The Usability of an Exercise-based Tele-rehabilitation Service
A Hybrid Methodology

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Abstract: Having usable technology is an imperative, especially for contemporary (elderly) patients with disabilities. The aim of the present document is to examine the usability of our exercise-based tele-rehabilitation service based on a hybrid approach in four different impaired user groups (elderly people with cognitive and/or movement and postural problems) and in its *context* (as a tele-rehabilitation service during rehabilitation treatment). A hybrid approach consisted of a task-oriented patient usability test and a one-year pilot-implementation during which problem software reports and change requests were collected from professionals. Across Europe, in total n=60 patients were included in the usability test suffering from pulmonary diseases, stroke, orthopeadic patients and patients suffering from Alzheimer. In addition, during the one-year pilot-implementation period in four European clinical centers (NL, PL, IT, ES), in total n=81 Software Problem Reports (SPR's) have been collected and n=43 Change Requests (CRs). In conclusion, this hybrid methodology allowed usability data to be retrieved from both an episodic and a longer period of use, controlled use and use in routine care, and focus on both the tele-rehabilitation software and service delivery, i.e tele-treatment protocols. Moreover, both the patient as well the professional perspective was incorporated.

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1 INTRODUCTION

The ageing of the population which leads to an aggravation of chronic conditions, the growing need for patients to become actors in their own health, and the necessity of controlling health care whilst maintaining high quality of care, place challenging demands on our current health care system. Within the European CLEAR project (= Clinical Leading Environment for the Assessment of Rehabilitation protocols in home care), an exercise based tele-rehabilitation service and clinical protocols have been developed and pilot-implemented in four clinical centers across Europe to treat (elderly) patients affected by pulmonary disease, stroke, Alzheimer, and orthopedic problems (requiring often total joint replacement) (www.habiliseurope.com).

Having usable technology is an imperative, especially for contemporary (elderly) patients with disabilities (Alexander and Staggers, 2009). The common goals of usability research are to improve the effectiveness, efficiency and satisfaction of people interacting with tools (Hornbæk 2006). Effectiveness includes the usefulness of a tool to complete (work) tasks. Examples of efficiency include time to complete specific tasks, the number of clicks to perform tasks or the amount of time needed. Satisfaction can include the perception of any aspect of the tool typically includes perceptions of the workload or the effectiveness of the specific design (Alexander and Staggers 2009).

Concerning the ISO 9241 definition, usability deals with the extent to which a product can be used by *specified users* to achieve the before mentioned *specified goals* (effectiveness, efficiency, and satisfaction) in a *specified context*. The users, goals (tasks) and context of our exercise-based tele-rehabilitation program are defined in Table 1.

Table 1: Specified users, goals and context.

Users	Patients suffering from pulmonary diseases, Alzheimer, Stroke and Arthritis
	Rehabilitation physicians, psychologists, physiotherapists
Goals	To enable multiple patients to exercise/train simultaneously in their own relevant context (either at home or at the clinic) under the remote supervision of an expert professional
Context	The location where the tele-rehabilitation is provided: at home, at the clinic or outpatient treatment facility
	The country where the tele-rehabilitation service is provided: The Netherlands, Poland, Italy and Spain

How to measure usability, by which tests and which parameters to be selected are important challenges in human-computer-interaction research (ISO, 1998; Frøkjær, 2000). The innovative and new context of tele-rehabilitation services even more increases the challenges associated with usability examination because it involves new technologies, new protocols for health care delivery (i.e. at home) and (often) impaired user groups (Monk, 2002). Expanding the knowledge on usability issues in the field of tele-rehabilitation would enable better fit between users (patients and professionals) and technology, thereby possibly maximizing the chances of successful adoption of tele-rehabilitation services in routine care.

The aim of the present document is to examine the usability of our exercise-based tele-rehabilitation service based on a hybrid approach in four different impaired user groups. This methodology is aimed at evaluating the usability of the service in its *context* (as a tele-rehabilitation service during treatment), thus the usability of the protocol for home-based treatment and keeping in mind a specific impaired target group (elderly people with cognitive and/or movement and postural problems).

