A Game-Based Solution for In-Home Rehabilitation

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Abstract. This paper presents initial concepts from the REHAB@HOME project investigating the patient-centered design of game environments aimed to raising patients' motivation and compliance with motor-cognitive rehabilitation programs. During the initial phase of the project a patient's client was developed to deploy five rehabilitation games through main gaming platforms and interaction devices (Kinect, LeapMotion, Sifteo Cubes). Also, a professional client was designed to enable clinicians the remote monitoring of patients' progress in home settings. We discuss main features developed for both clients that can inform the future realization of game-based solutions for upper body rehabilitation programs.

Keywords: Serious games · Motor-cognitive rehabilitation · Patient-centred design · Professional clients

1 Introduction

Stroke is the second most common cause of death in Europe (EU Cardiovascular Disease statistics, 2012) and it affects about 15 million people worldwide each year. Stroke survivors experience a broad range of problems that can impact their cognitive and motor systems, leading to chronic disability (e.g., hemiparesis) more often affecting the upper body (i.e., arms, Dobkin, 2005). The goal of rehabilitation is to help survivors become as independent as possible and to attain the best possible quality of life. For over half of stroke patients, rehabilitation will be a long-term process requiring work supervised by therapists, supported by specialized equipment, lasting several months. However, increasing cost pressure on the healthcare system is leading to shorter periods of intensive rehabilitation at specialized facilities. Therefore the

R. Giaffreda et al. (Eds.): IoT360 2014, Part I, LNICST 150, pp. 112–117, 2015.
DOI: 10.1007/978-3-319-19656-5_17

adoption of suitable technologies for in home rehabilitation, together with a proper training about the execution of a personalized program of exercises, can help reduce the patient's stay at the hospital, as well as the need and cost of reaching the rehabilitation facilities and helping in relapse prevention or improving the patient's state to his potential. In this work, we present early concepts for a patient client and a professional client, realized in the REHAB@HOME European project in collaboration with therapists and patients in Italy and Austria, aimed at supporting in-home rehabilitation of the upper body.

2 Related Work

In the area of rehabilitation research and practice, there have been previous attempts to leverage on low cost gaming platforms, such as Wii (Deutsch et al., 2008) and Playstation 2 EyeToy (Flynn et al., 2007), to support post-stroke therapy. However, these solutions are difficult to deploy with patients in earlier stages of recovery when they have only limited range of motion. For this type of patients other more specific game-based solutions have been recently proposed. Huber et al. (2008) and Jack et al. (2001) developed haptic glove based games in which users scare away butterflies, play the piano, and squeeze virtual pistons to improve the player's finger flexion and extension. Burke et al. (2009) built two webcam color tracked games similar to whack-a mole. In addition, they created a physics-based orange catching game and a whack-a-mouse game, both controlled with magnetic sensors and a vibraphone game, using a Wii remote as a pointing device. Game concepts and solutions more related to everyday tasks and activities of daily living have been explored to increase patients' motivation to play, by providing more meaningful settings (Sanchez et al. 2006; Burke et al. 2009). Flores et al. (2008) identified game design criteria that stem from stroke rehabilitation and elderly entertainment. Vandermaesen et al. (2013) developed the Liftacube prototype for training of the upper extremities and tested it with four patients (affected by cerebrovascular accident or paraplegia) finding encouraging results and benefits regarding patients' motivation.

In our work, instead of focusing on developing games for specific ranges of disability we aim to realize solutions that can be adapted for use by patients at different levels of recovery (a similar approach was proposed in Alankus, 2011). By informing our design with requirements from therapists and patients, we aim to realize a rehabilitation platform enabling therapists to select and tailor games for individual patients' programs.

3 Game Design for Motor Rehabilitation

During the first year of the REHAB@HOME project we conducted a patient centered design process to realize a set of rehabilitation games targeting post-stroke and multiple sclerosis patients in need of upper body motor rehabilitation. The design process also involved requirements collected by interviewing a number of therapists at Fondazione Don Gnocchi (Italy) and Neurological Therapeutic Centre Gmundnerberg (Austria).

We ended up developing a patient client providing access to four games, three of which could be played with the Kinect gaming platform, one with the SifteoCubes platform. We also decided to include in the experimentation an available game for the novel LeapMotion device (a sensor controller that supports hand and finger motions as input, analogous to a mouse, but requiring no hand contact or touching). The criteria for inclusion and development of these 5 games, was to assess their benefits for deployment in the context of arm/hand motor rehabilitation sessions. The specific movements required by the games were the following: shoulder abduction, adduction, flexion, extension, wrist flexion, extension, supination, opening/closing of hand, reaching movements and finger movements of precision. In the following we briefly describe the games realized and deployed in the first two years of the project (Fig. 1 shows the menu screen on the patient client for selecting the Kinect games developed):

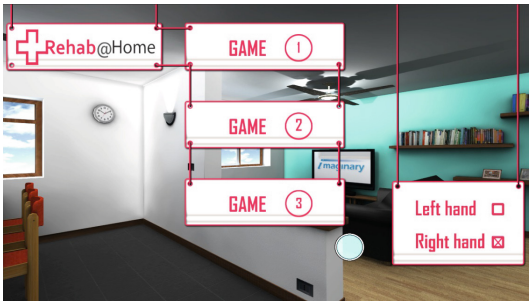

Fig. 1. Screenshot of the menu to select the Kinect games.

