Using a Multi-touch Tabletop for Upper Extremity Motor Rehabilitation

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ABSTRACT

Millions of people in Canada have impairments that result in a loss of function and directly affect their ability to carry out activities of daily living. Many individuals with disabilities enter into rehabilitation programs to improve their motor functioning and quality of life. Currently, many of the activities and exercises that are performed are monotonous, uninteresting, and do not inspire patients to perform to the best of their abilities. The usage of traditional exercises can also make it difficult for therapists to objectively measure and track patient progress. The integration of highly interactive and immersive technologies into rehabilitation programs has the potential to benefit both patients and therapists. We have developed a multi-touch tabletop system, the AIR Touch, which combines existing multi-touch technologies with a suite of new rehabilitation-centric applications. The AIR Touch was developed under the guidance of practicing occupational therapists.

Author Keywords

Multi-touch tabletop, interactive surface, occupational therapy, motor rehabilitation, patient progression

ACM Classification Keywords

H.5.2 User Interfaces: Input Devices and Strategies, H.5.m. Information Interfaces and Presentation: Miscellaneous; J.3 Life and Medical Sciences: Health

INTRODUCTION

More than 10% of Canadians are afflicted with impairments that influence their ability to perform everyday activities (CANSIM Database, 2009). These disabilities can stem from a variety of causes, including aging, disease, trauma, or congenital health issues. Most activities of daily living (e.g., eating, dressing, and bathing) require the use of the upper body, so occupational therapists work with patients to help restore upper body motor function and improve a patient's quality of life.

Current upper extremity rehabilitation activities, such as drawing images on paper, tracing letters in the air, or reaching for imaginary targets, require patients to perform repetitive movements that focus on increasing a patient's range of motion, coordination, muscle strength, and muscle endurance. Most of these activities are monotonous and unexciting, often causing patients to exert moderate effort or neglect them completely. In addition, many traditional rehabilitation activities do not provide objective performance measurements, making the monitoring and evaluation of patient progress difficult.

Figure 1. A 'therapist' and 'patient' using the Therapist Do-It-Yourself Activity on the AIR Touch.

Over the last decade, interactive surfaces and multi-touch tabletops have become very popular, partially due to their decreased cost. Multi-touch tabletops have the potential to greatly enhance patient motivation and compliance with rehabilitation activities because they are highly interactive and immersive, and they support natural methods of user interaction.

As immersive tasks can help to reduce the amount of pain or discomfort that a patient experiences (Berger-Vachon, 2006), we believe that the integration of multi-touch tabletops into the rehabilitation process can provide many benefits for both patients and therapists. Working closely with occupational therapists from the Glenrose Rehabilitation Hospital, we have developed an interactive, multi-touch tabletop and a suite of upper extremity, motor-based applications. Our open-source system, Ammi Interactive Rehabilitation Touch, or AIR Touch (Figure 1), aims to provide therapists with an easy-to-use tool that 1) can be customized to meet a patient's abilities and needs, 2) can increase patient motivation and engagement, and 3) can record a variety of objective measurements.

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RELATED WORK

The development of applications for multi-touch tabletops has steadily increased in the last decade due to the novelty, potential, and ease of construction and development of tabletop technologies. Multi-touch tabletops have been used for applications as diverse as remote interface control (Seifried, 2009), music composition (Jorda, 2007), and data organization (Scott, 2005).

It has, however, only been in recent years that multi-touch tabletops have been used for rehabilitation. Mumford et al. (2008) describe an interactive surface that can be used to assess and treat traumatic brain. Mumford et al.'s system provides only coarse measures of patient progress, the implemented activities do not appear to be intrinsically motivating, and the use of tangible objects prevents patients with poor fine-motor skills from using the system. Facal et al. (2009) describe a multi-touch surface that can be used to develop cognitive skills in the elderly. As with Mumford et al.'s system, the activities Facal et al. implemented do not appear to be engaging or motivating, and their system does not support therapist interaction or measure motor skill level.

Apted et al. (2006) and Al Mahmud et al. (2008) have developed design guidelines for tabletop-based applications for the elderly. Some of their suggestions include maximizing the size of interface elements, reducing the number of interface elements, and utilizing familiar metaphors and common knowledge to increase user learnability and understanding. As motor skills, vision, and cognitive abilities are decreasing in both elderly and rehabilitation populations, we feel that these same guidelines should be applied to multi-touch tabletop activities.

