RHYTHMIC ENTRAINMENT FOR HAND REHABILITATION USING THE LEAP MOTION CONTROLLER

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ABSTRACT

Millions of individuals around the world suffer from motor impairment or disability, yet effective, engaging, and cost-effective therapeutic solutions are still lacking. In this work, we propose a game for hand rehabilitation that leverages the therapeutic aspects of music for motor rehabilitation, incorporates the power of gamification to improve adherence to medical treatment, and uses the versatility of devices such as the Leap Motion Controller to track users' movements. The main characteristics of the game as well as future research directions are outlined.

1. INTRODUCTION

According to The World Bank [1], one billion people, or about 15% of the world's population, live with some form of disability. Motor disability is extremely common, and can result from medical conditions such as cerebral palsy, stroke, multiple sclerosis, and Parkinson's disease. Stroke remains to be the leading cause of disability around the globe [8], with incidence of stroke in Europe estimated to be between 1.01 to 2.39 individuals in 1000 [5]. Given the staggering number of individuals affected my motor impairment, accessible medical/therapeutic solutions are urgently needed to provide rehabilitative care for this population.

Motor impairment of the hand and fingers has particularly dire consequences on affected individuals, as these impairments impact daily-life activities, and severely limit employment options. And unfortunately, while the value of rehabilitative motor therapies is well recognized, "therapeutic strategies designed to restore function by minimizing impairment are by comparison poorly developed" [8]. The area of medical technology (MedTech) has great potential to help meet this need. For example, a number of new therapeutic systems have been designed to treat

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[1] https://www.worldbank.org/en/topic/disability

hand and finger motor impairments, and make use of high-tech components such as robotic exoskeletons to physically facilitate hand movements [3]. Unfortunately, many such treatment options are prohibitively expensive and are not widely available. Therefore, solutions that are cost-effective, easy to use, and can be deployed to a large community are needed.

In addition, scientists know that the most helpful interventions for improving physical function after motor impairments due to stroke are based around "repetitive, task-directed exercises" in which greater intensity exercises leads to faster and more pronounced recovery of motor function [4]. Unfortunately, adherence to prescribed physical therapy (PT) exercises is often low, which results in longer convalescence periods for patients. This warrants the development of therapeutic systems that are engaging and enjoyable to use. Given the widespread enjoyment of music across cultures, and the ability of music to engage patients in clinical contexts [6], we argue that music-based approaches to motor rehabilitation may offer an ideal solution to this clinical demand [1].

This paper describes the prototype of a music-based MedTech system for motor rehabilitation. The system employs a low-cost motion capture device for monitoring the position of the hand and fingers in 3D space. It offers a low cost alternative to traditional PT, and is designed to be enjoyable and engaging through the use of music and gamification techniques. The following section describes the prototype system in detail.

2. SYSTEM DESCRIPTION

Music is the driving force behind the proposed game. The rhythmic pulse, or beat of the music is used to cue the user to perform a given exercise at a specific time. The process of synchronizing one's movements to the rhythm of an external stimulus is known as *rhythmic entrainment*, and it has been shown to be beneficial for motor rehabilitation in different medical scenarios [2, 7]. The underlying premise is that the initiation of a given movement becomes easier when performed in sync to a rhythmic pattern or beat.

In Figure 1a, a screen shot of our game is shown. The objective of the game is to catch an object (in this case, a green sphere) as it travels from left-to-right across the screen. In this example, the user is performing a *Grab* exercise where the goal is to grab the sphere once it reaches the
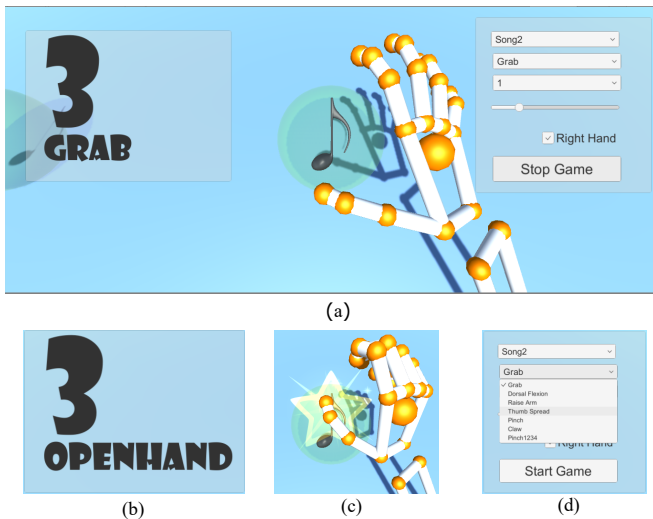
Figure 1. Screen shot of our hand rehabilitation game

end point in the center of the screen. The position of this end point coincides with the beat of the music track. This grabbing process is repeated continuously in sync with the beat of the music. The drop-down menu on the top-right of the screen allows the user to choose a song from a number of music tracks available. If the tempo of the song is too fast, the user can choose to perform the exercise either every beat (1 in the drop-down menu), or every two beats (2 in the drop-down menu), and so on.

Gamification is used as a way of breaking the monotony of performing intensive and repetitive physical therapy exercises. By increasing users' engagement, we aim at improving adherence to treatment, leading to better rehabilitation outcomes. During gameplay, real-time feedback is frequently presented to the user in order to give her an awareness of her performance. The game also indicates to the user which hand position is to be performed next. In Figure 1a, the user is expected to grab the sphere. In Figure 1b, the user is expected to go back to the initial position and open his/her hand. If the sphere is grabbed in time (on the beat), visual feedback is given with an animation (Figure 1c), and the user accrues points (Figure 1b). A difficulty slider (shown in the top-right of Figure 1a) allows the user to increase the tolerance in time, that is, the degree to which a hand position is considered to be performed correctly on the beat. The game currently offers a set of 7 exercises commonly used for hand rehabilitation (Figure 1d).

The Leap Motion Controller is used as a versatile hand tracking device. Leap Motion uses two cameras and three infrared LEDs to track the movement of the hands. The image data captured by the sensors is processed to identify the fingers, palm, and wrist of the hand. Filtering techniques are used for smooth temporal coherence of the tracking data. Our game is being developed with the Unity engine [2] using the Leap Motion SDK and Unity Modules [3].

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[2] https://unity3d.com/
[3] https://developer.leapmotion.com/unity/

3. CONCLUSION

We have developed a prototype game for hand motor rehabilitation using music and rhythmic entrainment as its core elements. Informal tests suggest that our system could be a viable, engaging, and low-cost solution for hand and finger rehabilitation. A formal study in collaboration with medical professionals is warranted in order to validate the game concept, and to test its efficacy in terms of rehabilitation outcomes and treatment adherence.

4. REFERENCES

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