Usability of the Remote Console (ReCon) for Virtual Reality Telerehabilitation: Formative Evaluation

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Abstract

Formative evaluation, a type of usability engineering methodology, was used to design and refine the Remote Console (ReCon). This is a telerehabilitation application, which allows therapists to remotely communicate with patients while monitoring and controlling their virtual reality rehabilitation exercises. It provides the therapists with visual representations of the patients' movements, as well as their exercise simulations replicated in a simplified form in real time. ReCon also provides therapists with the tools to conduct training without a face-to-face session. The Recon was evaluated by five physical therapists (acting as representative users) from different practice settings. 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.

Keywords

virtual reality, telerehabilitation, physical therapy, formative evaluation, usability engineering, ReCon.

1. INTRODUCTION

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

The Remote Console (ReCon) is an application for telerehabilitation which is a product of several iterations of development of its remote tools. The focus of the ReCon, the monitoring window, has evolved from a web-portal, which displayed finger angles of a single hand exercise [2] to a real-time web-based monitoring system for telerehabilitation, in which a 3D simulation is coupled with performance gauges from the rehabilitation site [6]. The development and refinement of the ReCon has followed usability 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 [7]. In Spring 2003, an initial usability study was conducted on the complete Rutgers Ankle Rehabilitation System (RARS) [8], including a session, which introduced therapists to the real-time web-based monitoring system [9,10]. This system was also tested as a component of a clinical trial on post-stroke individuals in the chronic phase [11]. As a result of these studies, several modifications were made on the interfaces of the RARS as well as 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) [12].

The ReCon system underwent a formative evaluation in Summer 2004 in order to gauge its ease-of-use and acceptance by representative users (physical therapists). This paper describes the ReCon's current implementation, its formative evaluation usability study, as well as proposed improvements to the system.

2. THE 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 [12]. This allows therapists to interact with a rehabilitation site from a remote location (Figure 1). Consistent with Rosen's recommendations [1] for telerehabilitation priorities,

the ReCon enables therapists to conduct training/counseling, monitoring/assessment, and therapeutic intervention from a remote location. Furthermore, the ReCon tools are available in real-time during a rehabilitation session.
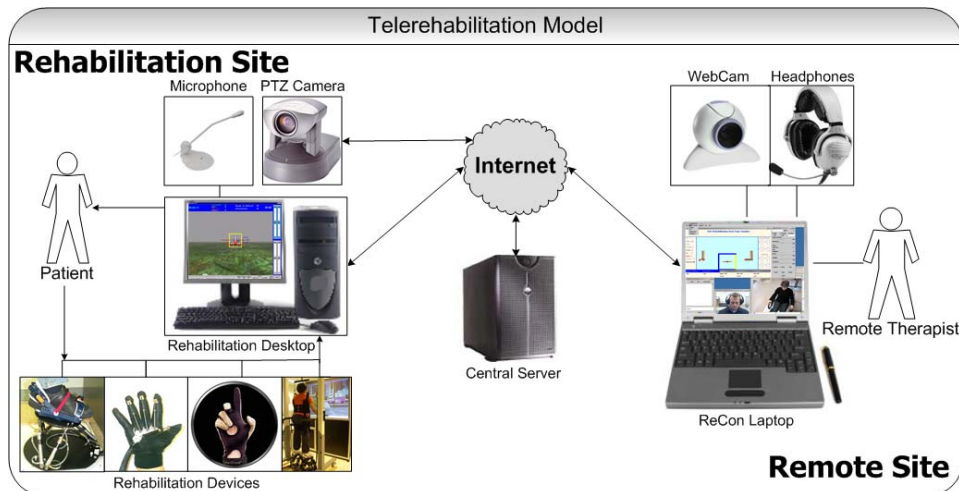

Figure 1. Telerehabilitation Model using the ReCon [12] ©UMDNJ, Rutgers University 2005.

