ICT for home-based service to maintain the upper limb function in ageing

M. Rogante, M. Bernabeu, C. Giacomozzi, H.J Hermens, B Huijgen, S. Ilsbroukx, R. Magni, E. Opisso, S. Scattareggia, M. Vollenbroek-Hutten, M. Zampolini, V. Macellari

***Abstract*—In the period 2005–2007 a European Project was conducted by the authors which dealt with upper limb tele-rehabilitation. Being the home apparatus focused on the reproduction of upper limb, daily-life tasks, this paper investigates its potentialities for maintenance of upper limb functionalities in people over 65.**

I. Introduction

During the last decade we assisted to an important progress in rehabilitation of motor functions and in related technological development. Tele-rehabilitation - a subfield of telemedicine consisting of the complex of systems and processes to deliver rehabilitation "at distance" – rises from the combination of these issues as an actual possibility of application and a promising development in the future [1]. Several new issues contribute to render tele-rehabilitation an appealing and fast growing application; among them the need of intensive rehabilitation, even in chronic phases, and the effectiveness of home setting.

In the period March 2005 – February 2007 the authors have been involved in the European Project HELLODOC (acronym for "HEaLthcare Service Linking Tele-rehabilitatiOn to Disabled peOple and Clinicians") [2].

For sake of clarity the structure of the consortium involved in the project is reported:

- Istituto Superiore di Sanità, Italy (ISS, Technical and Administrative partner)
- Fundació Institut Guttmann, Spain (FPING, Clinical partner);
- Roessingh Research and Development, The Netherlands (RRD, Clinical partner);
- National Multiple Sclerosis Centre, Belgium (NMSC, Clinical partner);
- Pragma Engineering, Italy (PRAGMA, Technical partner);
- Signo Motus srl, Italy (SITUS, Technical partner);
- ASL 3 Umbria, Italy (UORIN, Technical partner).

The primary objective of the Project was to validate the EU market – more specifically in Italy, Spain, The Netherlands and Belgium – for a home-care tele-rehabilitation service. Main aim of the service was to extend the rehabilitation treatment at patient's home under close supervision of the hospital. The tele-rehabilitation service was mainly addressed to neurological patients affected by Traumatic Brain Injury (TBI), Stroke or Multiple Sclerosis (MS) [3].

In this paper we report on the main results of the project and highlight in particular how the service was used by people over 65 to maintain their upper limb functionalities.

II. Materials and Methods

A. General aspects of the service

Basically, the service consisted of three main apparatuses: a portable unit to be installed at patients' home, a doctor PC software module and an in-hospital based server managing the transaction framework of the system. The portable unit (in the following HCAD) was an improved version of a prototype of a home-care activity desk which was developed in the framework of the previous European Project H-CAD [4]. The system installed at patient's home is shown in figure 1.

Within the HELLODOC Project the following rehabilitative exercises were implemented:

- PENCIL: patient was asked to follow a path on the screen or to perform writing activities on it; in both cases he had to use a RF pen-like tool.
- JAR: patient was asked to move a jar to and from the shelves, and on the sensorized area of the screen. The jar was covered with reflective tape, in order to be detected by each shelf position sensors.
- BOOK: patient was asked to move a book to and from the shelves. The book was covered with reflective tape, in order to be detected by each shelf position sensors.
- KEY: patient was asked to insert a key and then rotate it up to an established angular position.
- LIGHTBULB: patient was asked to screw and unscrew a tool which resembled a lightbulb, and to turn on and off two different switches.
- KEYBOARD: patient was asked to press the keys according to an established sequence
- CHECKERS: patient was asked to move the checker-like tool on the sensorized screen according to established

Manuscript received April 30, 2008. This work was supported by the EU, eTEN framework, Contract Number: 517508.