DESIGN OBJECTIVES

Given the variation in age and level of motor dysfunction within our target population, there is no single activity or exercise that can be used for every individual. Some patients have near-normal functioning, while others cannot move their fingers and rely exclusively on gross motor movements. In collaboration with our occupational therapist colleagues, we identified three objectives for our multi-touch tabletop system:

O1. Engage patients and ensure that activities are easy to learn

- If activities are not intrinsically motivating or immersive, patients may not put much effort in.
- When patients are immersed in an activity, they are less affected by pain, and may perform the activity longer.
- Activities should build upon known metaphors and existing knowledge to maximize a patient's comfort level.

O2. Ensure that activities are repeatable and that meaningful performance measures can be recorded

- Performance measures can help to quantify a patient's progress.
- Having repeatable activities ensures that measures are meaningful and can be compared to past performance.
- Presenting patients with performance measures can provide them with motivation and may speed up their recovery.

O3. Leverage therapist expertise and their knowledge of a patient

- No system can replace the expert judgment and abilities of a therapist.
- Therapists should be able to adjust the difficulty of activities to match a patient abilities, as well as goals and outcomes.

REHABILITATION SOFTWARE SUITE

We have designed a number of tabletop activities that replicate real-world activities or provide alternatives to existing activities. Guided by the design objectives identified above (as well as Apted et al. and Al Mahmud et al.'s guidelines), we developed a suite of five motor-based rehabilitation activities. Features common to all activities include the presentation of a visual 'touch map' (Figure 2), automatic comparisons between current and past performance, and the ability to store patient-specific activity configurations.

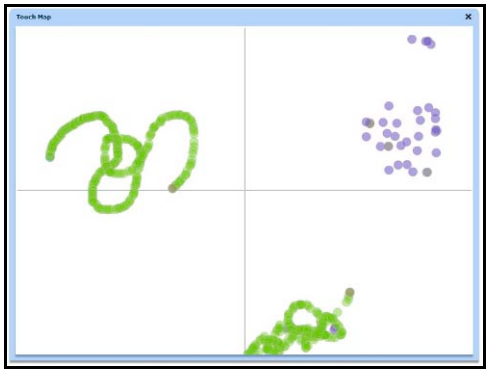

Figure 2. A Touch Map displays distributed touch events and helps in identifying functional asymmetries or regions of patient neglect.

Pop Those Balloons!

In Pop Those Balloons (Figure 3), a patient is presented with a landscape that has floating balloons. The patient is encouraged to think of their hands as stick pins, and use their 'pins' to pop the floating balloons. Once a balloon has been popped, it 'fades out' and disappears and a popping sound is played. At this time, the patient's score increases, providing immediate positive feedback.

This activity aims to enhance hand-eye coordination as well as dexterity. Therapists can tailor this activity to meet the needs of a particular patient by modifying the number of balloons that appear, changing the speed at which the balloons float from bottom to top, or modifying the area of the screen to which balloons float. While the patient is performing this activity, a number of metrics are gathered: the time-on-task, the time between balloon pops, the number of popped balloons, the total number of balloons that appeared, and the balloon touch accuracy.

Drumhab

Inspired by the popular Rock Band and Guitar Hero video games, we have created a music-centric tabletop activity. In this activity, there are 'beats' that radiate from the

Figure 3. The Pop Those Balloons! activity.

centre orb (synchronized with the music) and move towards four drums located in the corners of the tabletop (Figure 4). As each beat reaches its target drum, the patient must use their hands as drumsticks, and 'hit' the target drum to score points. If the drum is hit at the correct time, the beat 'explodes' and then disappears.

A therapist can change the difficulty of Drumhab by choosing to display more or fewer beats on the screen, changing the speed of the beats, and selecting which drums are targets. As the drums are located in the corners of the tabletop, this activity promotes an increased range of motion. The speed at which the beats move can help to develop a patient's reflexes. As a patient performs this activity, the AIR Touch records a number of measures: the time-on-task, the final patient score, the number of beats touched, the total number of beats that were presented, the number of false hits, and the beat touch accuracy.

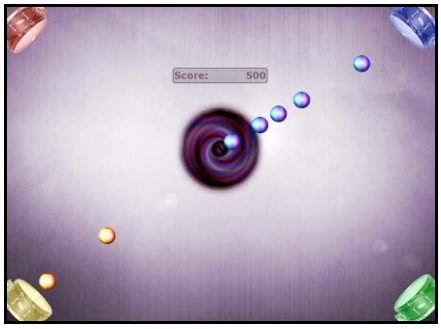

Figure 4. Game play during Drumhab.

Paint By Number

The paint by number activity encourages a patient to use their hands as a paintbrush to fill in a numbered outline (Figure 5). The patient can touch one of the numbered paint buckets located on the screen to change the colour of their 'paintbrush'.

