

THE DESIGN AND EVALUATION OF AN INTERACTIVE MUSICAL REHABILITATION SYSTEM

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ABSTRACT

Research has shown that children respond positively when interactive environments are used in physical therapy. Stair-climbing is a skill that is commonly practiced in physical therapy sessions by patients with cerebral palsy, brain injuries, and lower limb amputations. Conventional stairs used in these therapy sessions do not provide therapists with any quantitative feedback nor do they provide motivational incentives to the patient. A rehabilitation therapy device is proposed that will track patient's movements and provide auditory feedback to encourage progress climbing stairs. The system will be designed following the ISO 13407 framework for user centred design activities. The effectiveness of the system will be established in a research study comparing quantitative (e.g. time taken for each step, total therapy time, stride length) and qualitative (e.g. patient's enjoyment and engagement and the therapist's observations) outcomes during conventional physical therapy sessions to those with the new system. It is expected that the system will make stair climbing therapy fun and engaging for patients and will improve the outcomes of physical therapy sessions. Since the system is portable and adaptable, it is expected to be extended to other physical therapies as well, such as gait therapies.

INTRODUCTION

Rationale

Research has shown that children respond positively when interactive environments are used in physical therapy [1]. When a child

interacts with the environment of their therapy, it creates a sense of play and enjoyment [2] and at the very least makes the therapy fun and engaging. Previous studies have noted a measureable improvement in outcomes when a person is highly motivated in their physical therapy [3]. There are many people that require physical therapy, such as the 2-3 out of every 1000 school-aged children with cerebral palsy [4] and the thousands of Canadians who suffer from brain injuries, many of whom are young adults [5]. Physical therapy sessions for patients with cerebral palsy, brain injuries, and lower limb amputations involve gait therapy [6]. Gait therapy aims to restore the patient's normal gait while performing various activities, such as walking and stair-climbing. Conventional stairs used in these therapy sessions do not provide therapists with any quantitative feedback nor do they provide motivational incentives to the patient. The goal of this research is to design, construct, and evaluate an interactive musical stairs system for use in physical therapy sessions. It is believed that musical stairs will make stair climbing therapy sessions fun for children (and adults), increase their engagement and participation and ultimately reduce the total time required for therapy. For therapists, the musical stairs will provide additional quantitative measures to track and inform physical therapies.

Previous Work

Rehabilitation therapy is more effective if the patient is motivated to do their therapy [3]. While adults may be able to motivate themselves to do therapy, children are more motivated by fun and engaging activities [7].

One method of motivating children to do their therapy is to make it interactive, fun, and engaging. Several studies have looked at creating rehabilitation therapy devices that are interactive and fun [1]. For instance, Corrêa et al. [9] developed an Augmented Reality musical system to be used in music therapy sessions to encourage motor movements. The system consists of cards of varying size and colour, a video camera and computer monitor. By physically interacting with the cards, the child can affect changes in virtual cubes displayed on the monitor. This interaction is used as an interface to a Virtual Music Instrument. A proof-of-concept study was conducted with one child with cerebral palsy. The goals of the study were to evaluate motivation and satisfaction of the child with the system and the motor effort required to make music with the virtual music objects. Preliminary results showed that the child positively interacted with the system and engaged both dominant and non-dominant hands during the therapy session. The successful outcome of this study and others cited above provide us with the motivation to create a fun and interactive rehabilitation therapy system for stair climbing.

Objectives

This project has two specific objectives in meeting our goal of improving physical therapy.

1. User Centred Design of the System

The first objective is to design a portable tracking system that can be used to detect the patient’s steps and trigger auditory feedback using user centred design methods. This will be done using the ISO 13407 standard for user centred design processes for interactive systems.

2. Evaluation of the System

The second objective is to evaluate the efficacy of the system in a pilot usability study with physical therapists and children. This study will statistically compare performance (e.g. time taken for each step, total therapy time, stride length) and enjoyment (e.g. patient’s enjoyment and engagement and the therapist’s observations) measures collected using the

proposed system to those collected during conventional stair-climbing therapy sessions.

The focus of this paper will be on the first objective of the project, the user centred design process.

METHODS

The ISO 13407 standard provides a framework of five user centred design activities that can be used to guide the design process. These five activities and their iterative relationships are illustrated in Figure 1.

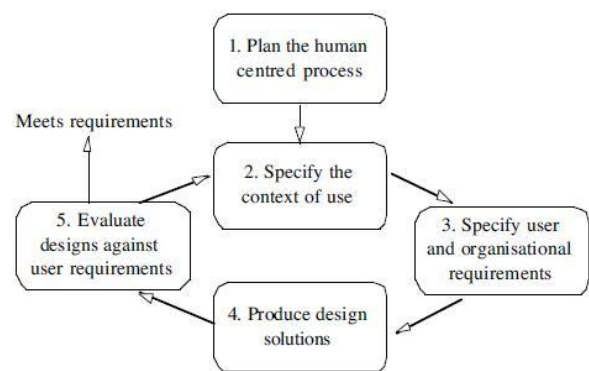


Figure 1 - The ISO 13407 user centred design process.

