

Improving brain injury cognitive rehabilitation by personalized tele-rehabilitation services: Guttmann Neuro Personal Trainer

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Abstract—Cognitive rehabilitation aims to remediate or alleviate the cognitive deficits appearing after an episode of Acquired Brain Injury (ABI). The purpose of this work is to describe the tele-rehabilitation platform called Guttmann Neuro Personal Trainer (GNPT) which provides new strategies for cognitive rehabilitation, improving efficiency and access to treatments, and to increase knowledge generation from the process. Cognitive rehabilitation process has been modeled to design and develop the system, which allows neuropsychologists to configure and schedule rehabilitation sessions, consisting of set of personalized computerized cognitive exercises grounded on neuroscience and plasticity principles. It provides remote continuous monitoring of patient's performance, by an asynchronous communication strategy. An automatic knowledge extraction method has been used to implement a decision support system, improving treatment customization. GNPT has been implemented in 27 rehabilitation centers and in 83 patients' homes, facilitating the access to the treatment. In total, 1660 patients have been treated. Usability and cost analysis methodologies have been applied to measure the efficiency in real clinical environments. The usability evaluation reveals a System Usability Score higher than 70 for all target users. The cost efficiency study results show a relation of 1 to 20 compared to face-to-face rehabilitation. GNPT enables brain-damaged patients to continue and further extend rehabilitation beyond the hospital, improving the efficiency of the rehabilitation process. It allows customized therapeutic plans, providing information to further development of clinical practice guidelines.

Index Terms—cognitive science, rehabilitation, telemedicine.

I. INTRODUCTION

Acquired Brain Injury (ABI) is defined as brain damage that suddenly and unexpectedly appears in people's life, being the main cause of disability in developed countries [1]. The World Health Organization (WHO) [2] predicts that by the year 2020 Traumatic Brain Injury (TBI) and stroke, the two main causes of ABI, will be within the top five etiologies considering not only the economic cost, but also costs related to Disability-Adjusted Life Year (DALY), that can be thought of as the number of years of normal life lost by the disability.

Cerebrovascular disease is the second leading cause of death and the eighth cause of severe disability in the elderly. Annually, 15 million people worldwide suffer a stroke.

Statistical data show that after a stroke, one third of patients die during the first month, and 40% of people who recover from the acute phase exhibit a high degree of impairment that decreases their independence and quality of life. Only one third of patients recover their basic functions and can resume a normal life [3]. The WHO estimated that in 2005, the number of people suffering a disability as a consequence of a stroke accounted for 30.7 million people [1].

On the other hand, according to the WHO, TBI will exceed many diseases as the major cause of disability by the year 2020. Worldwide, an estimated 10 million people are affected by TBI every year [4]. Its incidence over industrialized countries is in a range of 200 to 300 per 100,000 habitants, with an average age range between 16 to 35 and mostly male [5]. Although the incidence of TBI is lower compared to dementia, the associated cost is even higher, due to the early age of the affected people [6]. Furthermore, both stroke and TBI increase the risk to develop dementia earlier in the future [7].

According to the Brain Injury Association of America, consequences of an ABI vary between cases and can cause motor, cognitive and behavioral deficits to the patients, disrupting their daily life activities at personal, social and professional levels. Cognitive deficits are of particular concern regarding further independence, because they make even harder to cope with physical disability. The most important cognitive deficits after suffering an ABI are those related to attention, decrease of memory and learning capacity, worsening of scheduling and solving problems capability, reduction of abstract thinking capabilities, communication problems, and limitations on self-consciousness about their own condition. As a consequence, these cognitive impairments hamper the path to functional independence and a productive lifestyle [1].

New techniques of early intervention and the development of intensive ABI care have noticeably improved the survival rate. However, despite these advances, brain injuries still have no surgical or pharmacological treatment to re-establish lost functions [8]. Cognitive rehabilitation is defined as a process whereby people with brain injury work together with health service professionals and others to remediate or alleviate

cognitive deficits arising from a neurological insult [9]. This is achieved by taking advantage of the plastic nature of the nervous system [10], where the brain can reconfigure its connections, both creating new ones, or modifying the previously existing. Plasticity is an intrinsic property, being always present, but it can lead to either adaptive or maladaptive changes [11].