M. Rogante: Istituto Superiore di Sanità, Rome, Italy, corresponding author phone: +39-06-49902923; fax: +39 06 4938 7079; e-mail: marco.rogante@iss.it

M. Bernabeu : Fundació Institut Guttmann, Barcelona, Spain,

C. Giacomozzi : Istituto Superiore di Sanità, Rome, Italy,

H.J Hermens: Roessingh Research and Development, Enschede, The Netherlands,

B. Huijgen: Roessingh Research and Development, Enschede, The Netherlands,

S. Ilsbroukx: National Multiple Sclerosis Centre, Melsbroek, Belgium,

R. Magni: Pragma Engineering, Perugia, Italy,

E. Opisso: Fundació Institut Guttmann, Barcelona, Spain,

S. Scattareggia: Signo Motus srl, Messina, Italy,

M. Vollenbroek-Hutten: Roessingh Research and Development, Enschede, The Netherlands

M. Zampolini: ASL 3 Umbria, Trevi, Italy

V. Macellari: Istituto Superiore di Sanità, Rome, Italy

paths.

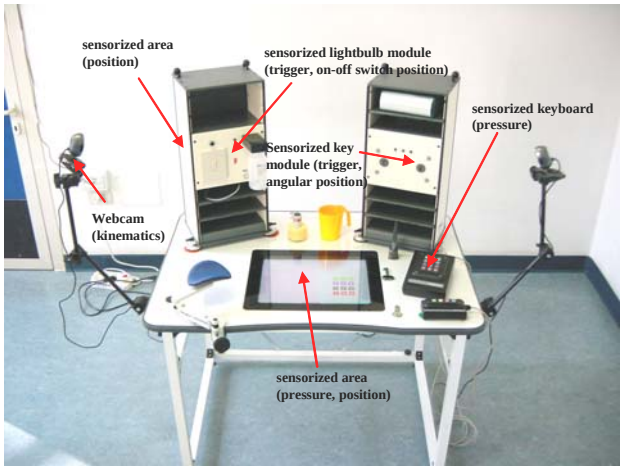

Figure 1 – The HCAD system

Each type of exercise entailed the acquisition of a number of variables which are potentially useful to better understand the quality of its execution: the objective was to collect day-by-day information about the performance of the patient during the exercises execution [5].

Data collected by each exercise were stored and forwarded to the doctor PC; depending on patient's physical progress, medical staff could remotely change the rehabilitative program by adapting the protocol. The communication between the Portable unit and doctor PC is managed by a Communication Server. The service is provided by the connection of the three apparatuses as shown in figure2; it is worth mentioning that the connection between the PU and the hospital unit was based on the public Network but it was based on a secure channel provided by a Virtual Private Network developed within the project.

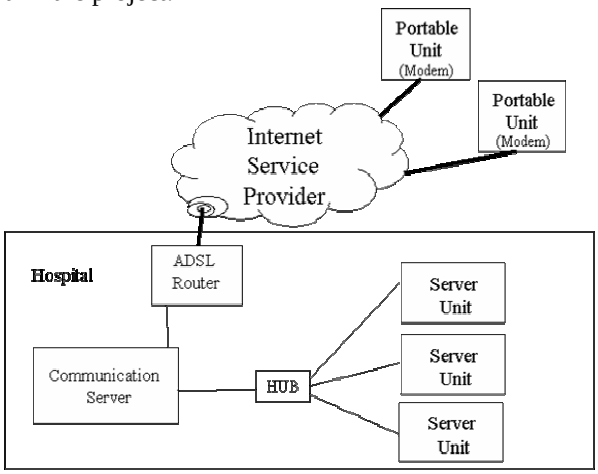

Figure 2 – Connection among the three main apparatuses of the HELLODOC service.

B. *Clinical Trials*

The physicians of the three rehabilitation centres included patients according to previously defined inclusion and exclusion criteria and asked for their signed informed consent. After baseline assessments, the patients were randomly assigned to the intervention or control group. A randomization scheme of 2:1 (two intervention patient groups for every control group) was used. To get insight in the number of patients needed in the clinical trial, a power analysis was performed [3,ex2]. It concluded that a total of 90 patients were necessary for the total trial, 60 patients in the intervention group and 30 patients in the control group, equally divided over the 3 diagnosis groups.