2 METHOD

2.1 Exercise Tele-rehabilitation Service

The exercise tele-rehabilitation service consists of a notebook with webcam, with newly developed software giving access to a database of exercise videos and a teleconference service to facilitate contact between the patient and professional. With this new service the professional can compose a tailored exercise program for his patient. The patient can carry out the program on a self-scheduled time at the clinical at home or. The patient can record an exercise with the webcam and the recorded exercise can be assessed by the professional. Patient and professional can contact each other by teleconference to discuss the rehabilitation progress. The professional can schedule, add and delete exercises in the exercise program of the patient during the rehabilitation. The exercise tele-rehabilitation service enables patients to exercise at home at moments preferred by the patients, which fits in the current trend of self management of the patient. Screenshots of the patient GUI is presented in Appendix 1.

Table 2: Patient usability test: evaluation parameters based on framework of Hornbæk (2006).

Effectiveness	Description (Hornbeak et al 2006)	Parameter description in current study	Operationalization of parameter in current study	Results
Recall	Refers to measures of how much information users can recall after having used the interface.	Remembering how to complete the task after instruction	Patients self-report (0-1-2-3-4-5): 0=unable to remember 5= perfectly able to remember	Table 3a
Accuracy	Quantify the number of errors users make either during the process of completing tasks or in the solution to the tasks.	The number of mistakes patients make in completing the task	The number of mistakes will be counted retrospectively based on screen recordings during the task execution	Table 3a
Task completion	Refers to measures of whether users complete tasks or not	The percentage of patients who successfully completed the tasks	Patients self-report (yes/no) Examinator's observation (yes/no)	Table 3a
Quality of outcome	Is a more extensive attempt to measure the outcome or goal, for example to quality of the product	Overall score on quality	Patients grade for overall quality 1= low quality 10=high quality	Table 3b
Efficiency				
Time	Refers to measures of how long users take to complete tasks	Measure of how long users take to complete tasks	The average durations (expressed in minutes and seconds) will be calculated retrospectively based on screen recordings during the task execution	Table 3a
Input rate	Usually measured in number of studies, typically in the form of text entry speed (words per minute) or throughput.	Not applicable	--	--
Mental effort	Concerns the mental resources users spend on interaction	Ease of use – patient perception	Patient self-report (0-1-2-3-4-5) per task and overall 0= low ease of use 5= high ease of use	Table 3a/b
Usage patterns	Include measures of how the interface is used. The rationale behind these measures is that usage pattern is indicative of the resources users expend when trying to accomplish a task	The number of unnecessary actions taken / ratio between actual and ideal usage	The number of unnecessary actions will be analyzed retrospectively based on screen recordings during the task execution (median and range)	Table 3a
Communication efforts	Refers to measures of the resources users expend in communication, typically employed in studies of groupware	Not applicable	--	--
Learning measures	Use changes in efficiency as an indicator of learning, for example in the time used for completing tasks	Not investigated since users performed each task just once	--	--
Satisfaction				
Satisfaction	Many studies do not give details on the questionnaires used for assessing satisfaction: only the construct they were intended to measure.	Satisfaction associated parameters defined were: enjoyment, text length, navigation, text size, colors, lay-out and icons.	Patient self-report (0-1-2-3-4-5) 0= low satisfaction 5= high satisfaction	Table 3b
Preferences	Capture/force users to express their preference with respect to different products/alternatives	Patients recommending tele-rehabilitation program	Percentage of patients recommending tele-rehabilitation program to other patients or friends Percentage of patients preferring tele-rehabilitation over	Table 3b

2.2 Methodology

A hybrid methodology was used in evaluating the usability of the exercise-based tele-rehabilitation service.

(1) Patient usability test: consisting of a task-oriented examination of the usability during episodic use of the program in a laboratory setting

(2) Pilot-implementation: collecting problem software reports and change requests during a one-year period among professionals in order to provide information on usability issues during routine use in rehabilitation setting.

2.2.1 Patient Usability Test

Four different patient populations were invited to participate in the usability study namely patients with pulmonary diseases (The Netherlands), stroke (Italy), orthopeadic patients (Poland) and patients suffering from Alzheimer (Spain). All patients were invited to local institutes to participate in a 2-hour usability test during which they have to complete four pre-defined concrete tasks being (1) start your computer and log in, (2) start the patient exercise module and watch tutorial, (3) Execute an exercise and record the execution with video, (4) communicate with the therapist by videoconferencing. The usability parameters defined by Horbæk (2006) were operationalized into concrete parameters for this study (see Table 2).

