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REHAP – Modular and Interactive Rehabilitation Tiles

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ABSTRACT

This paper describes the vision behind and development of a modular and interactive tile system, designed for patients suffering from a stroke. Traditional rehabilitation techniques are mainly based on mechanical structures and passive materials and are used in an improvising way by physiotherapists. On the other hand we see large-scale products equipped with a big amount of sensors and possibilities, however these are mostly complicated for both therapists and patients. In collaboration with medical researchers and practitioners a vision for individual and personalisable products has been formed. Observing and understanding the current situation in a stroke unit in a hospital in Sydney showed the strengths and on the other hand the needs of practitioners. Responding to this a modular and interactive approach was opted, which allows therapists to create exercises for single patients. Essential factors for physical rehabilitation are *motivation, customization and independence*. By using techniques like force sensitive resistors, magnetic and spring-loaded connections [1] and 3D printing, several sets of pressure sensitive floor tiles and a corresponding graphical interface with visual feedback have been produced, which are demo versions and frequently used as in-situ prototypes in hospitals in rehabilitation practices.

Author Keywords

Stroke rehabilitation, modularity, motivation, interactive, individualization

ACM Classification Keywords

H.5.2 User Interfaces: User-centered design

INTRODUCTION

In the world of medical and physical rehabilitation exercise techniques we can define two product types, the analogue and the products fully equipped with sensors. In the case of medical rehabilitation of stroke patients it is essential to keep track of the exercise results of the recovery process. The lack of ease to record data during physiotherapy exercises creates an opportunity for intelligent interaction design. During the last few years a vision and a variety of prototypes have been created with different design students and professionals [3,4,6]. The development and design of a modular pressure sensitive set of floor tiles, made for physical and medical stroke rehabilitation, will be described in this paper. The set of so-called REHAP tiles is displayed in Figure 1.

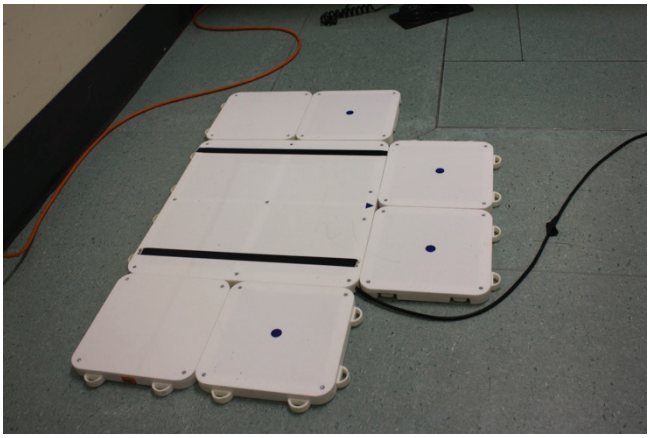

Figure 1. Tiles positioned in stroke unit in hospital.

APPROACH

The way of designing and developing has been according to a concept method developed by the first author, called OPTAR, which stands for Observe, Produce, Test, Analyze and Reproduce. By observing the situation it is possible to quickly see the practical environment, which does not only show problems but also strengths of the target group(s). This approach works inspiring, motivating and allows creating a vision and products that fit the needs of the target group(s) perfectly. Looking to problems and strengths, simple prototypes can be produced quickly that can solve issues for the chosen context. Prototypes will then be tested in the earlier observed environment. The tests and feedback will be analyzed, and from these results the prototypes can be reproduced. This cycle can be used iteratively, until a satisfying result has been produced. By working in this way, products can be developed that are thought out in detail. By frequently showing the end users possibilities (as prototypes, or 'provotypes' [2]) and involving them through out the process the initial ideas can turn into valuable product ideas, worth investigating and developing further.

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MODULAR INTERACTIVE STEPPING TILES

In response to the need of the therapies, as explained in the approach section, we developed a modular set of balancing and stepping task tiles. The work was inspired by an exercise mat [9], which is a design adapted from the Dance Dance Revolution game paradigm. With this mat, with fixed sensors equipped in it, elderly or less mobile people can practice dancing and stepping exercises in the home environment. Digital games for physical therapy have been used successfully before [5].

The REHAP sensor tiles however are developed with the vision that it should perfectly fit the needs of an average stroke patient, and moreover, it should be personalisable for separate patients. Thanks to the modular approach a therapist can lay down an exercise floor for every single patient, based on the disability and goal of the training of that specific patient. The sensor tiles are fabricated using instant manufacturing, which creates variable possibilities to quickly develop possible prototypes to test in practice. The tiles are in total only 20mm high, which is far lower than other entertainment robotic tiles, among others like the Wii Balance Board. The REHAP tiles set consist of a main tile which is 400x400mm which is the center tile of the exercise, and measures the pressure of 4 points, the back and front of the left and right feet. Subsequently there is the possibility to connect small 'sub tiles' around the maintile. These tiles with one single force sensor are 200x200mm, and therefore there can be exactly 2 sub tiles connected at one side of the main, so in total around the maintile there could be 8 sub tiles. The purpose of the sub tiles is to allow therapists to set up stepping exercises for the patients, which is crucial for weight shifting, an important ability to be able to walk [8].