All measurements were performed at the centre where the patient had been treated. The included patients received a baseline measurement (T0). The second measurement (T1) was performed after 1 month of usual care (for intervention as well as control group). The third measurement (T2) was performed after 1 month of HCAD intervention for the intervention group, and 2 months after baseline for the control group. One month after T2 a follow up measurement was performed (T3) for the intervention group. The control group received their last measurement (T3) 4 months after baseline.

The intervention group underwent 1 month of usual care, followed by approximately 4 training sessions with the HCAD system in the hospital. The actual intervention with the HCAD system at home consisted of 1 month, whereby the patients had an average of one training session a day lasting 30 minutes for at least 5 days a week. The set of the proposed exercises summarized the movements for a correct functional activity of the upper limb of the patient for reaching, grasping, lateral pinch, pinch grip, holding, manipulation and finger dexterity. The patient and the therapist had a weekly scheduled videoconference. After the month of exercising with the HCAD system, the patients continued their usual care at home.

Patients in the control group received usual care and generic exercises prescribed by their physicians. The therapists completed a diary which contained the exercises performed by the patients and the received treatment.

The User Satisfaction was asked with a Visual Analogue Scale (VAS) scale. Six aspects of the participant and therapist's impression (acceptance, aesthetic aspect, easiness of use, difficulty of the tasks, appropriateness of the tasks, general opinion) were evaluated. They were asked to score from very bad to excellent on those six aspects. VAS was turned into a numeric scale from 0 to 100 and normalized in order to obtain three different responses: positive, negative and neutral. Scores of each aspect were analyzed to interpret if the participants and the therapists were satisfied and consequently to plan future work to improve and/or adapt the system. Further analysis was conducted on the subset of over 65 patients in order to evaluate the acceptability of the system by the elderly.

C. *Technical assessment*

A Technical Assessment activity has been conducted by ISS within the project on the implemented tele-rehabilitation service. The activity was mainly focused on architectural aspects and a step by step monitoring of the service. It was mainly related to the following aspects: Service implementation, Service performance, Service integration and Fault management.

Main targets of the analysis were:

- mechanical aspects
- electronic aspects (attention has been paid to patient's security);
- software aspects (for evaluating easiness to interact with the interface);
- network aspects (focused on security in data exchange and service continuity);
- setup aspects (easiness in setting up the service was evaluated either in home and hospital environment).
- patient's security and service continuity.

D. E-learning

A web-based learning activity in the field of tele-rehabilitation was conducted by ISS within the Project. The activity aimed at training professionals to effectively manage the tele-rehabilitation service. ISS adapted the Moodle e-learning platform and implemented the PBL methodology. Moodle is a course management system designed to help educators to easily create good-quality online courses [6].

One clinical and one technical module were prepared by using traditional learning sources as well as interactive tools. Each module included 4 Units; each Unit was based on a 5-days cycle. The courses remained open from January to October 2006.

. At the end of 2005 a Clinical Teaching Module (HDOCCM) and a Technical Teaching Module (HDOCTM) were completed. The modules had the same structure, which is described in the following by making reference to the generic Teaching Module (TM).

TM was based on four units, each of them lasting for one week. Basic elements of TM were:

- the Introduction and the definition of clear objectives;
- a Preliminary Questionnaire;
- a Final Questionnaire;
- a Glossary containing those definitions which were relevant to the TM;
- a final Survey to assess the quality of the course.

Besides the e-learning offer, a complete set of pre-recorded videos was prepared and stored in the HCAD system to train the patient to properly execute the rehabilitative exercises.

III. RESULTS

A. Clinical trials

The most important activity within the HELLODOC Project dealt with the clinical validation of the service. Within the time-frame of the Project, 81 patients with chronic Stroke, TBI and MS were recruited; 50 out of 81 received 1 month tele-rehabilitation service, with one training session a day lasting 30 minutes for 5 days a week.