Neurorehabilitation aims to optimize the plastic nature by inducing a reorganization of the neural network, based on specific experiences. However, the probability of new maladaptive patterns is much higher than in normal conditions, where changes take advantage of phylogenetical evolution. Personalized interventions from individual impairment profile will be necessary to optimize the remaining resources by potentiating adaptive responses and inhibiting maladaptive changes.

In addition, it is well described in basic neuroscience whether neurobiological correlates of right responses are different than the neural network activated during wrong responses, having a differential impact on the establishment of plastic changes. This makes necessary to continuously monitor the responses, because exposure to stimuli would not be enough to induce adaptive changes, and a specific number of right responses seems to become critical in order to consolidate induced responses [12].

Despite the existence of empiric and experimental knowledge about the benefits of cognitive training in neuropsychological rehabilitation [13], extending it to most potential users fails because of important limitations. First, the traditional on-site intervention model requires a neuropsychologist supervising the procedure, to administer exercises and cues, based on patient performance. The cost of this process limits the intensity and length of the treatments, compromising sustainability, accessibility and scalability. Besides, the patient is forced to move to the clinical center, making the duration of the treatment conditional to the patient's availability. Second, clinical practice guidelines to allow a rational extension of these services are missing, and successful experiences find difficulties to disseminate results around professionals, generating the "lack of evidence" phenomenon.

In the last years some applications and software programs have been developed to train or stimulate cognitive functions of different neuropsychological disorders, such as ABI, Alzheimer, psychiatric disorders, attention deficit or hyperactivity disorder (ADHD). Some of the most relevant software solutions are BrainTrain, Feskits, Vienna Test System + Cogniplus/RehaCom, FastForWord or Cogmed. However, almost all of them are conceived as stand-alone applications oriented to train cognitive functions in single individuals, not allowing personalization and monitoring of the process, as well as data management for evidence generation and service innovation [14]. Due to the heterogeneity of lesions and deficits, individualization of therapeutic plans become

necessary, as well as their storage for further consideration in efficacy studies. In addition, performance monitoring of every cognitive exercise becomes essential to appropriately design well-controlled efficacy studies.

Besides, while there is wide documentation of efficacy of computerized cognitive training in dementia, there is no evidence in the literature of an evaluation carried out in large populations of ABI patients, trying to demonstrate the usability and effectiveness of this new kind of clinical rehabilitation programs.

Telemedicine allows improving the quality of clinical services, providing better access to them and helping to break geographical barriers [15]. Moreover, one of the main advantages of telemedicine is the possibility to extend the therapeutic processes beyond the hospital (e.g. patient's home). As a consequence, a reduction of unnecessary costs and a better costs/benefits ratio are achieved, making possible a more efficient use of the available resources [16,17].

A number of reported experiences have been trying to demonstrate the use of telemedicine as a better way to perform the neuro-rehabilitation, making possible for therapists to schedule rehabilitation sessions that patients can then asynchronously execute at home, on a supervised and more efficient way [18,19]. Furthermore, findings are comparable or better than those from reviews of more traditional, paper-and-pencil cognitive training approaches, suggesting that computerized training is an effective alternative [20].

This paper presents a tele-rehabilitation platform, called Guttman, Neuro Personal Trainer (GNPT), which has been integrated in clinical routine over the last three years in several rehabilitation centers. It addresses the rehabilitation of patients with cognitive impairments, using advanced technologies and knowledge, grounded on cognitive neuroscience, plasticity and neuropsychology (traditional rehabilitation experience and strategies). It allows the provision of individualized and personalized treatments, improving the traditional on-site rehabilitation processes. Besides, as one of the most differential distinctiveness, it incorporates a decision support system that systematizes the classification of each patient's individual characteristics, it identifies the comparable cases, and it provides to the therapist the most successful experiences stored in the system for his or her consideration. This procedure empowers the therapist to design the personalized plans based on the highest degree of evidence available at any moment.

