpace design, as well as observation of the OneSpace system in use by a physiotherapist, while considering the following research questions: 1) how do depth and shared-space support telerehabilitation in physical therapy? 2) What are the important design considerations when developing telerehabilitation systems for physical therapy? In answering these research questions, the expected contribution of this work is that it will begin to guide future development of tools and processes for physical telerehabilitation.

2. RELATED WORK

Since the beginning of research into Computer Supported Cooperative Work (CSCW), there has been a focus on allowing remote collaborators to share a workspace, and it has also been a goal to allow skills to be taught via these systems. While studies in physical telerehabilitation are being performed, they typically deal with more conventional videoconferencing technologies, such as pan-tilt-zoom (PTZ) cameras [6]. It seems that studies in telerehabilitation have not yet investigated the use of shared space or depth to support physical therapy remotely. The following outlines some work that has been done in physical telerehabilitation, research in CSCW systems, and their potential to support remote instruction of skills or tasks, which may relate to therapists guiding a patient in exercising remotely.

Rehabilitation using Video-Mediated Communication. Videoconferencing has become a common tool for communication with others remotely, and it has been utilized in many telemedicine applications [5]. While further studies must be performed, videoconferencing appears to be an effective tool to support telerehabilitation. Tousignant, et al. discovered through their pilot study with telerehabilitation after total knee arthroplasty (TKA) that physical telerehabilitation appears to be effective as an alternative to in-home visits by a therapist for rehabilitation, but note that expectations of both the patient and therapist should be modified [6]. While the use of this technology to perform physical therapy treatment remotely is not ideal, it appears that tasks can be performed and goals may be met satisfactorily. This study had a therapist treating patients remotely twice a week for 8 weeks following TKA surgery, and found that this telerehabilitation was feasible over a long period of time, resulted in reduced disability and improved function for the patient, and that health care professionals and patients were satisfied with the delivery method.

While much of the work with CSCW systems has focused on shared workspaces such as tables and white boards, the workspace that the physiotherapist actually uses is the patient, and the space that the patient inhabits. This unique type of work may require a unique tool, which allows the therapist a way to "enter" the patient's environment, and work closely with the patient within their space.

Systems for Cooperative Work. Finding novel and effective ways to share space has long been goal of researchers in the area of Computer Supported Cooperative Work (CSCW). An early system that focused on providing a shared workspace for remote collaborators was ClearBoard, which employed a metaphor of "looking through and drawing on a big glass board" [2]. ClearBoard afforded collaborators the ability to see the actual image of their partner in the drawing space, and allowed for gaze information to be conveyed along with deictic information through hand gestures.

A tool which focuses less on workspace and more on providing users a communication environment is HyperMirror, which allows for a "What I See Is What You See" representation of a shared space [4]. This system uses blue screen technology in order to overlay one collaborator's image onto the video image space of another. Through observation of the system's use, the authors were able to see that real world principles seemed to apply to HyperMirror. Personal space appeared to be respected by partners, people tended to point in order to communicate as in face-to-face conversation, one partner would move closer to the screen to show fine detail of an object, and people felt physically "closest" to the closest person on the screen, even if that person was remotely located. The information presented in the paper allows us to imagine how users of OneSpace may function given certain tasks, as many of the principles regarding shared space and image orientation transfer from HyperMirror.

OneSpace. The OneSpace system extends the work presented in HyperMirror by preserving the mirror metaphor, but unlike HyperMirror, OneSpace respects depth relationships between collaborators [3]. Rather than the traditional chroma-keyed implementation used by HyperMirror, which only allows one collaborator to be overlaid on the video feed of the other, OneSpace dynamically checks each pixel from all collaborators' feeds and reconstructs an image with only the front-most pixels being displayed. Figure 1 provides an illustrated example of this reconstruction.

While the authors of OneSpace expected to see the system used for conversation, the participants testing OneSpace chose to play with each other remotely rather than strictly conversing, which may indicate that it would be of value as a tool for play between children [3]. OneSpace provides a novel way for people to interact remotely in a shared virtual space, and the authors suggest that OneSpace may support remote physiotherapy instruction.

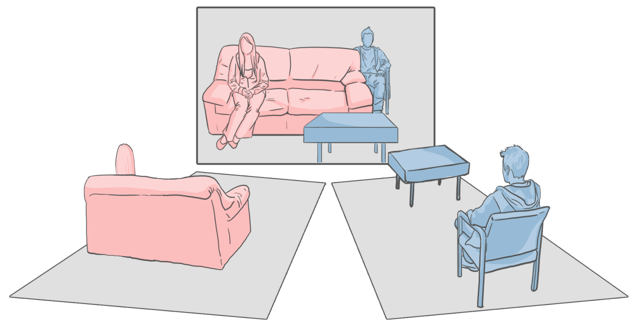

Figure 1. Image reconstruction with OneSpace [3].

