

# Usability of the Remote Console for Virtual Reality Telerehabilitation: Formative Evaluation

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## ABSTRACT

The Remote Console (ReCon) is a telerehabilitation application that allows therapists to remotely communicate with patients while monitoring and controlling their virtual rehabilitation exercises. It provides therapists visual feedback of patients' movements, their exercise simulations replicated in real time and with tools to conduct training without a face-to-face session. The ReCon underwent a formative evaluation (a type of usability engineering methodology) used to refine its design. Five physical therapists from different practice settings acted as representative users. During the evaluation, these users made errors related to manipulation and finding and understanding controls. Technical issues with the server and audio communication were identified. These findings were used to fine-tune the ReCon system.

## INTRODUCTION

TELEREHABILITATION is the provision of rehabilitation interventions at a distance.<sup>1</sup> This area of rehabilitation science and engineering is new and fast evolving.<sup>2-5</sup> The state of the art includes low-cost web applications, such as Java Therapy,<sup>3</sup> as well as applications for virtual reality (VR) telerehabilitation from a host site to a clinic or a home using real-time patient-therapist interaction.<sup>4,5</sup>

The Remote Console (ReCon) is an application for telerehabilitation, which is a product of several iterations of development. The main component, the monitoring window, has evolved from a web-portal<sup>2</sup> to a real-time web-based monitoring system for telerehabilitation, in which a three-dimensional (3D) simulation is coupled with performance gauges from the rehabilitation site.<sup>6</sup> The development and refinement of the ReCon has followed us-

ability engineering methods, primarily formative evaluations and usability studies. In such evaluations improvement of user interaction is achieved by iteratively placing representative users in task-based scenarios in order to identify usability problems.<sup>7</sup> An initial usability study was conducted on the complete Rutgers Ankle Rehabilitation System (RARS),<sup>8</sup> including a session, which introduced therapists to the real-time web-based monitoring system.<sup>9,10</sup> This system was also tested as a component of a clinical trial on post-stroke individuals in the chronic phase.<sup>11</sup> As a result of these earlier studies, several modifications were made on the RARS interfaces and the remote monitoring application.

The issues which arose, during clinical testing and the RARS initial usability study, led to the development of the Remote Console (ReCon).<sup>12</sup> The ReCon system then underwent a formative evaluation in order to gauge its ease-of-use and acceptance

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by representative users (physical therapists). This paper describes the ReCon's current implementation and its formative evaluation usability study.

*ReCon environment*

The Remote Console integrates real-time graphics, audio/video communication, private therapist chat, post-test data graphs, extendable patient and exercise performance monitoring, exercise pre-configuration and real-time modifications under a single application.<sup>12</sup> Therapists interact with a rehabilitation site from a remote location (Fig. 1). Consistent with recommendations for telerehabilitation priorities,<sup>1</sup> the ReCon enables therapists to conduct training/counseling, monitoring/assessment, and therapeutic intervention from a remote location in real time.

The elements of the ReCon viewed on a therapists' computer are: Navigation, Real-Time Monitor, MediaClient, PTZ Viewer (remote pan-tilt-zoom camera), and the Configuration Utility (Fig. 2). The MediaClient provides audio and video communication between the two sites as well as a chat window for private communication with local therapists. Remote therapists control a PTZ camera, located at the local site. The Real-Time Monitor incorporates simplified 3D graphics to represent the VR simulation, the patient's movements, as well as numeric information and performances gauges allowing therapists to evaluate exercise configurations and the patient's progress. These data are updated in real time during the exercise.

An earlier version of the lower-extremity rehabilitation remote monitoring system was implemented

for patients exercising in a virtual environment using the RARS. In this implementation, remote therapists were unable to alter simulation exercise parameters (such as airplane speed, exercise duration). Instead they directed a local therapist in the same room with the patient by communicating through third-party audio/chat software. This process was awkward and inefficient. Providing remote therapists direct control over the session was deemed an essential feature. To accomplish this, the ReCon was integrated with a new communication architecture,<sup>13</sup> which added the ability to send and receive flexible and predefined messages. In the current version of the ReCon, therapists can change individual exercise parameters during run-time, either just before a new exercise, or (for some variables) while the exercise is in progress. To extend the capability of remote control off-line, a configuration utility (CU) was added to Recon, allowing therapists to pre-configure sessions. Before an exercise, remote therapists are able to list configuration parameters to edit and save a trial. This trial configuration is then sent to the rehabilitation site and loaded by the configuration application on the local rehabilitation machine.