Summarizing, GNPT is conceived as a large-scale and holistic solution, enabling to complete and extend the traditional rehabilitation process beyond the rehabilitation centers towards day centers or patients' homes. The final aim of this work is to identify the instrumental and methodological limitations of the traditional face-to-face rehabilitation, and to develop a platform to manage, register and monitor treatments, increasing the efficiency of the process.

II. MATERIALS AND METHODS

A. Rehabilitation process

A model of the rehabilitation process has been developed to define the requirements and functionalities of the final system. The design process of the GNPT system is supported by a user-centered and model-based design methodology. For this purpose UML has been used, describing the system's behavior through use cases and sequence diagrams.

The rehabilitation process defined in GNPT starts by assigning a patient to a therapist responsible for the treatment. The therapist has then to perform the initial neuropsychological assessment, consisting of a set of validated tests used to evaluate cognitive functions (attention, memory or executive functions) prior to the treatment.

Each test's item has been semantically translated onto the International Classification of Functioning, Disability and Health (ICF) [21], as a common taxonomy to describe patients' cognitive and functional impairment. This process will help to escalate the use of the system, because it permits to introduce new evaluation tools and compare results in a common taxonomy framework. The results of these tests will be stored in the system as the PRE neuropsychological assessment. Then, the cognitive profile is calculated using these PRE results, after a normalization process that takes into account the patient's age and study level, following the ICF standard. This patient's profile gives the therapists relevant information to support their treatment decision.

Usually, cognitive rehabilitation treatments consist of 3 to 5 sessions per week, with a total of 60 sessions. The therapist defines these rehabilitation sessions by assigning a set of computerized tasks to a certain day, configuring the input parameters of each task in order to personalize treatments (e.g. number of images, presentation speed, or latency time). Once a rehabilitation session is defined, the patient executes the assigned tasks, sending the results back to the server, so therapists can asynchronously see the performance. These results help therapists to select the difficulty level for the next sessions, adjusting treatments to patient's evolution.

The system defines three different ranges of performance according to each task's execution score:

- Therapeutic range, when the score is between 65% and 85% of correct answers. The patient executes the task with an appropriate difficulty configuration in order to get the best treatment effectiveness.
- Infra-therapeutic, when the score is below 65%. The difficulty level of the task is too high for the patient's capacity and could also lead to frustration.
- Supra-therapeutic, when the score is above 85%. The difficulty level is too low for the patient's capacity and the neurological activation is not being high enough. Could also lead to boredom.

These ranges are used by the system to improve the effectiveness of the rehabilitation, by automatically re-launching a task when the score of the patient on that task is out of the therapeutic range, re-adjusting the difficulty level. The objective is to have the patient most of the time executing tasks in therapeutic range, trying to avoid the too easy (supra) or too difficult (infra) ranges during the treatment.

After a patient completes the treatment, the therapist performs the final neuropsychological assessment (POST), which is compared to the PRE one in order to determine the improvement of the patient's cognitive capacities.

B. User requirements analysis

For the elicitation and definition of user requirements a detailed process was followed, using requirements structured questionnaires and both face-to-face and online interviews and meetings, with the neuropsychologists from the Institut Guttmann. In order to achieve a more efficient rehabilitation, the following requirements have been identified:

- Therapists need to decrease their devoted time to manage treatments, using an asynchronous connection model.
- More personalized and more intensive treatments are needed, in order to provide more efficient cares.
- To obtain an objective evaluation, a remote continuous monitoring of patient's performance is needed, always based on clinical criteria.
- Real time results processing and intelligent data management are desirable in order to offer more suitable therapeutic options depending on the patient's characteristics and progress.
- The system must allow the establishment of clinical guidelines based on the knowledge extracted from data collected by computer systems.