2.2.2 Pilot-implementation Test

The exercise-based tele-rehabilitation program was pilot-implemented as part of the traditional care service for a period of one year. Besides investigating the clinical impact, the scope of this pilot-implementation was to collect in systematic way relevant information regarding the requested improvements of the service as a result of actual use in a daily setting for a long(er) period of time.

The feedback collected have been divided in two main categories (a) Software Problem Report (SPR) and (b) Change Requests (CR). SPR's deal with information related to software malfunctions of the service that prevent the proper delivery of the service. These are mainly related to bad functioning of modules noticed by the health care professionals during their activities with the software. CRs deal with a request of modification that is related to the particular service model in use. These requests deals

Table 3a: Patient usability test results for effectiveness and efficiency.

Usability tasks	TASK1: Start computer and log-in to the exercise-based tele-rehabilitation program				TASK2: Start exercise module and watch tutorial				TASK3: Record the execution of an exercise for the therapist				TASK4: Start a videoconferencing with your therapist			
Type of patients	PULM N=13	STROKE N=15	ORTH N=17	ALZH N=15	PULM N=13	STROKE N=15	ORTH N=17	ALZH N=15	PULM N=13	STROKE N=15	ORTH N=17	ALZH N=15	PULM N=13	STROKE N=6	ORTH*	ALZH*
EFFECTIVENESS															--	--
Ability to execute the task after instruction Patients self-report (median and range)	5.0 (0-5)	5.0 (1-5)	5.0 (3-5)	2.7 (1-4)	5.0 (4-5)	4.0 (1-5)	5.0 (3-5)	3.5 (3-4)	5.0 (4-5)	5.0 (1-5)	5.0 (3-5)	4.1 (3-5)	5.0 (4-5)	4.0 (3-5)	–	–
The number of mistakes (median and range)	0 (0-5)	0 (0-3)	0 (0-5)	0.7 (0-2)	0 (0-2)	0 (0-5)	0 (0-1)	0.5 (0-1)	0 (0-2)	0 (0-7)	0 (0-1)	0.5 (0-2)	0 (0-0)	0 (0-0)	–	–
%patients successfully completed the task Examinations judgment	100%	93.3%	100%	0%	100%	100%	100%	0%	100%	100%	100%	66%	92.3%	100%	–	–
%patients successfully completed the task Patients self-report	100%	93.3%	100%	86.6%	100%	100%	100%	100%	100%	100%	100%	100%	92.3%	100%	–	–
EFFICIENCY																
Time to complete the tasks (median and range)	52 s (12-263)	42 s (2-354)	37 s (8-165)	1m.48s (61-145)	45 s (30-232)	26 s (6-84)	60 s (30-120)	20.6s (10-34)	2m 42s (43-651)	22 s (12-86)	62 s (29-110)	15m 6s (660-1800)	3m 50s (30-343)	53 s (25-84)	–	–
Usage: number of unnecessary steps (median and range)	0 (0-5)	0 (0-5)	0 (0-1)	0.6 (0-2)	0 (0-4)	0 (0-5)	0 (0-0)	0.3 (0-1)	0 (0-6)	0 (0-7)	0 (0-1)	0.9 (0-2)	0 (0-1)	0 (0-0)	–	–
% patients who needed assistance during task completion	7.7%	40%	29%	100%	7.7%	40%	12%	100%	7.7%	33%	23%	40%	7.7%	17%		–
Ease of use Patients self-report (median and range)	5.0 (3-5)	5.0 (1-5)	5.0 (3-5)	3.5 (3-4)	5.0 (3-5)	5.0 (3-5)	5.0 (3-5)	3.5 (3-4)	5.0 (3-5)	5.0 (3-5)	4.0 (3-5)	3.9 (3-4)	5.0 (3-5)	4.0 (3-5)	–	–

*videorecording not part of the treatment protocol as such not tested for ALZH. Videoconferencing not tested for ORTH.

mainly with improvements request of a particular module or function that is not optimal for the scope, addition of new functionalities, interoperability aspects related to integration with the Hospital Information System (HIS) in use in the concerned centre.

2.3 Statistical Analyses

All analysis will be conducted on a group-level. For the usability parameters containing ordinal answering scales derived from the patient test, non-parametric descriptive statistics (median and range) will be calculated. For the usability parameters containing a dichotomous answering format, percentages will be calculated. For the pilot-implementation the amount of SPRs and CRs will be presented as well as a summative description of the categories for which SPRs and CRs will be provided.