(1) Bombs & Flowers minigame [Kinect]: the patient interacts in a living room environment where s/he has to touch flowers items and avoid bombs. S/he is required to use both hands moving them from the center of the body to the sides and is provided instructions, visual feedback, and total score achieved during the session.
(2) Can minigame [Kinect]: the patient needs to move cans from a central table to the correct shelf, by matching corresponding colors which change position during the game; s/he can use just one hand per session (s/he can change hands between sessions) and get instructions, visual feedback and overall score achieved.
(3) Blackboard minigame [Kinect]: the patient needs to move different shapes from the left side to colored spots on the right side, by following a random path using only one hand. Random pairings are proposed (e.g. star-blue, square-red) on the top of the screen, red dots appear along the path, which should be collected; instructions, visual feedback and overall score are also provided.
(4) Caterpillar game [LeapMotion]: the patient needs to guide a caterpillar around the screen with one finger to collect numbers in a sequential order, achieve levels and eventually become a butterfly; instructions, visual and auditory feedback are provided.
(5) Simon game [Sifteo Cubes, Fig. 2]: 3 (1.7 in) cubes are provided in fixed positions on a table which display colours randomly assigned by the system; the patient is

asked to tilt a fourth cube to select a colour on its display and put the cube in contact with the corresponding cube (same colour) in the fixed positions; visual, auditory feedback, number of sessions played and score are provided through the cubes displays; typically the patient plays by using one hand for 3 consecutive sessions.

Fig. 2. Simon game played with Sifteo Cubes

3.1 The Professional Client

In order to remote monitoring the rehabilitation process and manage the patients, a web application has been envisioned. The Web based graphical interface has two main views:

The professional station view, which has two main functions. As therapy management tool, it allows the continuous monitoring, management and communication with patients during their rehabilitation activities. It can be used by clinical staff to personalize and schedule the program of exercises for each patient, and tuning on the fly the rehabilitation program when needed. Besides this, it supports long-term and statistical analysis of collected data and information, taking into account the data collected by the patient station during his interaction with the games, such as motion data, games data and usage information. The analysis of the collected data supports therapists and clinicians in understanding the level of progress during the rehabilitation process and in choosing possible adjustments, both in the short and long term, thus providing, at the same time, a solid ground for a more effective planning of the rehabilitation process.

The design of the Professional client was conducted by following the results of the user requirements collection and analysis in the first year of the project. In particular, we complied with the Rehabilitation Plan of Care indications provided by therapists at the two clinics involved in the project. The Professional client interface is divided into four distinct areas (Fig. 3), each associated to a different colour, as follows:

- My Patients: including all functionalities for managing patients, like the assignment and configuration of exercises through the games, and the visualization of relevant data about progress with the rehabilitation process (Fig. 4).
- My Profile: providing all functionalities related to the staff profile, and tools to communicate with other staff involved in managing a patient.

– Games: an inventory of the available games, with their full description.
– Equipment: an inventory of the available equipments/devices, with their full description.

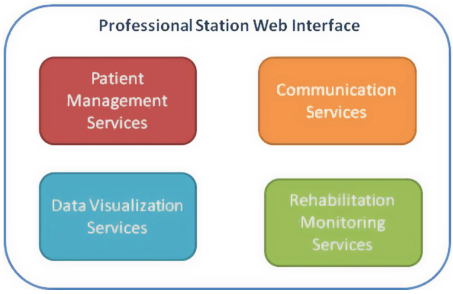

Fig. 3. Services integrated into the Professional Client Interface

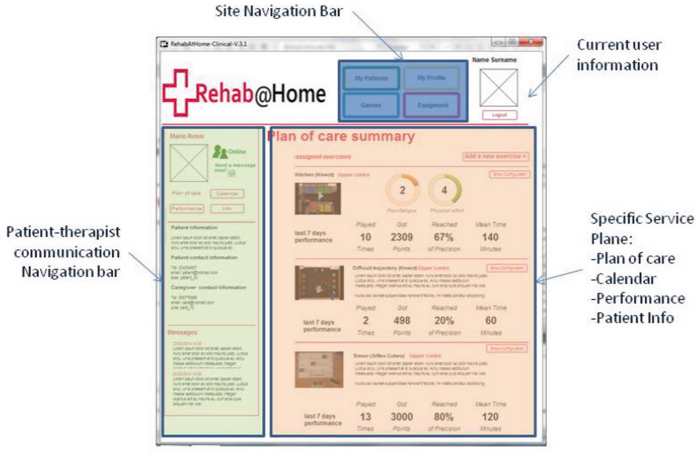

Fig. 4. Screenshot of main features provided by the Professional Client Interface

4 Conclusion

This work has presented initial design concepts for a patient client and a professional client to be used for in-home upper body rehabilitation and its remote monitoring by clinics. We are currently in the process of conducting pilot studies to assess the level of usability and satisfaction of patients and therapists with the games and interfaces realized. The architecture of the overall REHAB@HOME solution will also include a family client to support the involvement of family members and caregivers in the in-home rehabilitation process (e.g., providing possibility of playing co-located games to

sustain motivation of the patient, and to get an overview of patient's progress with therapy), which will be designed according to information collected from users. In addition the overall solution will include Web2.0 social and communication tools, which will support the communication between the patient and his medical professionals and promote communication with other patients using the system. A longitudinal evaluation of the integrated REHAB@HOME solution will be conducted in 2015 involving a large group of patients and therapists in Italy and Austria.

Acknowledgments. This work has been supported by the FP7 STREP Project REHAB@-HOME N. 306113.

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