Clinical results were in agreement with the expectations. The Action Research Arm (ARA) test showed a slight improvement in both the usual care and the intervention group. Also the secondary outcome measures showed a slight improvement or the maintenance of the same level over the testing period for both groups. There were however no significant differences between the HCAD intervention and usual care, which is in agreement with the expectations. The daily training duration in the HCAD group and usual care group was comparable.

With reference to the execution time during the month of treatment the intervention group showed significant improvements on the individual tasks. Patients who had a lower baseline score on the ARA test had more chance to improve during the HCAD treatment. Additionally the patients that used the HCAD system more frequently had more chance to improve arm/hand function.

B. Technical assessment

From a general point of view, the service worked in a quite satisfactory way, especially considering the pioneering nature of the Project.

A variety of troubles happened - most of which with a low impact on the service continuity - that can be considered typical of the debug or post-debug phase, which was too short in view of the Project complexity. The positive consequence of those troubleshooting was a deeper analysis of system functions and thus a better compliance with service needs. A remark about high levels of security is mandatory: the system was conceived to fulfill the safety requirements of the European directive on medical devices (93/42/CEE); no fault for its nature had any impact on human safety, which denotes good design criteria and practices.

C. e-learning

At the end of the on-line e-learning courses – one Clinical and one Technical Teaching Module –, some statistics on the attendance, results, and effectiveness of the experience highlighted the following relevant findings:

- only half of the registered students attended the courses, most of them during the working cycle of February 2006;
- within each working cycle, the level of participation showed a significant decrease from Unit 1 to Unit 4;
- for both modules, the percentage usage of traditional learning resources was comparable with the usage of novel learning tools like interactive tools, on-line meetings, and the step-by-step discussion of an open problem (PBL methodology);
- from a technical point of view, the e-learning platform was considered reliable and effective. Both courses had been continuously and easily accessible for the whole duration of the on-line offer to all students of the 4 European Countries involved in the Project, either from Hospital Computers or from their own PCs;
- feedback from the experts was positive with respect to both structure and content quality of the teaching offer, even though they remained a little doubtful with respect to the direct usability of such educational tools. Small residential preliminary courses seem to be still necessary in order to introduce the e-learning methodology and to motivate the professionals to become active participants of the courses.

As for the multimedial training material available on the

PU, it was proved to be a useful support to complete the overall educational offer of the Project.

D. Survey analysis for user's satisfaction

The overall satisfaction of both patients and therapists was high. More specifically, results of the survey related to the entire population treated with the HCAD system are shown in table 1

Population: 81 subjects	Positive feedback	Negative feedback
Acceptance	65	6
Aesthetic aspects	44	9
Easiness in use	82	0
Difficulty of tasks	59	3
Suitability of the tasks	71	3
General opinion	76	3

Table 1: Patients' responses to the survey (% of the population)

19 of 81 patients (24%) were over 65 and table 2 shows the results of the survey of this population

Population: 19 subjects	Positive feedback	Negative feedback
Acceptance	63	0
Aesthetic aspects	50	0
Easiness in use	75	0
Difficulty of tasks	63	0
Suitability of the tasks	88	0
General opinion	88	0

Table 2: Elderly patients' responses to the survey (% of the population over 65)

IV. Discussion and conclusion

The described tele-rehabilitation service has high potentialities in improving the quality of care delivery for the three pathologies (stroke, TBI and MS), by granting continuity and extension of care outside hospital. However the service, as it has been conceived, has poor chance to be cost effective and sustainable by hospitals or local health authorities.

The service worked in a quite satisfactory way for the whole treated population; however, from a direct comparison of table 1 and 2, the following considerations are mandatory:

- the general opinion about the service was better in elderly than in under 65 population;
- over 65 considered the rehabilitative tasks more suitable to their needs;
- over 65 found some difficulties either in the tasks execution and in the system utilization.

The project was positively concluded, and the service proved its usability also for seniors. Anyway, the above considerations imply some re-design or a certain adaptation of the HCAD system as for mechanics and software interface. Furthermore, simplification of training tasks is needed for an effective ICT-based action to maintain the upper limb function in ageing.

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