**METHODS**

Using feedback from the initial usability study, the current implementation of the ReCon was developed and underwent a subsequent formative evaluation. Four of the PT's, who tested the previous version, were asked to test the new system (user P1 [pilot], P2, P3, and P4). Each therapist re-

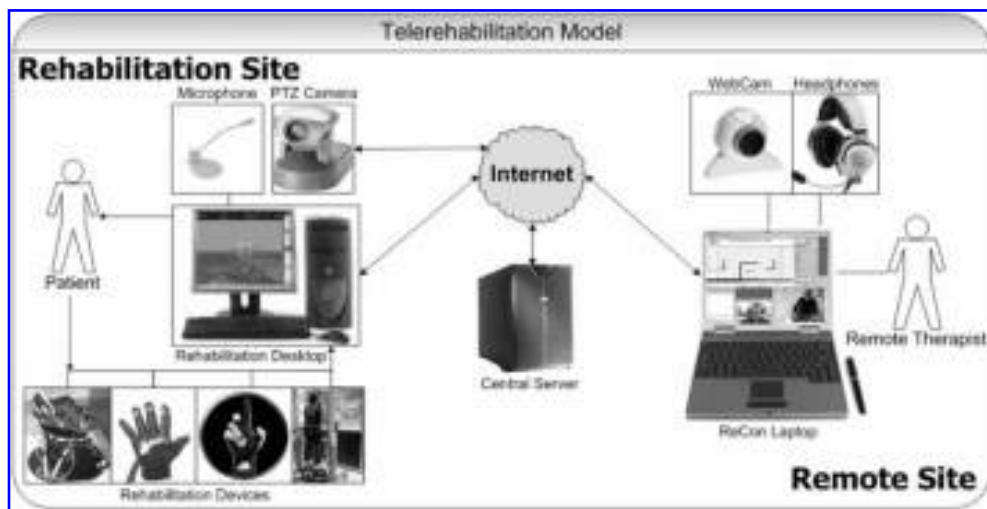


FIG. 1. Telerehabilitation Model using the ReCon.<sup>12</sup> (©UMDNJ, Rutgers University, 2005.)

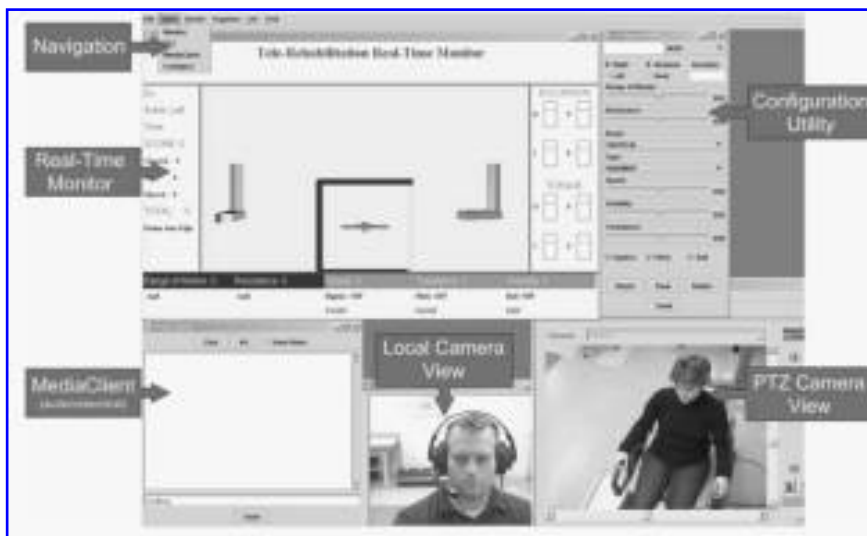


FIG. 2. ReCon desktop for a lower extremity exercise.<sup>12</sup> (©UMDNJ, Rutgers University, 2005.)

ceived instruction with the ReCon and returned for a training retention session. During the instructional session, therapists were given an overview of the system and its elements, followed by practice using each of the interfaces. Three exercises were completed immediately following the practice. During the next session, the therapists completed three training exercises with a healthy user. A fifth PT who was familiar with the RARS but had never used the telerehabilitation system was also tested (user P5). All sessions were videotaped and IBM usability questionnaires were administered after the Recon session. Statements on the questionnaire were answered using a Likert scale, rated as 1 (strongly disagree) to 7 (strongly agree).

Questionnaires were summarized. Videotapes were coded using methods designed by a usability expert (W. Quesenbery, personal communication, 2004). Tapes were viewed and problems encountered, while using the ReCon, were documented. Figure 3 shows a portion of a coding sheet. The completed coding sheets were compiled and observations were organized by task. Each task was separated by their "Problem Type" categories. The following section details the problems encountered.

## RESULTS

### Video coding

In Figure 4, the results of the formative evaluation are summarized, and the main problems encountered by the users are categorized by problem types. Each problem was tabulated by the number of sections in which a problem occurred (Sec.) and by the number of users who encountered that problem (Users). Clinical comments and terminology problem types are not included here.