C. Rehabilitation computerized tasks

The rehabilitation content used in GNPT consists of a set of computerized cognitive exercises covering different cognitive functions and subfunctions (see Table I) [22]. Every task has been specifically designed by neuropsychologists of the Institut Guttmann based on cognitive paradigms to address specific cognitive subfunction, in order to obtain a better personalization of the treatment according to the patient's specific needs. In total, GNPT has 95 different tasks designed for rehabilitating ABI patients.

TABLE I.
COGNITIVE FUNCTIONS AND SUBFUNCTIONS CLASSIFICATION

Category	Cognitive function	Cognitive subfunction
ABI	Attention	Sustained
		Selective
		Divided
	Memory	Verbal
		Visual
		Working
	Executive functions	Scheduling
		Inhibition
		Flexibility
		Sequencing
		Categorization

To make possible that patients with different degree of impairment maintain a certain critical level of right responses, every rehabilitation task has a set of parameters (e.g. number of images, presentation speed, or latency time), which can be used to configure different difficulty levels. Therefore, therapists can adjust the difficulty level to the specific needs of each patient. Neuropsychologists have also defined how the execution result is calculated, based on several performance parameters (correct and wrong answers, omissions, execution time, etc.) depending on each task. Thus, when a patient performs a task, a score between 0 and 100 is always calculated and stored related to that execution.

Universal accessible interfaces are a key factor in every telemedicine platform, even more when the target users are patients who have suffered an ABI with problems in their cognitive capacities [23]. In general, a simple and consistent design is desired to make the patient feel familiar with the environment. Thus, every rehabilitation task has a common interface design, which aims to achieve the maximum usability, based on the common cognitive deficits of brain-damaged patients, related to perception, attention or the semantic memory system. For enhancing usability, patterns of consistency and coherence have been applied in order to maintain uniformity in screen design regarding backgrounds and layout of the different elements and accessibility usability guidelines have been used [24]. Likewise, the same colors prevail in the common elements of the different tasks for an easier and more intuitive identification. Besides, using simple interaction methods, such as mouse clicks on big buttons, facilitates the possibility of using the same interface for touch screen devices.

Two examples of rehabilitation tasks are shown in Fig. 1:



Fig. 1. a) Working memory task example; b) Sustained attention task example

In order to show examples of how each task has been specifically design to treat a cognitive function, the task shown

in Figure 1.a consists of presenting a sequence of visual stimuli (pictures) and, after a latency time, the patient has to click the elements in the same order that they appeared before. The main cognitive function treated here is working memory, specifically the difficulty that a patient has to remember objects seen previously. On the other hand, Figure 1.b represents the bingo task, where the patient has to find the target number, shown at the top of the screen, among all the numbers of the card. This task tries to rehabilitate sustained attention, specifically the difficulty that a patient has to maintain the attention on a specific task over a long period of time.

D. Exploratory study

A preliminary study has been carried out to analyze the clinical outcomes of the process. GNPT system is running at the Institut Guttmann Hospital in clinical routine, so specific ethical approval is not required to carry out this study. Nevertheless, clinical data usage is aligned with the Declaration of Helsinki, and every treated patient had previously agreed to allow for the use of anonymized data derived from their treatment, for research purposes.

In total, 887 patients have been included in the study, all of them having a complete PRE and POST neuropsychological assessment. From these 887 patients, 663 of them have received treatment at the Institute Guttmann, 141 in other clinical centers, and 83 have completed their treatment at home. The inclusion criteria for ABI patients was to be older than 17. Regarding the distribution of the cohort, 602 are men (67.96%) and 285 women (32.23%), and considering the etiology, 612 (69%) patients suffered ABI from a TBI, 152 (12.13%) from stroke and 123 (13.87%) from other causes.

III. RESULTS

A. Tele-rehabilitation platform architecture

GNPT system is based on a telemedicine architecture that has been defined to support this kind of tele-rehabilitation services [25], grouping related functionalities into modules. Security aspects come transversally, and have to be taken into account across every module to keep information and all connections safe to ensure patient confidentiality. The security module is responsible of controlling every access, including those related to the patients' Electronic Health Record (EHR).