This activity can be customized by changing the image that is displayed, the location and size of the image, and the number of colours that are used. AIR Touch determines the accuracy of a patient's painting (if the painting was in the lines), if the correct colours were used, the number of paint strokes the patient made, the number of paint bucket selections that occurred, the proportion of the image that was painted and the time-on-task. This activity can be used to improve fine motor skills and to encourage gross motor movements such as flexion and elevation.

Figure 5. A simple image being completed during the Paint By Number activity.

Picture Tracing

The picture tracing activity closely mimics an existing rehabilitation activity in which a therapist draws a pattern on a whiteboard and then asks the patient to trace overtop of the pattern (Figure 6). In our tabletop adaptation, therapists can draw a pattern on the surface and ask the patient to trace overtop of it. Alternatively, the therapist can load image files for tracing (e.g., complex patterns, letters, words, or outlines of emotionally salient images such as faces or animals).

Like the paint by number activity, therapists can change the size and location of the tracing pattern or image. This flexibility permits therapists to target both fine and gross motor skills. While this activity is performed, a number of measurements are recorded, including the time-on-task, the accuracy of tracing, the average tracing speed, the percent of the pattern that was successfully traced, and the number of paint strokes the patient made.

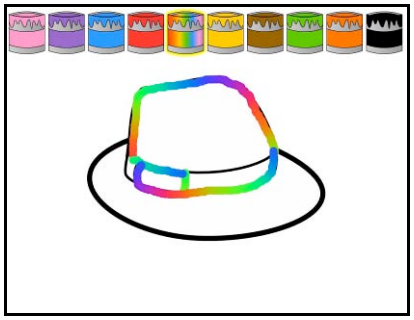

Figure 6. A complex image is being traced during the Picture Tracing activity.

Therapist Do-It-Yourself

This activity is analogous to an existing rehabilitation activity that requires therapists to place targets on a table so that a patient can reach out and touch them. In our table-based implementation of this activity, therapists can touch the tabletop to define target locations. The defined targets are then presented to the patient. Once the patient has touched a target, it 'flies away' and the next target in the sequence is presented.

For patients with asymmetric dysfunctions or with regions of neglect, this activity provides therapists with a tool to directly target their disability (Figure 1). As a patient performs this activity, the time-on-task, the target touch accuracy, the time between correct target

selections, and the number of non-target touches are all recorded.

SYSTEM DESIGN

The AIR Touch (Figure 7) is a cross-platform, multi-touch system that combines open-source software with a readily available multi-touch surface[1]. Our multi-touch tabletop screen (90cm x 55cm) was designed and manufactured by NOR_/D and uses the FTIR (frustrated total internal reflection) principle (Han, 2005).

Figure 7. The AIR Touch system.

All touch events are captured by an infrared camera and processed using the open source, openFrameworks software library. The openFrameworks software library allows us to modify the touch sensitivity of the tabletop. It is imperative that therapists are able to modify the amount of pressure required to generate touch events on the tabletop, because our target population has different levels of motor dysfunction.

After a touch event is detected, it is relayed to our Flex-based activities. Flex is a very extensible framework that combines ActionScript with an XML-derivative. Flex also has a large library of visually appealing user interface objects and animations that can be combined to create highly interactive, easy to use activities and interfaces for therapists and patients.

CONCLUSIONS AND FUTURE WORK

There is a large demand for motor rehabilitation due to the prevalence of impairments caused by stroke, brain injury and other diagnosis. A number of problems including less than optimal patient engagement and immersion, a reduced ability to grade the intensity and difficulty of activities, and insufficient objective evaluation metrics can limit traditional motor rehabilitation activities. We have developed a suite of multi-touch tabletop-based applications that address the needs of practicing occupational therapists and their patients. Our applications are engaging and exciting to use, can record and compare performance measurements, and allow therapists to guide and tailor activities to meet individual patient needs.

The AIR Touch is in the process of being installed in the rehabilitation hospital. The initial responses we received from the therapists have been positive. They commented that the system is easy to use and were looking forward to using it with their patients. Once the system is in place, we will use the diverse population at the Glenrose hospital to validate patient acceptance of the system in their rehabilitation program, their level of understanding and enjoyment with the activities, and the level of immersion they experience while performing the activities. We will also examine the usability of the system from the point of view of the therapists and evaluate the relationship between our objective metrics and the therapist-evaluated progress of patients.

[1] There are a number of do-it-yourself tutorials available that describe how to build a multi-touch surface (Castle, 2009; NOR_/D, 2009).

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