SHRUG: Stroke Haptic Rehabilitation Using Gaming

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ABSTRACT
In this paper we present SHRUG, an interactive shoulder rehabilitation exerciser. With this work-in-progress system, we intend to (1) explore the effectiveness of providing interactive and just-in-time feedback to the patients and therapists; (2) explore the effect of adding a gaming element on the motivation of the patients. The SHRUG prototype was developed in collaboration with the rehabilitation therapists by augmenting their existing exercising system. We present the implementation details of the system and some of the initial reactions from the therapists on various aspects of the SHRUG prototypes.

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Serious Games, Stroke Rehabilitation, Responsive Objects

INTRODUCTION
Exercise programs focusing on the rehabilitation of the shoulder are a common occurrence in post-stroke rehabilitation as the shoulder can significantly improve the ability to perform activities of daily living. These programs, commonly feature exercises that utilise both shoulders together such that the 'strong' shoulder is able to guide the 'weak' shoulder through the proper movements. One such activity[1] involves the placing of a wooden pole into a pair of horizontal hooks . Multiple pairs of these hooks are fixed at various heights to a simple backboard (exercise ladder), requiring a patient to stretch both arms, and therefore both shoulders incrementally. Additionally, the patient is required keep the pole horizontal throughout this activity, ensuring that the weak shoulder is worked and guided by the strong shoulder. This rehabilitation program may be carried out in a one-to-one session, within a group session, or away from medical supervision in a home environment.

[1]http://goo.gl/7XdjHE

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While the exercise is in fact effective, our observations at the rehabilitation ward of a local hospital revealed some key major limitations faced by the patients, therapists and the doctors. Firstly, the lack of feedback from the exercise devices requires therapists to constantly keep and eye on the patients. This is a key limitation during a group rehabilitation session as there are only a few therapists overlooking the process. In addition, this often results in the patient repeating erroneous actions until noticed by a therapist. Secondly, the lack of recording and storing the specific activity information such as hand movements patterns, speed, etc. limits the doctors/therapists to look at the patient's rehabilitation history in finer detail in order to customise the exercise programs. Furthermore, it is almost impossible to review the patients rehabilitation process when they performed them at home. As our observations revealed, these limitations could often reduce the effectiveness of the rehabilitation programs and even demotivate patients.

Figure 1. The SHRUG Prototype.
Video: http://goo.gl/d5a99B

To address the above limitations we introduce SHRUG - Stroke Haptic Rehabilitation Using Gaming (Figure 1). The main goal behind SHRUG is to examine the use of interactive technology principles to enhance the rehabilitation experience for both the patients and the therapists. The approach of SHRUG is two pronged. Firstly, enhance the effectiveness of rehabilitation process for the therapists by converting the existing shoulder rehabilitation exercise platform into an interactive object that monitor, record and provide timely alerts. Secondly, enhance the experience of the rehabilitation process for the patients by providing immediate feedback of their actions and introducing motivational 'gamified' shoulder

rehabilitation exercises. In this paper, we report the current work in progress state of SHRUG with the implemented system, games and the initial reactions from the therapists. The main contributions of this paper are as follows.

- Design of an interactive shoulder rehabilitation platform that responds and guides the patient through the exercise program
- Investigating the possibility of adding a gaming aspect and initial reactions from the therapists

RELATED WORKS

Several past works discuss the attempts to enhance the rehabilitation process through the introduction of new technologies and gamification of existing processes. In [4], authors introduce and compare the use of virtual reality based approaches where the users' movements are tracked using Microsoft Kinect and more expensive OptiTrack optical systems. These are focused on the upper limb motor tasks that are incorporated into game-based rehabilitation applications. Furthermore, in [1], the authors discuss use of a Kinect device for arm movement and the use of a haptic feedback with a PHANToM device [7].However, most of these devices require heavy processing, setup time and effort, and may require tuning for each of the users. In addition, the devices could be quite intimidating for the patients as they are heavy, bulky and are generally very different from the existing systems the patients are used to. Therefore, with SHRUG we explore the ways of augmenting the existing non-responsive exercising machine with interactive and responsive capabilities.