3 RESULTS

3.1 Patient Usability Test

In total n=60 patients participated in the usability test. Among these are n=24 males and n=36 females. The mean age of the participants is 63.6 years (range 31-94). The results of the patient usability test are presented per parameter per task per pathology in Table 3a.

3.1.1 Effectiveness

Except for the patients suffering from cognitive impairments due to Alzheimer's disease, participants were confident about their ability to remember how to execute the different tasks. Interestingly, on average few mistakes were made in the completion of the tasks by the participants. However, the ranges indicate that mistakes were made. Typically, mistakes were associated with remembering passwords or typing errors (task 1), forgetting to click the start (Task 2, 3) and/or stop button (Task 3). In addition, as illustrated by the percentage of patients who not completed the tasks successfully the tele-rehabilitation software also contained some problems. For instance, webcam connectivity problems were faced as well as poor image quality during videoconferencing (Task 4). As indicated by the discrepancy in % interpretation of successful completion between the examinator and patients'self-report, Alzheimer patients' seem to be not fully aware whether or not they completed the tasks successfully.

3.1.2 Efficiency

As shown in Table 3a, the duration to log in (Task 1) and to start and watch the exercise tutorial (Task 2) was rather comparable between patients suffering from pulmonary diseases, stroke and orthopedic problems. Patient suffering from Alzheimer's disease needed more time to log in. For task 3, large differences existed between the patient populations.

Table 3b: Results of the laboratory usability for satisfaction of use (n=60).

Satisfaction	PULM N=13	STROKE N=15	ORTH N=17	ALZH N=15
Text length	4.0 (3-5)	4.0 (4-5)	3.0 (3-4)	3.5 (3-4)
Understandability	4.0 (3-5)	4.0 (4-5)	3.0 (3-4)	3.4 (3-4)
Quality of images	3.0 (1-4)	4.0 (4-5)	3.0 (3-4)	3.4 (3-5)
Qual. navigation	4.0 (3-5)	4.0 (4-5)	3.0 (3-4)	3.5 (3-4)
Text size	4.0 (3-5)	4.0 (4-5)	3.0 (1-5)	3.5 (3-4)
Colours	4.0 (3-5)	4.0 (4-5)	3.0 (3-4)	3.8 (3-4)
Lay-out	3.0 (3-5)	4.0 (4-5)	3.0 (3-3)	3.7 (3-4)
Pictograms	4.0 (3-5)	4.0 (4-5)	3.0 (3-4)	3.7 (3-4)
Ease of use	5.0 (3-5)	5 .0 (1-5)	4.0 (1-5)	3.4 (2-5)
Comfortability	3.0 (2-5)	3.0 (2-4)	2.0 (1-4)	3.7 (3-5)
Enjoyment	3.0 (2-5)	5.0 (2-5)	5.0 (3-5)	3.9 (3-4)
%patients who would recommend program to other patient	77.0%	93.4%	100%	73.3%
who would recommend program to friends	69.2%	86.8%	100%	80%
%patients who prefer tele-rehabilitation over traditional care	15.4%	46.6%	29.4%	80%
Overall score on quality (median and range)	6.0 (4-9)	7.0 (5-10)	9.0 (7-10)	8.0 (5-10)

These data can however not be directly compared between the populations since they all recorded different exercises, relevant to their pathologies. The relatively long duration to set up a videoconferencing by patients with pulmonary diseases could be explained by connectivity problems (one patient had to wait three minutes). One patient forgot to put on the headset which was necessary to communicate by voice/audio with the therapist. Remarkably, despite the fact that patients were rather satisfied about the ease of use (>3.5) of the tele-rehabilitation program none of the patient groups was able to complete the tasks without help (to a greater or lesser extent). As could be expected, patients suffering from Alzheimer had an inefficient use pattern of the software which is (again) probably due to their cognitive impairments

3.1.3 Satisfaction

The results of the satisfaction parameters are illustrated in Table 3b for the different pathologies.

On average, patients were satisfied with the text length and understandability of the instructions as well as the quality of the navigation, text size, colors and pictograms (median satisfaction scores > 3.0). The quality of the interaction with the software was perceived sufficient to excellent varying from grade 6.0 by patients suffering from pulmonary diseases to a score of 9.0 by patients suffering from orthopedic problems. In general, the majority of patients (> 69.2%) patients stated that they would recommend the software to another patient or friend.

