The SMART Project: An ICT decision platform for home-based stroke rehabilitation system

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Abstract. Stroke is the largest factor to severe disability in the UK, with the majority of cases linked to the elderly population. The SMART project aims to develop a home-based stroke rehabilitation system, that can provide support until maximum recovery has been achieved. This paper describes the design and development of the information and communication (ICT) platform, interface module and user feedback. Process and outcomes of User involvement in the development of the system are also described.

Keywords. ICT platform, stroke, home-based rehabilitation, user involvement

Introduction

In the United Kingdom (UK) stroke is the most significant cause of adult disability with a quarter of a million people living with a substantial loss of their independence and quality of life (QoL) [1]. Stroke rehabilitation is primarily aimed at maximising the functional and cognitive abilities of the patient and enabling their return into the community [2]. Research shows that intensive and repetitive training may be necessary to modify neural organization [3][4]. However, in the UK, inpatient rehabilitation length of stay for patients with stroke is decreasing, with limited outpatient rehabilitation. A National Framework for Older People recommends that rehabilitation should continue until maximum recovery has been achieved [5]. There is therefore a need to develop a low-cost, accessible system that can augment existing rehabilitation services for post-stroke patients. A recent technical review [6] has shown that it is feasible to apply the emerging information and communication technology (ICT), together with the sensor technology and robotic technology, to develop a low-cost home-based systems to support rehabilitation. To be successful the device/system should meet the needs of users in terms of required outcomes, usability and ultimately provide evidence of clinical effectiveness [7]. In this paper, we present the design and

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development process of an ICT platform to support home-based upper limb rehabilitation, with full consideration given to usability for users.

The remainder of this paper is organised as follows: Section 1 introduces the SMART consortium and the architecture of the system. In Section 2, the user centred design strategy is presented and the ICT decision platform is described. Section 3 details the design and development of the ICT platform. In Section 4, we summarise the usability of the platform. Through the project we have involved end users in the design process and suggest that this model can be applied to the design of other healthcare related systems.

1. SMART Project

1.1. SMART consortium

The project, entitled 'SMART rehabilitation: technological applications for use in the home with stroke patients', is funded under the EQUAL (extend quality of life) initiative of the UK Engineering and Physical Sciences Research Council (EPSRC). It is a partnership of four universities, one industrial motion tracking company and one voluntary sector organisation. The project aims to examine the scope, effectiveness and appropriateness of systems to support home-based rehabilitation for older people and their carers (http://hsc.shu.ac.uk/smart/). A home-based rehabilitation system, SMART rehabilitation system, is under developed by the SMART consortium (Table 1).

Table 1 SMART consortium and partners

Consortium Partners	**Collaborators**
University of Bath	Bath Sport and Exercise Science
RNHRD	Head Injury Unit RNHRD
Sheffield Hallam University	Sheffield Teaching Hospitals / Chippenham Stroke Unit
University of Essex	RUH Bath Care of the Elderly
University of Ulster	Charnwood Dynamics Ltd.
Stroke Association	

1.2. SMART rehabilitation system

The SMART rehabilitation system consists of three componnents, namely (i) motion tracking unit; (ii) base station unit; and (iii) web-server unit (Figure 1).

The motion tracking unit consists of two inertial sensors (MT9, Xsense Dynamics) [8] which are attached to the patient's upper limb to track the movement during specific exercises such as drinking or reaching. The MT9s record changes in arm positions and angles resulting from the movement of two joints, i.e. elbow and shoulder. The information is then sent to the base station, which is a multimedia PC, for further processing by the ICT decision platform. The ICT platform will display the movement in a three dimensional (3D) environment at the base station; store and analyse the data; then upload this to a central server. Healthcare professionals can assess and monitor movements remotely via the internet by accessing the central server, ultimately they can provide comments/instructions over the web-based system [9]. The ICT platform will provide the comments/instructions as feedback to the patients and their carers alongside other more detailed analysis.