Additionally, some of the shoulder rehabilitation devices discuss features such as adaptable game-play, in which difficulty is tailored to patient performance in real-time [5, 3]. In this work we explore adding serious gaming aspects [2, 6] to motivate patients during sessions and encourage them to practice continuously.

THE SHRUG SYSTEM

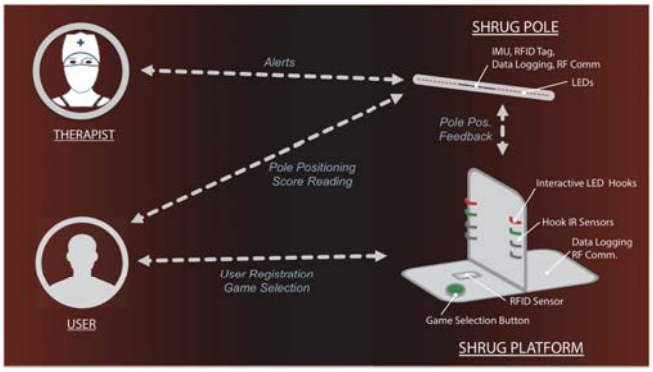

Figure 2. Overall System Diagram of SHRUG

In order to provide an intuitive interface to the patients and the therapists, the physical appearance and affordances of SHRUG was modelled after the existing exercise platform at the hospital. The overall system of SHRUG is as in Figure 2. The SHRUG system mainly consists of the SHRUG Pole and the SHRUG Platform.

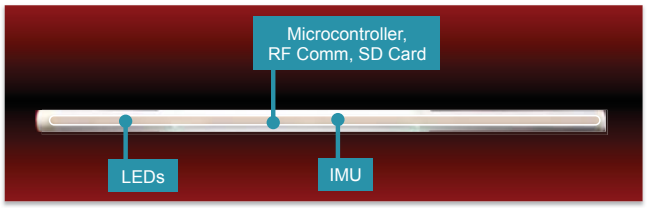

Figure 3. SHRUG Pole Contents

SHRUG Pole: The SHRUG Pole consists of a few main hardware components which provides its functionalities. A Teensy 3.0[2] is used as the main microcontroller on board. An orientation sensor (ArduIMU[3]) detects and keeps track of the orientation and movement data of the pole. A strip of 40 RGB LEDs is spread throughout the pole in a single profile. This provides the user with feedback when the pole is not horizontal or indicate progress results when the pole is held vertically. An RFID (Radio Frequency Identification) tag embedded in the pole gives each pole a unique ID. Once the pole is placed on the platform, the system recognises the patient. A micro SD memory card on the pole records all the movements data of the patients. This data can be downloaded later by the therapists for analysis.

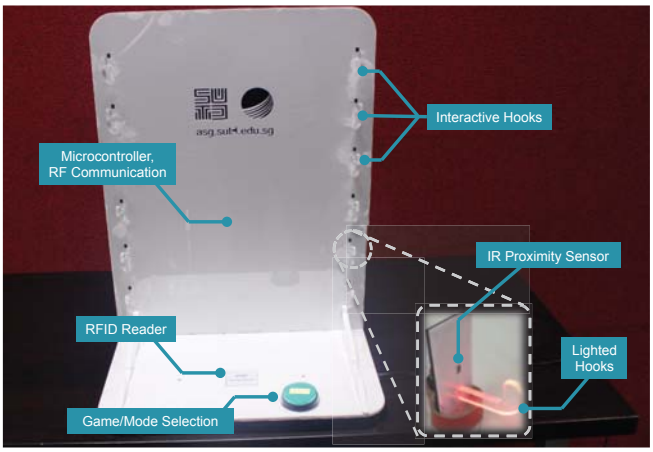

Figure 4. SHRUG Platform Contents and Features

SHRUG Platform: The SHRUG Platform (Figure 4) uses and Arduino Due[4] as its main controller. The RFID reader on the platform is used to identify the RFID tag of the pole and register the patient. Each hook of the platform is embedded with a RGB LED which makes the hook light up in different colours. Infrared (IR) proximity sensors placed just behind the hook is used to detect