Although the standard outlines these five activities, the specific methods to accomplish each are not provided. Bevan [10] has provided a comparison of various methods available to implement each activity. This review was used to guide our design process. Table 1 shows the various methods and associated activities that will be carried out in our system design..

Table 1 - The methods used to accomplish each activity of the user centred design process.

Design Activity	Implementation Methods
Plan the human centred process	Planning, Stakeholder meetings
Specify the context of use	
Specify user and organizational requirements	Focus group meetings, User observations
Produce design solutions	Design guidelines, Prototyping
Evaluate designs against user requirements	Diagnostic evaluation, Performance testing, User survey questionnaire

RESULTS

1. Plan the human centred process & 2. Specify the context of use

A stakeholder meeting was held with physical therapists at Holland Bloorview Kids Rehabilitation Hospital. The purpose of the meeting was to gauge interest in the project and to understand the context of use. The outcomes from the meeting were:

- All physical therapists felt the system would be beneficial
- The system should be able to work on a variety of stairs (carpeted/uncarpeted) and a variety of locations (stairwell, gym, etc.)
- It should be easy to use

Based on the positive feedback from this initial stage, we decided to continue with the design process.

3. Specify user and organizational requirements

To gain further information in order to form requirements, a focus group of physical therapists was formed who would further guide the requirements. As well, several physical therapy sessions with stair climbing were observed. From these sessions and consulting with the focus group, the following requirements were developed:

- The system must be portable. No one set of stairs in the exercise gym is used by all therapists and sometimes the hospital stairwell is used. The system should be able to be used on any stairs.
- If any sensors are to be attached to the patient, they must be small. Nothing can be attached to the patient that would interfere with the therapy itself or the safety of the patient.
- The system must be easy to use. A complex system will not be used by the physical therapists.
- A user interface must allow the physical therapist to control audio feedback volume and allow the

patient to select the type of sound feedback.

- The audio feedback should reward progress (i.e. only the first time a step is climbed should feedback be generated).
- The system should be adaptable to gait therapy.
- Quantitative measures (e.g. number of stairs climbed, rate of stair climbing) would be useful for physical therapists and tracking patient progress. Data must be easy to access, visualize, and manage.
- Cost of the system must be low and reliability/durability high.

4. Produce design solutions

In order to create a portable and versatile system, it was decided that instead of instrumenting a single set of stairs, sensors would be attached to the patient to allow footsteps to be detected. In order to determine the most suitable sensor for this application, a review of sensor use in human tracking was conducted [11]. From the review, it was decided that wireless accelerometers would be used, since they are small, portable and can be unobtrusively attached to the body, they can detect footsteps and measure distances and only track the patient with the sensors attached. The rest of the design consists of a computing device (such as a laptop or smartphone) that connects to the wireless accelerometers. The computing device will process the sensor data in real-time, detect footsteps and trigger audio feedback. The computing device will also provide the user interface allowing the patient to select the type of sounds to be played and allow the therapist to control the volume and collect quantitative data from the session.

5. Evaluate designs against user requirements

This has not yet been designed, however it is planned to have two studies. The first will be an evaluation study in order to determine if the system works with the target audience and the second study will determine the effect of the system on physical therapy.

DISCUSSION

A user centred design process has been adopted to design an interactive rehabilitation system. The process has sought the input of stakeholders and has resulted in a portable, user-friendly and robust system that will provide audio feedback to encourage progress in physical therapy sessions using stairs. The initial design has been completed and work has commenced on the first prototype of the system. Once the project is complete and the system is validated, not only will it make physical therapy sessions more enjoyable and engaging, the technologies developed can be used in other applications such as fall detection while climbing stairs and gait assessment.

Our design is strong as we have consulted with key stakeholders early on and have formulated requirements with their input. However, there are limitations with our design, such as:

- It is not known whether the system will have any lasting impact on physical therapy sessions once the novelty wears off.
- Even if unobtrusive sensors are used, will patients accept the sensors being attached to them?

To determine the impact of these limitations in our design, we will proceed with the next step in the project. Our next task is to implement our design and create a rough initial version of the system. This iteration of the system will be tested and evaluated by physical therapists and a usability study. Any shortcomings of the design will be addressed before proceeding to the evaluation study.

CONCLUSION

A user centred design process is extremely important in the design of interactive rehabilitation systems that meet the needs of the intended audience. By using the guidelines early in the design process, we have avoided designing a solution that would not be ideal, such as instrumenting a single set of stairs. The process has highlighted the importance of the multi-disciplinary and participatory research practices, which help designers avoid the

pitfalls of groups working in isolated silos designing solutions that are not realistic in the real world.

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