A Model-View-Controller (MVC) pattern has been followed, so the view and the logic to access and process data are separated. The main modules defined in the architecture are described below:

- *Communication*: the main element of this module is a customized and very usable videoconference, which allows therapists to do tele-appointments with their assigned patients, helping to avoid isolation when following treatment at home. One of the main challenges addressed in this work has been the implementation of a web-based videoconference application, so the users do not need any local software installed in their computers. For this module OpenMeetings has been used, which implements the Real

Time Multimedia Protocol (RTMP), using a red5 server for the audio and video streaming. Additionally, a virtual community has been integrated into the platform, where patients and therapists find a place to interact, sharing experiences and concerns related to the disease. Besides, this module implements an alert service, helping users to remember what tasks they must accomplish.

- *Operational information management*: this module groups functionalities related to the generation and edition of information that depends on the patient's EHR. A reporting module can also be used by therapists and supervisors to visualize graphs and detailed statistics on the use of the system comparing different parameters, such as information regarding completion of sessions, time expended executing tasks, set of tasks used for a specific patient, or activity done by other therapists and centers. JQuery libraries have been used for its implementation.
- *Monitoring*: in order to comply with the Data Protection Law every action carried out is stored in both the database and a log file, so the administrator can track every action related to any user and its data. Apart from this, the system offers a module to monitor the execution of the tasks, so the therapist can then reproduce a task as it was performed by the patient. This allows the therapist to see exactly what a patient did in the monitored task, which is very useful because sometimes it is not enough to merely see the numeric results.
- *Data Analysis and Knowledge Discover0079*: the main objective of this module is to extract the maximum knowledge from the information stored in the system. To achieve this, a tool for knowledge management was designed, and it is applied to each data collected, being able to filter, analyze and extract the necessary knowledge to help the neuropsychologists in their decision making. This module, by analyzing a set of data defined together with the clinicians, is able to assign a patient to a cognitive profile [26], which groups patients with similar characteristics using clustering techniques. Using this input, a decision support system called Intelligent Therapy Assistant (ITA) has been also designed and implemented, which automatically configures and schedules personalized rehabilitation plans. The ITA selects the most suitable tasks for each cognitive profile, by taking into account all the performance results obtained by similar patients in the past. Besides, it automatically configures the difficulty level considering both the initial neuropsychological assessment and the patient's progress during the treatment, increasing personalization. For this module, statistics and data mining techniques have been used. All data mining and clustering algorithms have been programmed using the Weka tool (University of Waikato, New Zealand).

B. User Interface

Regarding the web application for therapies and content management, one of the main efforts has been the design of the user interface, following the user-centered design model, whose

principles are based on classic ergonomics and the accessibility guides. During this designing phase an iterative mock-up has been used to show the experts not only how GNPT would look like, but also the different functionalities they would find and how they would perform every action. The user interface is personalized depending on the user's role. It is also multi-language, and comes in Catalan, Spanish and English, but it could be easily adapted to other languages. In Fig. 2 an example of the interface used by therapists to configure, schedule and visualize the previous results is shown.



Fig. 2. Left hand column: rehabilitation session configuration. Right hand column: previous sessions' monitoring window

C. Interoperability

Given that any hospital in which GNPT is used may have its own Health Information System, a procedure to integrate it with the GNPT database has also been designed, so therapists do not need to enter the same patient's information twice. GNPT has been integrated with other rehabilitation platforms too, making possible to share users, clinical data and results in a transparent way for users. For this purpose, a solution implementing the open source MirthConnect health care integration engine has been used. By supporting numerous standards and protocols (like HL7 or TCP/LLP, HTTP, JDBC, and File/FTP/SFTP), Mirth Connect allows for the filtering, transformation, and routing of messages between disparate systems to allow them to share data.

Since GNPT has been defined to be used not only in the Institut Guttmann, a procedure to ensure data protection has been implemented. This is achieved by storing the user's private data in a separate database, so it can be externally managed by each center that uses the system.