[2] https://www.pjrc.com/store/teensy3.html
[3] http://goo.gl/x7nmq9
[4] http://arduino.cc/en/Main/arduinoBoardDue

the pole positioning on the platform. The game selection button on the platform allows the users to identify and select various games of the exercise program.

Communication: The platform communicates with the pole using RF (radio frequency). At the initial stage of the game, this communication channel is used to exchange patient identification information in order to pair the pole and the platform. During the exercise, the pole records the orientations of itself and its position on the platform that is sensed by the IR sensors.

Figure 5. Typical usage of SHRUG (a) Place the pole on the platform for identification (b) Select the game using the selection button on the platform (c) Place the pole on the platform hooks as required by the game

Interacting with SHRUG

A typical interaction scenario is shown in Figure 5. As the pole is placed on the platform, all hooks on the platform light up and blink to indicate successful identification and pairing. Next, the patient can select the required game and continue with the program. As the patients interact with the SHRUG, various states are represented visually through the lighted up hooks on the platform and the pole (Figure 6)

Once the exercise is completed the pole is returned to the therapists who can retrieve the data from the SD card on the pole. This allows therapists to have access to the performance history of the patients. By reviewing performance history, the therapists can identify and personalise the the rehabilitation program for the patients according to their performance.

GAMIFICATION

The current SHRUG prototype has four main modes as follows. The modes were designed to evaluate the effects of interactivity and gamification of rehabilitation exercises using SHRUG prototype in the next stage of our research.

Mode 1: In this mode, the platform and the pole does *not* provide any form of feedback to the patient. As the physical form of the SHRUG was designed to be similar to the specifications of the existing exerciser, this mode is considered the *control state*. This is because in this mode, SHRUG operates very similar to the existing rehabilitation exerciser.

Mode 2: Patients follow their own pace with the exercise but are provided with immediate interactive feedback through the platform (lighted up hooks) and the pole. The effects of *interactivity* are evaluated by comparing the evaluations of Mode 1 and Mode 2.

Mode 3: In this mode, a set of hooks lights up and sequentially advancing positions on the platform. The patient has to follow these moving lights with the pole. As the patient keeps up, the game increases the challenge by speeding up the process. The effects of gamification are evaluated in this mode by comparing the evaluations of Mode 2 and Mode 3 (as the only difference between Mode 2 and Mode 3 is the gamification). In this mode, the difficulty is furthered by having the hooks light up at random locations.

In addition to the in-game performances, the pole records the task completion time, and the accuracy of the process (holding the pole horizontal being the desired position). The evaluation intends to target various factors such as the patients' motivation, speed of recovery, experience of the therapists etc. These will be evaluated through interviews and discussions.

In addition, we intend to correlate the logged data with the standard evaluation done by the therapists that includes evaluating performing certain tasks such as completing activities of daily living[5].

INITIAL REACTIONS

The development of the SHRUG prototype involved continuous collaboration with the therapists. These included interviews and focus group studies with the therapists with different versions of the SHRUG prototype. At the initial state of the prototyping that involved wooden mock-ups, etc. the therapists indicated that it is key to present the new system as close as to the existing exerciser. In addition, some of the most important requirements for the SHRUG were: safety - use the system without any exposure to danger; simplicity- use the system without any complex training; cleaning- ability for the SHRUG to withstand general cleaning procedures of the hospital. The SHRUG prototype presented in this paper is the 4th iteration that has been approved by the therapists with minor modifications. Following summarises the initial reactions of the therapists.