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 (Figure 2). The MediaClient provides audio and video communication between the two sites as well as a chat window for private communication with the local therapist. The remote therapist can 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 the therapist to monitor and assess the exercise configurations and the patient's progress. As new simulations are created, 3D simplified versions are rendered and ported to the monitoring software. These data are updated in real time during the exercise.
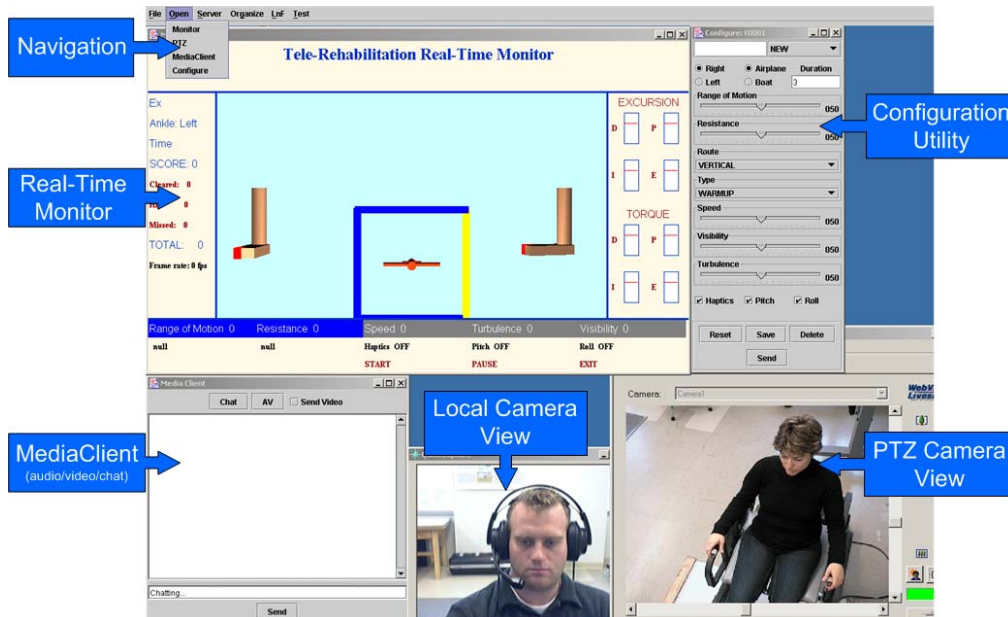

Figure 2. ReCon Desktop for a Lower Extremity Exercise [12] ©UMDNJ, Rutgers University 2005.

In 2003 a remote monitoring system was implemented for patients exercising in a virtual environment. The patients controlled a virtual airplane with their ankle, while overcoming resistive torques produced by the Rutgers Ankle robot [8]. In this implementation of the monitoring system, the remote therapists were unable to alter exercise parameters (such as airplane speed, resistive torques levels, duration of exercise) directly. Thus they

had to direct a local therapist located in the same room with the patient by communicating through a third-party audio/chat. This process was awkward and inefficient. Providing the remote therapists direct control over the session was deemed an essential feature. To accomplish this, the ReCon was integrated with a new communication architecture [13], which added the ability to send and receive flexible and predefined messages. In the current version of the ReCon, a therapist 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 this version of the Recon, which allows therapists the functionality of pre-configuring sessions. Before an exercise begins, 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 rehabilitation machine. This allows remote therapists to pre-set a sequence of exercises customized for the abilities of a given patient.

3. METHODS

In the initial study, conducted in 2003, five physical therapists (PT's) from different practice settings participated in a usability study primarily of (RARS). The study also introduced the earlier implementation of the remote monitoring software [9,10].

In this initial study, therapists attended two sessions. In the first session they read a set of instructions on how to use a virtual reality rehabilitation system (RARS). This entailed positioning a patient, setting and modifying exercise sessions. During the training, the computer screen, viewed by the therapists, as well as their comments, were recorded on video. The videotapes provided a record of therapists' questions and difficulties experienced while using the computer interfaces. The PT's returned for a second session to test their ability to reproduce what was learned in the first session. Next, they had the opportunity to learn how to run the VR system from a remote computer. The second session was also videotaped. Upon completing this session, users were asked to fill out a questionnaire that assessed the ease of use of the remote monitoring interface and their recall of the interface features.

Using feedback from the initial usability study conducted in 2003, the current implementation of the ReCon was developed. The subsequent formative evaluation, designed specifically for the ReCon system, is reported here. 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 received instruction with the ReCon and returned for a third training retention session. During the instructional session, the therapists were given an overview of the system and its elements, followed by an opportunity to practice using each of the interfaces. They then completed three exercises immediately following the practice. During the third session, the therapists were asked to complete three training exercises with a healthy user. A fifth PT was added who had never used the telerehabilitation system, however was very familiar with using the RARS from the rehabilitation side (User P5).

Questionnaires were tallied and videotapes coded. Video coding was performed according to methods suggested by a usability expert (W. Quesenbery, personal communication, August 2004). For each user, the tape was viewed to identify the points in the session where a problem was encountered during the use of the ReCon guided by the Therapist Manual. Figure 3 shows a portion of a sample coding sheet. The coding headings, definitions, and examples are described in Appendix I.

#	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

Figure 3. Sample of a video coding sheet. ©UMDNJ, Rutgers University 2005.