The design process was highly inspired by the practitioners, who suggested most of the key elements in the current design. Showing a continuous signal on a display of the pressure points has more value than only showing the balance right/left. For example the feedback is on a screen in front of the exercising patient, as looking forward is essential for a proper balance. This feedback is also of big advantage for the therapist, as it can be used as a communication and explanation tool, as shown in Figure 2.

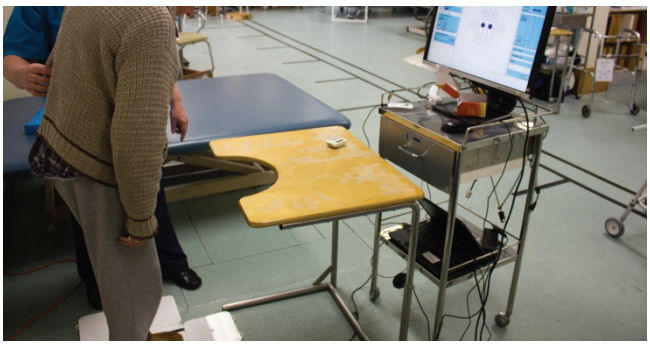

Figure 2. Patient exercising with therapist assistance.

The advantage of having a modular system [7] has proven when therapists asked if the tile could be used in a tilt table bed exercise, in which patients have to push themselves up in a bed by pressing against the footboard of the bed, as can be seen in Figure 3. Most patients were not aware of the behavior and strength of their legs and could not even believe that they actually had power in their leg to be able to press up. Getting feedback on the amount pressure on the back and front of both feet helps the patients to train the stability and strength in their legs. Another patient was not even with very motivating help from the therapist able to press up at all. He was not aware and didn't believe he had the ability and power to do so. When implementing the main tile and the GUI the patient saw a very little dot, which gave feedback of his own movement, allowing to believe in himself and to press even harder. The simple growing dot was of incredible motivating value for the patient.

Figure 3. Main tile being used in tilt table bed exercise.

GRAPHICAL USER INTERFACE

The Graphical User Interface (GUI) is build for the functions to control the settings of the exercise and overview, the live and direct feedback and a results section. A screenshot of the GUI, which is build in MAX/MSP, can be seen in Figure 4. As mentioned the interface is an information and communication system for both the patient and the therapist. The graphical illustration of growing dots based on increasing pressure has proven to be a simple yet very informative representation during balance and stepping exercises for stroke patients.

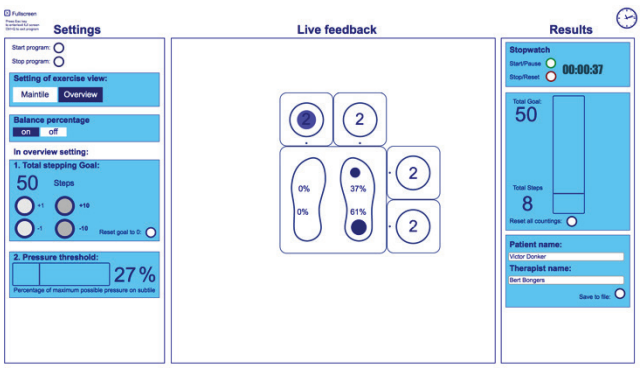

Figure 4. Graphical User Interface.

The interface corresponds directly to the layout of the physical tiles on the floor. When attaching a sub tile to the main tile the interface reacts to this and displays the attached tile directly on the screen. These sub tiles on screen show the amount of stepping repetitions on those single tiles, based on the pressure that has been put on them, when reaching the pressure threshold, which is to be controlled in the Settings part on the left of the screen. In the settings part the user can also choose to display percentages of the single pressure points, relatively to the complete pressure. Next to

this the user can set the goal of amount of steps to be taken in total. The right part of the GUI shows a stopwatch and the progression of the total amount of steps toward the stepping goal. This is very valuable for therapists to have an overview of how the patient increases the average amount of steps per minute.

For logging purposes the right bottom part of the GUI also allows to fill in the patient and therapist name, with a possibility to write some notes of the exercise. When hitting the save button a .csv (comma separated value) file will be automatically produced, with information about that certain exercise. These .csv files are readable in Microsoft Excel and can be used to create graphical overviews of the process. Keeping an overview of the progression of a patient over a long time will help the guidance and will give a better view on if and how goals are achieved on long term.

CONCLUSION

Concluding from the development process and results we find that it is essential to go into the context early in the process to find the strengths and needs of the user. By observing the way of working, proposing ideas by bringing physical and quickly made ideas it is easier to test, analyze and discuss to find several key factors to design for. This frequent and iterative way of designing and including the users helped to create a modular balance and stepping exercise product that is currently used in the context where people benefit from the created values based on their needs. Values in this case include motivation, customization and independence. These values and the iterative OPTAR approach can be valuable for any design case and can be considered as valuable to pay attention to in the future for human-computer interaction. Especially creating individual products and systems by using a modular approach is an essential value in the project looking to the fact the product has been proven to be very valuable for patients and therapists in practical context.

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