Safety: The therapists found the SHRUG platform to be suitably rigid for patient use. However, they suggested that the SHRUG pole be strengthened. It was mentioned that patients with weak shoulders generally tend to place the pole rapidly on the platform. Therefore, we intend to strengthen the pole by reinforcing with several layers of thicker materials.

Simplicity: The therapists were pleased with the simplicity of the device. The use of the exact same physical structure in the design allowed the therapists to intuitively understand the usage of the system.

Interactive Feedback: One of the key comments during the discussion was to introduce a mechanism to control the brightness of the lights on the platform and the pole. It was mentioned that some patients (for example, those with Autism) may react to sudden changes in the lights.

[5] `http://goo.gl/X22GUK`

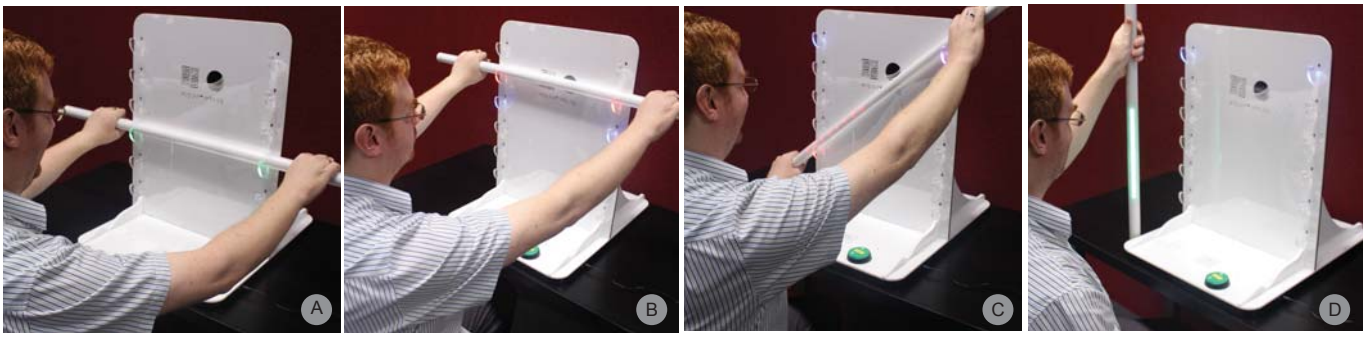

Figure 6. SHRUG States (a) Green hooks indicates the correct placement of the pole on the platform (b) Red hooks indicate an incorrect placement of the pole on the platform. The blue hooks indicate the target hooks (c) The pole lights up if not held horizontally (d) Holding the pole vertical displays the progress/game score of the patient

Therefore, this is a key modification we intend to do before the trials.

Games: The therapists were generally pleased with the simplicity and the minimalistic approach of the games that were presented.

Taking the above comments into consideration, we are modifying the SHRUG prototype with a strengthened pole and a LED brightness control interface. With the completion of these tasks, we intend to carry out our user evaluations with the patients following the IRB approvals.

CONCLUSION AND FUTURE WORKS

In this paper we introduced SHRUG, an interactive shoulder rehabilitation platform. The introduction of the device to rehabilitation therapists resulted in generally positive feedback. Thus, following the minor modifications proposed by the therapists, we intend take the following major steps as the next stage of the project.

Formal Evaluations: We are in the process of getting IRB approval by both the university and the local rehabilitation centre. Clinical trial with the patients would begin upon receiving IRB approval. The proposed evaluations are targeted at finding the effectiveness of the interactive platform and finding the effectiveness of gamifying the rehabilitation process.

Designing therapist's interface: In addition to the above, SHRUG system will feature a therapists' platform that has two main components. Firstly, we intend to design a therapists' console which allows the therapists to place each patients' pole at the console to read and download the performance data. The data visualisation interface would allow the therapists conduct analysis and individual customisations of the rehabilitation program. Secondly, we intend to design a smart wristband to provide just-in-time alerts. These wearables will activate if a patient is making too many errors while executing their prescribed exercises or even in emergencies depending on the context.

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