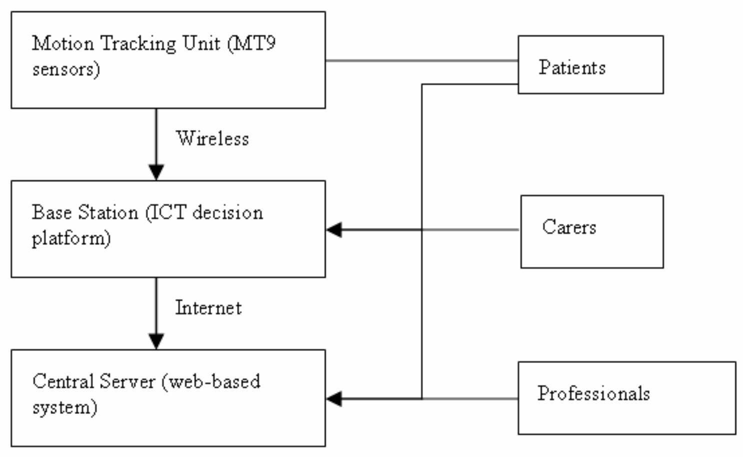

Figure 1 Architecture of the SMART rehabilitation system

2. Design strategy and the components of ICT decision platform

2.1. Design strategy

The primary users of the SMART system are stroke patients, their carers and healthcare professionals. The usability and feedback of the ICT platform were two key issues that needed to be addressed at an early stage in the design process to ensure the SMART system is acceptable as a home based rehabilitation solution. The consortium introduced a strategy of involving all users in the design procedure, which is thought to be novel to technology research in health care. Focus groups were used to provide feedback on the concept of home based rehabilitation, the ICT platform and the methods of attaching the motion sensors to the patient.

In the early stage of the project, focus group identified a number of key principles:

- It is an aid to therapy, not a stand-alone therapy;
- It is not specific to any one model of therapy;
- It is a generic device applicable to a variety of rehabilitation aims for upper and lower limb;
- No two people who have had a stroke are the same: there must be flexibility in all elements of the device;
- Device must be as simple as possible to use, and adaptable to individual needs. Stroke patients have complex impairments often incorporating cognitive difficulties such as problems with perception, attention, information processing, language and memory.;
- The device provides accurate feedback on performance.

In the later stage, keys factors on user interface, type of feedback and outcome measurement were identified as illustrated in Table 2.

Table 2 Key factors for designers: the feedback mechanism/s

The feedback mechanism/s	**Implications for design**	
Real Time (Knowledge of Performance)	- Choice of methods (auditory, visual, written, storable and retrievable) -Simplicity of information display	Instructions – Different methods / clarity / simplicity Targets, possible to set Accuracy of results
Results for User (Knowledge of Results)	- Choice of methods (auditory, visual, written, storable and retrievable) Feedback presented positively Simplicity of information display	
Results for Therapist (Knowledge of Results)	Visual, written, storable and retrievable records	

2.2. System components

The system consists primarily of five modules to provide the following functions: database, user interface, decision support, communication and user feedback.

The database module stores patient's personal information, individualised questionnaires to check the safety of carrying out the exercise, patient's rehabilitation history (movement data) and the comments/instructions from healthcare professionals. The interface module provides tools and menus for accessing system functions, and particularly, it provides the functions to allow individual patient to select their preference presentation of the interface, such as color, font size and feedback style.

The decision support module will carry out the analysis of outcome variables, while the communication module manages the transfer of information with the central server.

The feedback module is the core module, which provides different types of information to patients, namely 3D movement information, comments/instructions, and analysis of performance.

In this paper, we focus on the design of the interface module and feedback module, as these two modules contribute the most to the usability of the system.

3. Design of interface module and feedback module

3.1. Interface module

Three focus groups were held for carers, stroke patients and professionals. Each group was shown the interface and given opportunity to discuss it. The focus groups were taped and the transcriptions analysed to identify key issues about the usability and feedback methods. Following the focus group sessions it became evident that each user has a unique and indivdual opinion with respect to the interface. The stroke patients in particular preferred to have larger font size with the ability to alter the font/background colour. Another feature that appealed to the users was the facility to change the amount of information that can be displayed at a given time. This history setting could be customised to view all information since the start of rehabilitation or defined as a set period. In order to meet the individual requirements, we have developed a user preference interface setup in the interface module for the ICT decision platform.

Figure 2 shows the screen shots of the preference interface setup. The interface module allows the user to select the text size, color, background color, history time scale and render mode.

