PhysiTable: Tangible Interactive System for Physical Rehabilitation of Children with Cerebral Palsy

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ABSTRACT

Cerebral Palsy is a permanent movement and posture related disorder. It happens by birth so generally physiotherapy starts at a very early age. So many of the patients are kids. Treatment involves a lot of physiotherapy which further includes varied exercise with different equipment. These equipment lags engagement and for kids it becomes very important. From many physiotherapy we have chosen fine motor skill development, precisely improving hand rotation. Solution targets the kids and uses light and sound feedback to enhance their engagement. This solution also helps in eye hand coordination and color concept. Further evaluation was done with some kids at a NGO and results came to be positive. Kids showed interest in playing with the board. Though no statistical analysis could be done as every individual is different and have different severity of diseases so analysis was difficult.

CCS Concepts

• **Human-centered computing~Accessibility systems and tools** •*Human-centered computing~Haptic devices* • **Hardware~Tactile and hand-based interfaces**

Keywords

Tangible User Interface, Cerebral Palsy, Physiotherapy.

1. INTRODUCTION

The consensus definition for cerebral palsy (CP) states that "Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain."[1] There is no known cure for CP and as such it is lifelong condition. CP is one of the most common causes of childhood physical disabilities, though the effects differ from person to person depending on severity, meaning the condition can manifest as a very mild weakness in one or more limbs for one person, or present as a more severe impairment, preventing all voluntary movement, in another.

Children with cerebral palsy experience limitations in gross and fine motor control, strength, and range of motion. Muscle imbalance and poor control of movement can have an impact on the daily occupational functioning of children with cerebral palsy. These deficiency dramatically limit their ability to perform daily tasks, such as feeding, dressing, bathing, and communicating independently. Children with CP also suffer from challenges in school while taking class notes, finishing assignments, or performing additional physical activities [2]. These deficits can reduce participation in community and leisure activities, and even negatively impact occupational perspectives [3].Participating in repetitive exercises can help children with motor disabilities overcome the limitations.

Researchers suggest that occupational therapy can sufficiently stimulate brain to remodel itself and provide better motor control [4]. Identifying motivating and effective methods of encouraging people with motor disabilities to perform exercises is crucial for helping them retain or enhance their motor control and increase their independence. In contrast, traditional methods of physical therapy (such as bending, stretching and reaching tasks) that are highly repetitive, games that involve physical activity, such as the movement of limbs and joints to play the game, have become increasingly popular due to the higher level of motivation, engagement and perceived sense of achievement required by the game.

This study aims to use tangible user interface in designing tabletop activities to help motivate children with motor disabilities to increase the number of exercises and improve the motor proficiency and quality of life. The system also includes an interactive interface with visual and audio feedback to enhance children's motivation, interest, and perseverance to engage in physical rehabilitation.

2. BACKGROUND

Physical therapy is a branch of rehabilitative health that is considered one of the most important aspects of treating children with cerebral palsy focusing on stretching and strengthening of muscles. The goal of physical therapy is to maintain and/or increase the range of motion, prevent deformities and contractures, increase muscle strength and enhance coordination of movements, in order to maximize the comfort, independence and functional control of the body.

As with any therapy, success largely depends upon the dedication of the patient and his/her motivation to actively take part in the physical exercises. These factors determine the quality of the exercises and extends the quantity of physical therapy. Although patients often look forward to spending time with the therapist [5], the actual motivation for executing repetitive, tiresome, and boring exercises is not always present. A research [6] has shown

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that exercises for patients recovering from physical disabilities and injuries are more effective when the exercises are integrated within a game.

Children get more engaged and motivated through a game environment and they tend to forget the pain caused by and the dull repetitive nature of rehabilitation exercises. Games can offer an entertaining alternative to repetitive tasks. Audio and visual feedbacks provided by the game helps in engaging their attention on the exercise and keep them motivated to execute the exercise repeatedly [7]. Also, engaging the attention of the children on the game helps in improving their concentration. Therefore, identifying motivating and effective method of encouraging children with motor disabilities to perform exercises is crucial.

3. RELATED WORK

Motivation for using games in the rehabilitation process derives from the fact that the brain can reorganize itself and account for motor dysfunctions, to some degree. This reorganization is what most rehabilitation methods aim for and it is much easier to achieve in younger patients. Several research projects have taken a similar attempt of designing physical games forrehabilitation of children with motor disabilities.

Cifuentes-Zapien et al. [8] propose an upper limb rehabilitation method for children with cerebral palsy (CP) that uses a video game and a robotic platform. They aim at pronation and supination movement rehabilitation and thus, they have developed a racing video game where a child controls a car using a motorized force feedback controller. Wu et al. [9] have developed a robotic ankle rehabilitation platform, targeted at children with CP. The system is portable, thus enabling rehabilitation at home, and is able to perform passive stretching as well as active movement assistance to thechild's ankle.