Teaching Skills with CSCW Systems. Through evaluation of various CSCW systems, scenarios that involve teaching specific skills have been explored, and since physiotherapy is largely about teaching exercises to a patient, this history is important in guiding current research. For example, Ishii, et al. [1] evaluated the TeamWorkStation-2 (TWS-2) system by having an instructor provide calligraphy lessons to a student using TWS-2, which allowed the collaborators to convey drawing information, as well as gesture information. Another system that has been used to teach skills remotely is ClearBoard, which was utilized to teach the game of Backgammon [2]. ClearBoard allowed the instructor to use gestures while monitoring this student's gaze to ensure that they were focusing on the proper space on the board. The research also showed that the players rarely looked at each other's faces while focusing on playing a game, but shifted their focus frequently during the teaching phases.

Xiao and Ishii [7] created MirrorFugue as a tool to support remote piano instruction. MirrorFugue explored the use of projection of an instructor's hands onto the student's piano in various orientations, and found that the students learned best when the image of the instructor's hands was offset just above the keyboard, with the orientation the same as the students' orientation. This setup allowed the student to see not only which notes were being played by the instructor, but also conveyed information about the instructor's hand gestures while playing. This work is important, as it illustrates the potential for various CSCW systems to support remote instruction, and these principles may extend to physiotherapy.

3. PROPOSED WORK

The work performed in this study can be divided into three phases: 1) Investigation and Discovery, 2) Design, and 3) Evaluation. This will allow us to gather more information about the aspects of the system that are most important in telerehabilitation, which will allow us to see if any alterations to the OneSpace system are necessary. The final phase will allow us to observe use of the system by an experienced physical therapist, and will provide us with valuable information that will allow us to begin answering our research questions.

3.1 Investigation and Discovery

In order to guide the work performed in the study, we will acquire more information about use of telerehabilitation systems, with a focus on how we can effectively evaluate the OneSpace system. We would also like to become more familiar with the various physical therapy procedures in practice that are currently being used in traditional face-to-face therapy. In order to acquire this information, we will interview physical therapy professionals, with the goal of speaking with those who have not made use of telerehabilitation in practice, as well as those who have. Since use of telerehabilitation in practice has been limited, this may be difficult, but would be valuable in guiding our work. Apart from these interviews, we will also continue with a more in-depth literature review of prior work in telerehabilitation research as it relates to physical therapy.

3.2 Design

After completing the Investigation and Discovery phase, we will have information that will allow us to guide a redesign of the OneSpace system. Since time and resources are limited, we will not be able to make major changes, but we may find that we are able to make small changes that will allow us to produce more meaningful results in the evaluation phase. An example of this might be finding a way to visually emphasize depth by altering brightness of pixels based on depth value, with those closest to the cameras being brighter than those further away. Another example, which would begin to classify OneSpace as a tool for virtual environment telerehabilitation, would be to allow the therapist to draw on the screen or be able to insert targets for the patient to interact with and support certain exercises.

3.3 Evaluation

Once the Design phase has been completed, we will begin to evaluate the OneSpace system by observing its use in practice. Our goal for the evaluation is to understand: how the therapist changes his methods in order to work with OneSpace, how well the patient can follow the therapist's instructions, and how satisfied and comfortable all participants are in using the technology. After evaluating the system, we should have a better understanding of how technology such as OneSpace can support remote physical telerehabilitation, and what improvements could be made to existing technology to better serve telerehabilitation specialists. While the actual process for the evaluation of the system may change after the other phases are completed, we will outline an example method.

3.3.1 Environment

The spaces for the evaluation will be two identical rooms in the University of Calgary, sized similar to a living room, with the displays being typical televisions, since this kind of therapy would likely take place in a patient's living room. Both cameras will be run off the same computer for practical reasons, but the results will transfer to networked or Internet use.

3.3.2 Process

An experienced physical therapist will be asked to lead a number of participants in some basic physical therapy exercises in two separate conditions. One condition will be a standard videoconferencing setup and the other will be OneSpace. These conditions will be counterbalanced, in order to minimize bias. The exercises will be standard throughout all participants, and will include a range of exercise types.

3.3.3 Evaluation

Video will be captured from the OneSpace cameras in both rooms, and additional in-room video will be taken in each of the lab spaces. This video will be coded to look for instances of use of depth and deictic gesturing, with quality of communication being analyzed as well. We will also interview the participants and have them complete questionnaires, with the therapist being involved in a more substantial exit interview. The questionnaire and interview questions will be developed with the aim of assisting in answering the research questions that we have developed.

4. TIMELINE

Date	Task
Jan 7 – 15	Literature review
Jan 25	Proposal due
Jan 25 – Feb 8	Investigation and Discovery phase
Feb 8 – 22	Design phase
Feb 22 – Mar 8	Evaluation phase
Mar 8 – 22	Analysis of data
Mar 22 – 31	Draft of final report
Apr 5	Final report due
Apr 10 – 16	Final presentation

5. REFERENCES

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