D. Implementation technologies

The GNPT platform consists of two main components: (1) a web application for managing treatments, where the therapists

configure and schedule rehabilitation sessions consisting in sets of personalized computerized tasks; and (2) the client application that patients use to execute the scheduled rehabilitation tasks and send the results to the server.

The local application for patients does not have to be pre-installed in the patient's PC, but rather it is automatically downloaded the first time he or she access the web application. This is achieved thanks to Java Web Start (JWS), using Java Network Launching Protocol (JNLP), which allows users to download and run Java applications from the web, providing an easy, one-click activation of applications. Besides, it guarantees that users are always running the latest version of the software, eliminating complicated installation or upgrade procedures.

The web application requires Java (jdk 1.6, jre 6.x) and runs over Apache Tomcat 6.X, as it is based on Servlet/JSP and Java 2 Platform (J2EE, Enterprise Edition). The database used is MySQL Server 5.X and MySQL Java Connector 5.X (JDBC). However, thanks to the MVC, the platform could be easily adapted to other database models.

E. Rehabilitation sessions and clinical outcomes

Regarding the total number of patients treated, and their rehabilitation sessions and executed tasks, the GNPT system has already collected data from 40,237 scheduled sessions with a total of 260,308 executed tasks. In terms of compliance, 901 rehabilitation sessions have been not completed by patients, meaning a drop-out ratio of 2.24%.

Related to clinical outcomes, the improvement of the cognitive capacities after completing treatment has been measured, comparing the results of the PRE neuropsychological assessment to the POST intervention assessment, as described before in the rehabilitation process section. This first explorative study has yielded a 67.53% of patients who improved their cognitive capacities after completing treatment. An improvement of the patient's cognitive capacities is considered when he or she improves, at least, on one of the three main cognitive capacities, and does not get worse in any of the others.

IV. EVALUATION

GNPT was originally implemented at Institut Guttmann, expanding its use to other 26 cognitive rehabilitation centers, and 83 patient's homes. After three years of use, the efficiency of GNPT system has been evaluated, in order to analyze how the system reduces treatment's costs. Furthermore, a usability evaluation study has been carried out.

A. Usability Evaluation

Usability evaluation has been performed in order to determine the ease of use and learnability of GNPT. System Usability Scale (SUS) [27] has been used, studying separately three different groups of users: 10 therapists, 25 patients, and 13 administrators. SUS is one of the most accepted questionnaires to assess usability in computer systems and it has become a popular questionnaire for end-of-test subjective assessments of

usability, as it has been shown to discriminate well between systems that have poor usability and those that are considered usable. SUS has ten items, so it is easy for users to answer the questionnaire. These ten items were translated to Spanish, and respondents were asked to record their immediate response to each item, rather than having time to think about them. SUS yields a single number representing a composite measure of the overall usability of the system being studied.

Considering this usability evaluation, for therapists the SUS average score was 80.83; for patients 70.00; and for administrative role the score was 75.58.

B. Efficiency study

An efficiency study has been done to see how GNPT helps to reduce the costs associated to the rehabilitation treatment. The provision of the rehabilitation service using GNPT has been compared to the traditional face-to-face one.

The intensive cognitive rehabilitation treatment proposed in GNPT consist of a total of 60 sessions (5 sessions per week, during 3 months). By using the traditional face-to-face model, the approximated cost would be US\$55 per hour (according to the Catalan hospital's network), meaning a total cost of US\$3,300. Then the costs associated to the PRE and POST neuropsychological assessments have to be added (2 hours plus indirect costs, that is US\$247). So, the complete intensive face-to-face treatment would cost US\$3,547 in total.

On the other hand, GNPT allows the provision of these 60 rehabilitation sessions, with the same level of personalization, but expending only 30 minutes for each 10 sessions. In total, the therapist will dedicate only 3 hours to manage the treatment of each patient. So, the efficient ratio in terms of personnel costs is 1 to 20, that is US\$177 versus US\$3,547.