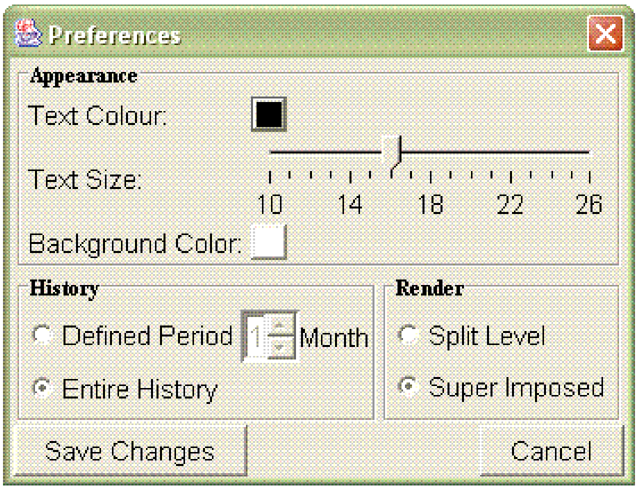

Figure 2 Interface preference setup

3.2. Feedback module

The feedback module provides relevant information to users by four forms: text; 3D visualisation; tabular and graph. Text feedback is used to display comments/instructions from healthcare professional. Users group analysis suggested that they would like to annotate their records in order to explain variation in performance. This would enable them to look back at their history and note that they were not feeling well or had an injury and would help both users and professionals to interpret the outcomes of exercise sessions. This text facility is built into the feedback module so that when a file is accessed the acccompanying notes are displayed.

3.2.1. Visualisation feedback

The visualisation feedback displays and replays the movement of rehabilitation exercises to users in a 3D environment. To improve the realism, 3D rendering is applied for a virtual head and arm based on the movement data collected by the MT9 sensors. A normal template was created and can be used to give the patient an optimum target and this plays in the background. The template was constructed from age matched normative data collected through a full 3D video motion analysis system. However, it will also be possible for the patient to create their own template using movement data collected under supervision of the therapist. Figure 3 shows two types of methods used in presenting the 3D information, one displays exercise movement and the target template movement in two seperate windows; and the other displays them in the same window with the template movement as a ghost layer. From the focus group it was clear that stroke patients were quite sophisticated in their observation of differences between their movements and the template. This confirmed the effectiveness of the strategy and through preference settings, of users being able to choose their preferred mode for the 3D rendering.

Figure 3 Screen shot of 3D rendering

3.2.2. Tabular and graph feedback

Feedback is an extremely important part of the overall rehabilitation process, therefore alongside textual feedback from the healthcare professional, there are outcome measures, such as length of reach or arm angle, that will be calculated automatically. Outcomes were required to be relevent for motor learning but also clinically useful for improving function. The professional focus group considered this aspect in depth and identified appropriate key variables. These are available in two forms namely tabular and graph. Two types of feedback are shown in Figures 4 and 5.

Figure 4 Screen shot of graph feedback

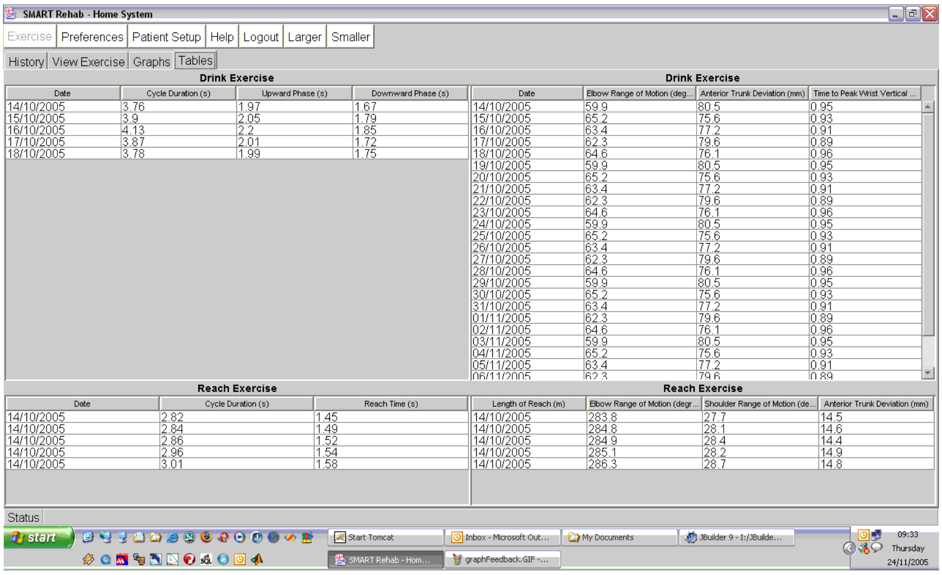

Figure 5 Screen shot of tabular feedback

4. Conclusion and discussion

The ICT decision platform has been demonstrated to a group of users and developed according to the feedback gained from the focus group transcripts. The current version of the system has received very positive feedback from the users. The design procedure shows that it is an important research strategy to involve users views in the design process. It is anticipated that this model of user engagement will ensure that ICT will play a maxium role in healthcare delivery, such as the home-based rehabilitation system, to enhance the quality of life for patients. Further work is to enhance the decision support module, which will provide various analysis tools for professionals. The clinical trial is being planned to start in early 2006, and training will be provided to users.

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