Under the can't find control category, finding the pull-down menu in order to connect to the local web camera was the most frequently occurring problem. Four users had trouble with this task both in the overview and during the final set of exercises. Other difficulties in this category included finding the buttons to modify the exercise type (four users), the camera presets (three users), and camera zoom (one user).

The most frequently occurring problem observed in the study was in the manipulation category, where a modifier was left unchecked. Although users knew that they wanted to remotely change a parameter, such as the speed of the airplane in the VR simulation, they would forget to select the

#	Time	Observation Details	Task	Problem Type	Window	Comments
6	0:07	"Haptics, I forgot what that is" - JD explains	Overview	Terminology	Configuration Monitor	?
9	0:11	"OK I give up, where is it" (START button)	Overview	Can't find control	Real-Time Monitor	Couldn't find START button

FIG. 3. Sample of a video coding sheet. (©UMDNJ, Rutgers University, 2005.)

Problem Type	P1				P2				P3				P4				P5				Totals	
	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Sec	Users
<b>Can't Find Control</b>																						
Selecting Rivers from pulldown at PF2	1				1				1	1			1	1			1				4	4
Can't find Ex Type in Mon																					4	4
<b>Manipulation</b>																						
Leave Modifier unchecked	1	1	1																		7	4
Capture Monitor Sizing Problem	1				1								1				1				4	4
<b>Understanding Concept</b>																						
Not clear what happens CU Sends Data			1														1				4	4
Confusing Modify and Configure	1		1																		3	1
<b>Understanding Control Function</b>																						
How to use CU			1														1				3	4
START Button			1										1								4	4
<b>Visibility of System Status</b>																						
Asked local to open window that was open	1								1								1				3	5
<b>Technical Problem</b>																						
Config Utility Not Sending			1	1													1				4	3
Audio quality													1								3	3
Audio echoing	1												1								3	2

FIG. 4. Select identified problems from usability study. (©UMDNJ, Rutgers University, 2005.) Ov, Overview; Pr, Practice; E1&E2, Exercise 1&2; P1-P5, PT User ID.

green check mark. Thus, the change was not implemented. This error was committed across all sections and often more than once in each section. Resizing the local video monitor, which displayed the user's image, was another manipulation challenge. This was due to a problem with the Java Media Framework (JMF)<sup>14</sup> monitoring functions compatibility issue with Windows. The window did not appear properly on the user's display and needed to be manually resized. The remaining problems under manipulation were Windows manipulations problems (resizing, moving and arranging windows in a manageable way).

Use of the configuration utility generated problems that were classified in two categories: understanding concept and understanding control function. Observations of four users showed that it was "Not clear what happens when CU sends data." Additionally, one user continuously had trouble determining when to use the configuration utility to "pre-configure" an exercise and when to use the remote monitor to "modify" an exercise in progress. Users were not clear on what happened when the Configuration Utility sent data, they did not know which buttons to use, specifically when to "Save" an exercise configuration and when to "Send" it to the rehabilitation site.

In addition to the Configuration Utility, several other issues arose for understanding control function. These related to transitioning between the set-up and use modes. To advance the patient from the exercise configuration screen to the exercise simulation screen, the remote therapist must press the "START" button. Once in the exercise screen, they must then press the "START" button again if they want the exercise to begin.

The only problem noted for all five users, was a visibility of system status issue. The PT users asked

the local therapist to open a screen that was already open. In many cases this was due to the user directly following the Therapist's manual. However, it did not appear to be clear, that the same screen type shown on the monitoring window, was open at the rehabilitation site. It may also be possible that they did not clearly recognize the difference between certain monitoring screens.

The most frequently occurring technical problem was the CU, which was not properly sending data to the rehabilitation site. This was caused by a bug in the server software, which crashed the server when several commands were sent simultaneously. The configuration utility sent the same information as a single remote modification, however several commands were sent in sequence, which periodically required the server nodes to be restarted.

The majority of the other technical issues occurred with audio communication. Initially there was a built-in echo that caused the voice of the users to be repeated into their headphones. Additionally, when the audio was received at the rehabilitation site, the voice would come back to the remote site again through the user's headphones. This was due to the placement of the microphone too close to the speakers, causing audio echoing and complaints about audio quality. Furthermore, the method to connect the MediaClient was very tedious, and required both ends to be restarted before either side initiated communication. This led to problems with establishing an audio connection, or losing a connection.

User questionnaires

Questionnaire scores ranged from 1.75 to 6 (out of 7). In response to the statement *Overall, I am satisfied with how easy it is to use this system*, the average

response was a 6. Comments regarding the organization of the interfaces were rated positively, for example, *The organization of information on the system screen is clear* had an average rating of 6. On average, users rated *I am able to complete my work quickly using this system* as a 4, and *I can effectively complete my work* was rated 4.6. The lowest rating (1.75 average) was scored for *The system gives error messages that clearly tell me how to fix problems*.