The completed code sheets were then compiled and observations were organized by the task in which the problem occurred. Each task was separated by their "Problem Type" categories. The following section details the problems encountered.

4. RESULTS
4.1 Video Coding

Figure 4, summarizes the results of the formative evaluation, and identifies the main problems encountered by the users in select 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 the problem (Users). The group headings (Problem Type) are listed alphabetically, and the specific problems, are listed by frequency, then by number of users who experienced the problem. Technical Problems were also identified and compiled in a similar fashion and are presented at the bottom of Figure 4. Clinical Comments and Terminology problem types are not included in the scope of this paper.

Problem Type	P1				P2				P3				P4				P5				Totals Sec.	Totals Users
	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Ov	Pr	E1	E2	Ov	Pr	E1	E2		
Cant Find Control																						
Selecting Rivers from pulldown in PTZ	1				1			1	1			1				1					6	4
Cant find Ex Type in Mon.						1				1				1				1			4	4
Manipulation																						
Leave Modifier unchecked		1	1			1		1			1				1	1					7	4
Capture Monitor Sizing Problem	1				1								1				1				4	4
Understanding Concept																						
Not clear what happens CU Sends Data		1										1				1				1	4	4
Confusing Modify and Configure	1	1	1																		3	1
Understanding Control Function																						
How to use CU		1					1					1							1	1	5	4
START Button				1			1				1				1						4	4
Visibility of System Status																						
Asked local to open window that was open	1						1	1			1		1							1	6	5
Technical Problem																						
Config Utility Not Sending		1	1									1								1	4	3
Audio quality								1			1			1							3	3
Audio echoing	1		1										1								3	2

Figure 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]

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 camera presets (for 3 users), and zoom (for 1 user). These errors, however, occurred only during the Overview section. Finding the button to modify the exercise type was an issue for four users. This difficulty was attributed to poor labeling as the button displayed the current exercise (such as warm up), rather than an "Exercise Type" label. The cognitive demand of knowing that warm up was a type of exercise proved too great for some users. Similarly, difficulties occurred with the "Route" button, which only displayed the current route without displaying the proper label. This problem was not as challenging as only two users were unable to find this button without cues. In each case, the users only required one cue to find this control, and could find it in the remaining sections.

The most frequent problem with **Manipulation** and across all categories**,** was, *Leaves modifier unchecked*. Although users knew that they wanted to remotely change a parameter, such as the speed of the airplane in the VR simulation ("Speed"), they would forget to select the green check mark to send the data to the exercise, and move on to the next parameter. This occurred across four users, and during the course of seven separate sections. Within each section, in most cases, users committed this error on several attempts to remotely modify a parameter. Another manipulation challenge occurred while users resized the local video monitor window. This window displayed the image that the web camera, at the user's site, was capturing and transmitting to the rehabilitation site. This was due to a problem with the Java Media Framework (JMF) [14] 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 common problems under the Manipulation problem type were Windows manipulations problems, such as resizing a window, moving windows and arranging the items in a manageable way.

The Configuration Utility (CU), a new feature introduced in this version of the software, proved to be confusing for most users. The CU is used for pre-configuring which should be done to set up future exercises, whereas the remote monitoring window is used to modify an exercise in progress. The problems with the CU 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. The same four users who were not clear on what happened when the Configuration Utility sends data, were unclear on 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 the "Understanding Control Function" category. 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. P2 asked "You have to press START twice?" and three other users had to be cued to do so.

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 to them, that if a configuration screen was being shown on the monitoring window, a configuration screen was open at the rehabilitation site. It may also be possible that they did not clearly recognize the difference between certain monitoring screens.

Throughout testing, several **Technical Problems** were encountered. The most frequently occurring problem was the Configuration Utility 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. Additionally, 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.

4.2 User Questionnaires

In addition to coding the videos, the PT users answered questionnaires after using the ReCon. Several statements were listed, and each was rated on a scale of **1** (strongly disagree) to **7** (strongly agree). In response to the statement *Overall, I am satisfied with how easy it is to use this system*, the average response was a **6**. The comments regarding the organization and usage of the interfaces were also rated positively. The statement *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 slightly higher. In general the response to the ReCon was positive, however the lowest rating (with an average of **1.75**) was for the statement *The system gives error messages that clearly tell me how to fix problems*.

Users were also asked to list positive and negative aspects of the ReCon system. The 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 that she would have to refer to the Manual several times before she could begin an exercise. Similarly, one therapist suggested, "the process of getting to different tasks must be memorized." When listing positive aspects, other therapists stated that 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."