V. DISCUSSION

The platform has been initially implemented and tested in 27 cognitive rehabilitation centers, including the Institut Guttmann, and afterwards in 83 patients' homes.

The system is conceived as a tool to enhance cognitive rehabilitation, strengthening the relationship between neuropsychologists and patients, and offering treatment personalization, results' monitoring, and computerized rehabilitation tasks' performance. The system allows therapists to efficiently manage rehabilitation treatments, configuring and scheduling computerized tasks and evaluating the patients' performance results and their evolution. The efficiency studio shows a ratio of 1 to 20, meaning a considerable reduction of the costs associated to the treatments, in terms of both money and dedicated time by therapists. Furthermore, the modularity and flexibility of the telemedicine system architecture has enabled us to easily extend the rehabilitation process to other pathologies rather than ABI, such as dementia, neurodevelopmental disorders in childhood, or schizophrenia.

GNPT allows personalization and individualization of therapies, one of the main advantages compared to the traditional therapy and also to other stand-alone application solutions. In order to enhance this feature, a data analysis module has been implemented, helping neuropsychologists in decision-making processes. Moreover, this knowledge is being used to learn about the neuro-rehabilitation processes and to improve the designed rehabilitation tasks, as well as for modifying those that appear not to be appropriate for certain kind of patients, depending on the assigned cognitive profile and the previous results of similar patients, increasing personalization.

Considering the usability evaluation, the SUS score obtained from the questionnaires reveals that users perceive the system to be efficient and more satisfying to use, as well as easy to learn. As the typical minimum reliability goal for questionnaires used in research and evaluation is 70 [27], we can consider the system presented here as a usable system.

The neuropsychologists particularly highlight the design of the user interface that allows, for example, the possibility to visualize the results of previous rehabilitation sessions while they are configuring and scheduling new ones. This helps them to efficiently adapt treatments to the patient's evolution. On the other hand, the set of rehabilitation tasks used in GNPT allows to apply rehabilitation procedures devoted to rehabilitation of all the defined cognitive functions and subfunctions, allowing the therapists to individualize treatments to the specific patient's needs.

Evidence may be found in the literature supporting neuropsychological rehabilitation and cognitive training [28,29]. However, despite the existence of studies trying to demonstrate the effectiveness of the process, the results are still limited and inconclusive. The main reasons are the clinical variability of the patients, the heterogeneous nature of the procedures, and the lack of objective information related to the different kind of treatments and how patients completed the rehabilitation tasks. The extensive use of GNPT will continue in the future to be focused on extracting all the hidden knowledge from this stored information, so each executed rehabilitation task will be considered as a new therapeutic hypothesis. These new knowledge will help therapists: a) to know if a patient is able to finish a certain task; b) to see if a positive result improves the cognitive function; and c) to see if this improvement helps the patient in his or her daily life. Thus, the final goal will be to get evidence about the proposed treatment effectiveness, apart from establishing clinical practice guidelines in cognitive rehabilitation.

In order to study the efficacy of the treatment, it is still necessary to carry out a detailed clinical analysis of the data, to determine all the factors related to the improvement of the patient's cognitive capacities. Since the development of the GNPT aimed to increase the efficiency without reducing effectiveness of the rehabilitation procedure, and to monitor a list of variables that theoretically have an influence in the evolution of the process, making possible to include them in future researches. On the other hand, there is still no evidence

demonstrating that an improvement in cognitive functions turns into an improvement in Activities of the Daily Living (ADL). In this regard, we plan to introduce ADL questionnaires to assess how the improvement of cognitive functions benefits patient's quality of life.

VI. CONCLUSION

GNPT tele-rehabilitation service enables brain-damaged patients to continue and further extend cognitive rehabilitation beyond the specialized neuro-rehabilitation hospital, improving the efficiency of the rehabilitation process and reducing treatment costs. In addition it allows customized therapeutic plans based on cumulative evidence about clinical outcome, providing information to further development of clinical practice guidelines.

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