Users listed positive and negative aspects of the ReCon system. Negative aspects included comments regarding losing the connection with the server and the echo from the audio channel. One user commented that the "ankle view [was] partially blocked by the table." Another commented on relying on the Manual several times before she could begin an exercise. Similarly, one therapist suggested, "the process of getting to different tasks must be memorized." Positive statements made by therapists were: the system was "easy to learn," and it is "easy to see how a subject is doing." Several users commented on the ability to change the parameters while the remote patient was exercising, and the ability to store previous exercises. One therapist stated: "it allows for a lot of monitoring options," and "it is different—might appeal to a therapist who likes variety."

## DISCUSSION

The purpose of the current formative evaluation was to address issues raised with the previous implementation of our remote monitoring system and test the acceptance of new features. The therapists' responses to questionnaires and comments extracted from the videotapes show that the users generally enjoyed having control over the session. Given the complexity of the procedure and monitoring software, these results are very good. Specifically, the therapist users rated the system ease of use as 6 (7 being maximum). The study identified issues ranging from basic manipulation ability to finding and understanding a control. Technical issues were also identified.

One of the important findings of the study was the challenge users encountered with the configuration utility. This was a new feature added to the system and was anticipated to improve therapists' ability to organize exercises by being able to pre-configure them. Therapists, however, were confused between the modifications provided through the real-time monitor and the pre-configurations provided through the CU. We attribute this confusion to the fact that they were similar in function though implemented in separate interfaces. Instead

of having to use separate utilities, it may be advantageous to combine their functions into a single interface. This will allow a therapist to modify parameters for current or future exercises in real-time with the same set of tools.

Transitioning between interfaces was problematic for users. This could be attributed to GUI buttons having the same labels and being difficult to find. One solution is to increase navigation buttons visibility by making them larger and changing them to icons which will draw the user's attention.

The visibility of the system's status is very important and may be underemphasized in the current ReCon version. Specifically, it would be helpful to make the state of the rehabilitation site more obvious. Showing the status of the connection to the server, and the number of active rehabilitation sites, may be helpful for the user to get a sense of the current rehabilitation network activity.

The most common technical issue occurred in the server which mediated the ReCon communication with the rehabilitation site. This has been addressed since the usability study completion. The most recent version of ReCon now allows the nodes to remain active without locking up the computers they are running on. Furthermore, the server does not crash due to an increase in messages sent by the configuration utility. Issues with communication are being addressed with each ReCon iteration. Subsequent to the usability study described here, the manual connection procedure on connecting the two sites with the MediaClient was eliminated. Each server node now sends out a location identifier, which can be accessed by the ReCon. The remote therapist then chooses from a list of online rehabilitation sites to connect to using the MediaClient. When the server on the desired node receives this request message, it automatically loads the MediaClient using the ports designated in the message. Furthermore, the server will send the requesting node (the ReCon) the ports from which it will broadcast. This allows the therapist to initiate the contact to the rehabilitation site. A similar method may be suited for opening the other site-specific elements of the ReCon.

Improving the latency and quality of audio and video will require some fine-tuning. To gain control over the sending and receiving of media, a Java interface was written to control buffer sizes. When the buffers are too large, there is an increase in latency, yet when the buffers are too small, the audio and video will appear choppy. In the future, it would be ideal to create an adjustable buffer, which is based on network availability, as well as allow video quality to adapt to give priority to audio quality.

Aside from being a functional system, the ReCon will only be effective in telerehabilitation if therapists find the software to be useful and ease to learn. According to the questionnaires, most therapists were overall satisfied with the systems use. There were some neutral comments, which suggest that the ease of use could be improved. Therapists felt strongly that they would also benefit from having error messages. Some therapists felt that they would require a longer period of learning to feel more comfortable with the system, while others felt that the system was easy to use. Problems observed with basic windows manipulation skills suggest that therapists with different computer backgrounds may adjust to the use of this technology differently. Those with less experience may require longer training, before proper comfortable use. In addition, other comments relating the system's stability must be addressed before a therapist will feel that they can operate the ReCon independently.

## CONCLUSIONS

Revision of the ReCon screen layout and appearance is in progress. To reduce the manipulation demands on the user, each window will be embedded into the application and be hidden based on viewing preferences. The pre-configuration and real-time modifications utilities will be combined and embedded into a similar structure. The current exercise status and non-configurable information will be grouped together, and the control buttons will be made more obvious. Finally, this application will be extended for use with several patients simultaneously. The current version of the ReCon is an improvement over the previous telerehabilitation software developed by our group. Some suggestions for improvement have already been implemented, while others are in progress. To facilitate its clinical adoption, this system will continue to be refined based on suggestions by therapists and patients.

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