Van Loon et al. [10] have developed a set of games in an effort to motivate children with CP to exercise in decoupling the movement of their hands. The authors have used two horizontal levers as game controls and developed appropriate games. One lever controls horizontal and the other controls the vertical displacements. Biel Moyà-Alcover et al. [7] transferred the ASPACE balance therapy tasks to a video game. The author implemented a video game that consists in changing the user's gravity center: trying to cause a specific body movement in order to change their gravity center. To do this, users must interact with objects that cannot be reached without changing their center of mass. This way, users focus their attention on the video game instead of their posture. Gentle/s system of Loureiro et al [11] is an example of a haptic-based rehabilitation system for upper extremities of CVA patients .The system includes a haptic robot, the MOOG HapticMaster, and a custom-made ADL gimbal with overhead frame to support the hand and elbow during the training. PhysiCube explores the use of tangible objects and pervasive technologies to train patient with motor disabilities patients on gross motor and fine locomotion movements.

Other researchers developed games for therapeutic purposes with other input devices, such as haptic gloves, robotic devices, and pen-like haptic devices. As research on making the training system more engaging and home-based is gaining attention, most works on rehabilitation these days includes haptics, exoskeletons and robotics. While these are very effective in physical and neuro-rehabilitation, they are too expensive and impractical for residential training.

4. METHODOLGY

The study was conducted in two stages. In the first stage, the study began with a few subject matter expert (SME) interviews to get in-depth knowledge of this field and validate the presumptions made through literature review. Second study included contextual user research to gather qualitative data about the physiotherapies, exercises and equipment being used for rehabilitation of children with cerebral palsy and their limitations.

Four children with cerebral palsy, with all having different levels of abilities were studied and keenly observed during their physiotherapy session in Shishu Sarothi, a rehabilitation center in Guwahati for children with multiple disabilities. Following are the research findings formed on the basis of the contextual research:

- Equipment being used in the physical rehabilitation center of Shishu Sarothi are very conventional and involve no technological interventions.
- Most of the physiotherapy equipment are focused on gross motor skill development and there are very few equipment available for fine motor skill development (grasping, supination of wrist, extension of the fingers etc).
- For fine motor skill development they use manual and passive therapy techniques. For example, for improving the wrist movement and rotation children are made to open the cap of a bottle.
- A child do all the exercises and therapies under the supervision of therapist or caretaker. Children look forward to spending time with the therapist.
- While doing any activity children do not focus their attention on the activity instead get distracted easily by their environment.
- To motivate a child and engage their attention on the activity, therapists talk to them and give them feedbacks continuously.

Three physiotherapists working in physical rehabilitation at the Shishu Sarothi were interviewed to obtain insight into criteria that technology should meet to be useful and usable in assisting fine and motor skills training in children with cerebral palsy. The design of the final solution is based on the physiotherapists' knowledge and observations about their patients. The following research hypotheses were formed on the basis of those interviews:

- H1: Audio and visual feedbacks such as sound effects or bright colors and lights engages children's attention and keep them motivated. although sound effects are more helpful at the end of each game.
- H2: Progress feedback for completing the exercises will motivate the child to repeat the exercise.
- H3: Gradually increasing the difficulty of the game will accelerate rehabilitation.
- H4: The simple and uniform use of colors as visual feedback/instructions will help to focus attention.

In order to validate and demonstrate the impact of the above stated hypotheses we designed and developed a tangible

interactive tabletop game aimed at improving fine motor skills of the children with cerebral palsy.

5. PhysiTable

5.1 Design

Our research finding suggest that Shishu Sarothi lack equipment for development of fine motor skills. We decided to help by proposing the use of PhysiTable, a programmable electronic board game involving tangible and tactile interactions, along with audio and visual feedback to train several movements, such as grasping, supination of wrist, extension of the fingers, and movement of the shoulder. Along with improving the motor skills, the proposed system improves eye-hand co-ordination and cognitive skill of the children. Lastly, the therapists are able to control the level of difficulty of the games, which would help in mapping child's improvement.

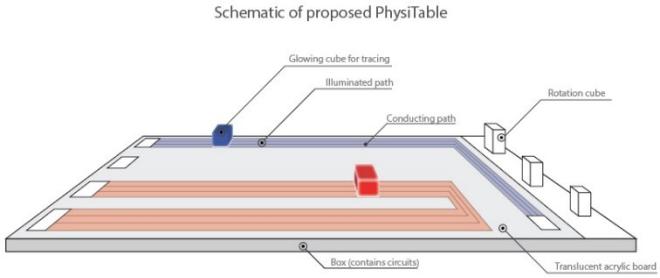

Figure 1. Schematic of the proposed system

5.1.1 Components

Components of the system includes one tracing cube, three rotating cube and a board which has three paths built on it. Paths are like train rails and child is expected to move the cube on the rails. Led stripsare attached beneath each path which glows on the basis of levels that the child needs to practice. Whentracing cube is brought in contact with the paths it will glow with same color as that of path. Rotating cube is attached to the board whereas tracing cube is free. There are three types of path. First is blue path with only one turn. Second is red path with two turn. Third is Green with zigzag motion.