However, the variance in percentage of patients who preferred tele-rehabilitation over traditional care is high between the pathologies. In our opinion, this variance could be explained by the difference in treatment protocols, i.e. the extent to which the tele-rehabilitation service substitutes traditional care. For instance, 80% of the orthopedic patients prefer tele-rehabilitation versus 15.4% of the pulmonary patients. In the latter group, tele-rehabilitation partially substituted traditional care whereas in the orthopedic group tele-rehabilitation was provided supplementary to traditional care.

3.2 Pilot-implementation Test

During a one-year pilot-implementation period in four European clinical centers (NL, PL, IT, ES), in

total n=81 Software Problem Reports (SPR's) have been collected and n=43 Change Requests (CRs). The exact nature of the SPR's and CRs are too specific for the technology used to describe and analyze in detail in the current paper.

In general, the SPRs sent by the clinical centers concern hanging applets, usability of log in and tutorials for patients and professionals, bugs, more flexible use of the tutorial management (should be possible to add new exercises or remove ones and show adequate sequence of exercises), connectivity and/or audio quality of the videoconferencing, patient exercise interface, webcam management, and browser interactions.

In general, the description of the CRs concern viewing back a just recorded exercise, delete a just recorded exercise and replace by a new one, add mandatory fields in forms, network policies, to allow therapists to define a proper order in which the selected tutorial will be shown to the patient, increase the size of the log out button, bandwidth issues, a videoconferencing call should not be able to interrupt the patient during exercising, translation of content to different languages, add personalized exercise instructions, and client stations should be allowed to access the service without the needs of a VPN connection.

4 CONCLUSIONS

The current study investigated the usability of an exercise-based tele-rehabilitation service in four different countries, representing four different patient populations being patients suffering from pulmonary diseases, stroke, orthopeadic problems or Alzheimer's disease. Patients (n=60) were characterized by physical and/or cognitive impairments typically associated with their pathologies and relatively high age. A hybrid usability methodology was embraced consisting of (1) a laboratory patient usability test and (2) a pilot-implementation period of one year duration.

For the usability test, the patients had to execute four predefined tasks (start up PC and log in to the service, start and view exercise tutorial, record an exercise, start and conduct a videoconferencing with a therapist). The usability parameters examined were derived from the framework of Hornbæk (2006). During the one-year pilot implementation the usability of the service was examined by means of collecting n=81 Software Problem Reports (SPRs) and n=43 Change Requests (CR).

The innovativeness and strength of our hybrid methodology lies in the retrieval of usability data from both an episodic and a longer period of use, controlled use and use in routine care, and focus on the tele-rehabilitation software and service delivery, e.g. tele-treatment protocols. Moreover, both the patient as well the professional perspective was incorporated in this methodology. In addition, our operationalization of the framework of Hornbæk (2006) into concrete parameters could be valuable for other researchers in the field of evaluating the usability of similar services.

Because of the fact that the patient study and pilot-implementation contained different methodologies and parameterizations not all results may be easily comparable. In our view, this should not be considered to be a weakness of the methodology but a valuable strength. Together this information provides a broad(er) perspective on usability and recommendations to improve it. Interestingly, commonalities in usability issues were found between the patient usability test and the pilot implementation. These commonalities dealt with log in and log out problems and issues with respect to the videoconferencing module and connectivity.

The methodology could be improved by repeating the patient usability test over time during the (pilot-) implementation (Hornbæk, 2006). Another recommendation for methodology improvement is to extend the measure of satisfaction by post-use Likert-scales as done in the current study by validated and standardized questions. As illustrated by the 'regression to the mean' trend, results of the satisfaction questionnaire tended towards 'socially desirable' answers by the users.

Lastly, the parameters used are not intended to serve as an exclusive list of usability parameters. Instead, according to Hornbæk (2006), it provides usability researchers an overview of the possible parameters that *can* be applied. Researchers should select the parameters to be most relevant for their own research purposes and concretized for the service they want to evaluate.

As could be expected on advance, patients with Alzheimer's disease had more difficulty in using the tele-rehabilitation service compared to patients suffering from pulmonary diseases, orthopaedic problems and stroke. This is probably due to their severe cognitive impairments of the Alzheimer population included in the present study. This result does reveal the recommendation for other investigators to take into account the characteristics of the target users and their pathologies when designing innovative technology-based treatment

concepts. For instance, instead of remembering passwords fingerprints log in would have been more suited for patients with cognitive impairments.