5. 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, specifically, the addition of remote modifications and a configuration utility for pre-configuring exercises. The therapists' responses to questionnaires and comments extracted from the videotapes, show that the users generally enjoyed the control over the session that ReCon allows. 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 highlighted some problems with ReCon, which should be addressed to facilitate its clinical adoption. Instead of having to use separate utilities to remotely modify an exercise in progress or to pre-configure a follow-up exercise, it may be advantageous to combine their functionalities. Thus the CU that is present on the remote screen should be similar to the one used on the local screen. This will allow a therapist to modify parameters for future exercises, or modify the parameters of the current exercise 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 or being difficult to find. A solution may be 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 implementation. 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 perhaps 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 allows the ReCon to communicate with the rehabilitation site. This has been addressed since the usability study completion. The most recent version of ReCon 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 its media. 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. In order to gain control over the sending and receiving of media, a Java interface was written to control the sizes of the buffers of media sent. 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 so 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.

6. CONCLUSIONS AND FUTURE WORK

As a result of the formative evaluation described here, several common problems were identified. These issues ranged from basic manipulation issues to the therapist not being able to find a control, to not having a clear understanding of what a control is supposed to do. Additionally, several technical issues were identified during normal operation. The usability study was helpful in both identifying problems, as well as assisting in finding solutions.

A complete rework of the ReCon screen layout and appearance, using the same principle components may be very useful on the next iteration of the software. Figure 5 illustrates one concept layout for the next version of ReCon. To eliminate clutter and reduce the manipulation necessary by the user, each window would be embedded into the application and could be hidden based on viewing preferences (bottom). The pre-configuration and real-time modifications would be embedded into a similar structure to reduce the confusion between the two (left), and to allow for more intuitive usage. The current exercise status and non-configurable information will be grouped together (center), and the control buttons will be made more obvious (right-middle). Finally, this application can be used to monitor several patients simultaneously. Tabs (top) will allow the PT to organize the windows by patient.
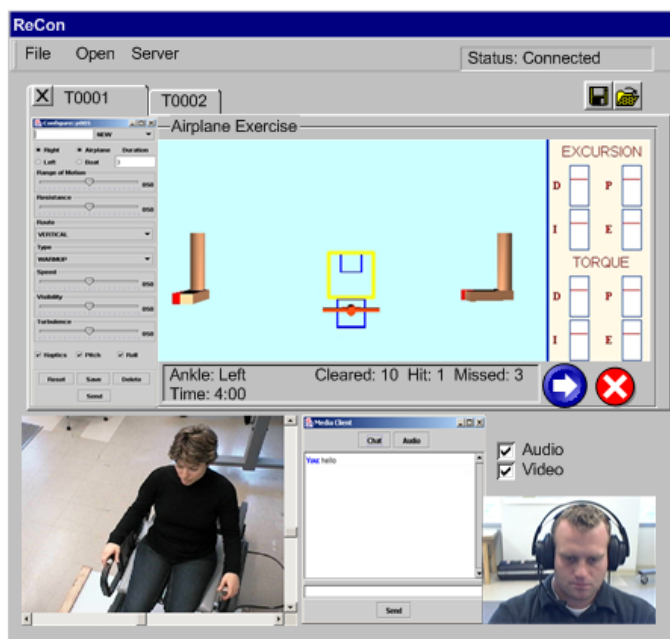

Figure 5. Layout for next version of ReCon [15] ©UMDNJ, Rutgers University 2005

The current version of the ReCon is an improvement over the previous telerehabilitation software developed by our group. Some suggestions for improvement, identified previously, have already been implemented. The remaining solutions will be implemented before its next use. The development of a complete telerehabilitation system is an iterative process. This system will continue to be refined based on suggestions by therapists and the patients.

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APPENDIX I

- **Index Number**
- **Observation Details** (user quote or observation of user action)
  - ie: "Is there a way to get a better view of this ankle?"
  - ie: does not select green check for speed setting
- **Task** (as defined by the manual)
  - Overview
  - Practice
  - Exercise
- **Problem Type**
  - Can't find control *(can not find a button or element)*
  - Terminology *(does not understand a label or other term)*
  - Manipulation *(does not properly use elements (ie: buttons, windows))*
  - Visibility of system status *(is unaware of the state of the system)*
  - Technical problem *(error due to system trouble (not user))*
  - Understanding control function *(does not under stand what a control does)*
  - Understanding concept *(does not understand how or why something works)*
  - Navigation *(does not properly load or change windows)*
  - Clinical Comment *(comments by therapist of a clinical nature)*
- **Window** (the ReCon element where the observation is made)
- **Comments** (coders comments on solutions or explanations)