5.1.2 Working of Physiotherapy

Child is first asked to rotate the Rotating cubes and stop when the color of the rotating cube is same as color that of the path. Child is then asked to move the cube on the path which is glowing. As soon as the child put the cube on the rail, cube starts glowing with the same color as that of path and a pleasant sound starts coming. If the child is able to move the tracing cube on the path without slipping the cube out of the path then the light and sound keeps on going. When the cube dislocates from the path the tracing cube stops glowing and the sound also stops playing. Child has to put the tracing cube back on the rail and complete the path. Basic Red, Green and Blue color has been used for the paths.

5.1.3 Levels of Challenges

First the child will be asked to go for first type of path. As soon as he gets acquainted with that he would be asked to practice with second and third path. After this at fourth level he will have all the three paths glowing and therapist or the caretaker will only specify the color and the child has to follow that path.

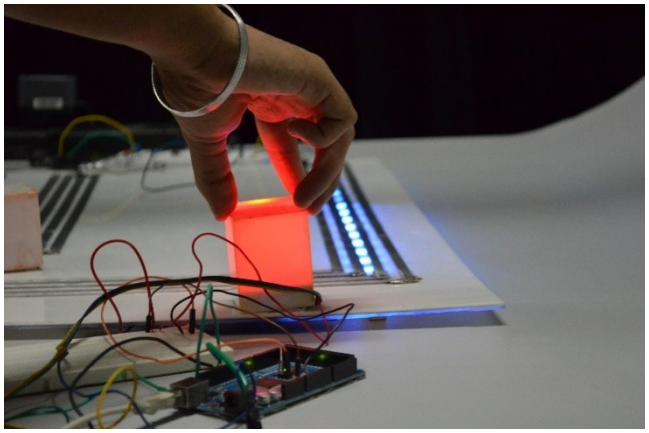

Figure 2. Prototype of the system

6. EVALUATION

The prototype was evaluated in an initial qualitative study with therapists to assess the potential of PhysiTable in daily Physical rehabilitation practice. In this stage, the therapist decides to what extent the system fulfills the needs of the target patients. This approach contributes in finding the right balance between initial technology and exploration with therapists. We included two therapists treating children with CP, in Shishu Sorathi for the evaluation of the system. After shortly explaining the interactions and game play, each therapist played with our prototypes. During and after playing with each prototype, the therapists explained their vision and opinion on our system and discussed with each other and with the researchers.Overall, the therapists were very positive and enthusiastic about the PhysiTable as tangible training system. They enjoy exercising with our cubes and declare that the cubes provided a lot of variation possibilities for physical training. They stated that these cubes offered many possibilities for physical rehabilitation, and that they would definitely use ourSystem for their patients once it is proven to be effective.

First hand evaluation of the first phase prototype was conducted in nearby areas of Guwahati with children suffering from cerebral Palsy falling in the age group of 6-14 years. Evaluationwas done in presence of 2 physiotherapists from Shishu Sarothi School. Following are the Evaluation outcomes:

- Constraint Required: Children suffering from high mental retardation needs constraints on either the edges or in between the rails to make sure they are able to do the task at first. After practice constraints can be removed to learn further and also to make it accessible for others who are not suffering from mental retardation.
- Engaging System: Kids use to keep the cube stationary at the end of the path if it was glowing and if cube got out of the track and stopped glowing he would go to the start because from experiencehe learnt that it works at the starting point and he was doing this repeatedly.
- Enjoyable Experience: Kids were smiling all the time they were working with this tangible board.
- Aesthetics: About the appearance, physiotherapist suggested not to add too many colors because that might

distract children's attention. They commented that the plain looking is working well and lights and sounds are good enough to engage kids.

- Grasping: The size of the graspable cube was perfect enough for providing a good grip but the size of the rotating cube was slightly big. Children were feeling difficulty in rotating the cube because of the poor grip.

Figure 3. Discussion with the Physiotherapists

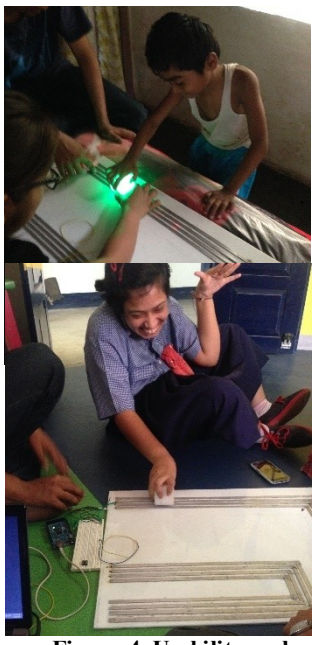

Figure 4. Usability evaluation of the system

7. CONCLUSION

Children suffering from Cerebral palsy have multiple disabilities and not everything could work for everyone and also the severity of disease might not be the same for everyone. The challenge in this scenario was about engagement of children with system sothat they feel motivated to carry out physiotherapy exercises themselves. It will make their learning easy and better. These type of tangible boards will make the task engaging and enjoyable. Further we want to measure if their development is faster than theconventional physiotherapy exercises. Also to validate the assumption thatthe level of engagement that kids feels with the equipment persists.

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