Results showed that the majority of patients were able to complete the tasks successfully without many unnecessary actions and mistakes. However, despite the fact that all patients were trained in using the service under study prior to participation (some of them actually used the service during their rehab treatment!) and that patients reported to be rather satisfied about its ease of use, the majority of them still needed help/assistance. Apparently, it is not realistic to assume that patients who passed the training and believe they are confident to use the service are actually able to use the service adequately independently. This result has major clinical implications. Without having insight into the effectiveness and efficiency of use of software by patients, therapists will hardly be able to explain (poor) clinical impact due to inadequate use and the (content of the) treatment. This lack of insight in the use can be addressed by the technology and/or the service delivery. From a technology perspective, automatic usage logs and compliance measures could be integrated in the system. From a service delivery perspective, it is strongly recommended to organize assistance for patients while interacting with the service e.g. by therapists (when interacting inside the rehab facility) or informal caregivers (when interacting at home).

Results showed that the majority of patients would recommend the service to other patients or friends. Major reasons for recommending the service is the fact that it offers the opportunity to receive additional specific instructions during training (at home or at the rehab facility) as a mnemonic. Nevertheless, the patients groups differed in the degree to which they preferred the tele-rehabilitation service compared to regular in-person care (with lowest preference score for patients with pulmonary diseases and highest score for patient with Alzheimer disease). These differences could be explained by the differences in the way the tele-rehabilitation is embedded in regular in-person care during the pilot-implementation between the groups. For instance, for pulmonary patients, tele-rehabilitation is offered as a (partly) replacement of traditional in-person care, i.e. service delivery whereas for patients with Alzheimers' disease the tele-rehabilitation service is used as an extra training modality inside the rehabilitation facility. Consequently by carefully considering an optimal design for the service delivery for tele-rehabilitation innovations one could be able to affect the users' attitude and possibly the degree of (future) adoption by these users.

A recent systematic review showed that the usability evaluations differed in methodologies and quality indicators for usability making it difficult to reveal abstractions, i.e. commonalities in failures and facilitators for usability of clinical technology that can be used by others (Alexander and Staggers, 2009). However, it can be concluded that the present study revealed at least three recommendations for usability design for exercise-based tele-rehabilitation services. First, one should carefully consider the characteristics (e.g. cognitive versus physical impairments) of the pathologies of users involved. Our results showed different usability issues for the different pathologies. Second, insight in adequate use of the technology is crucial when evaluating the clinical impact. Our results showed that the majority patients were not capable of using the program adequately despite them having successfully passed their instruction session. Third, careful consideration of how the tele-rehabilitation is embedded in regular in-person care, i.e. the service delivery, affects the attitude of patients toward and possibly the successful adoption of these innovative interventions.

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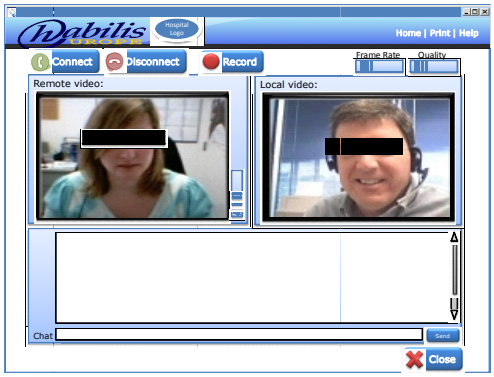
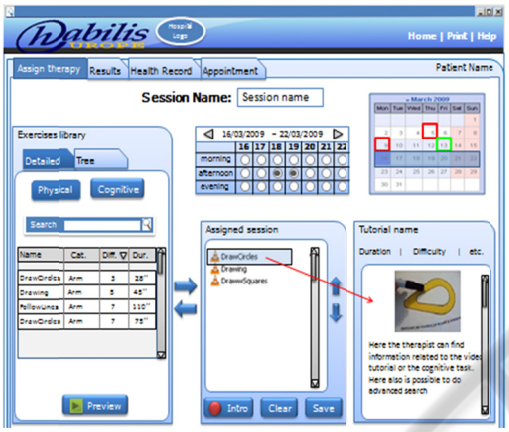
APPENDIX 1

Screenshots of the tele-rehabilitation service



Videoconferencing therapist - professional



Assigning exercise from library to patient

Example of an exercise video