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Lateropulsion Rehabilitation Using Virtual Reality for Stroke Patients

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***Abstract*—Virtual reality (VR) is being explored as a method of rehabilitation for stroke patients, specifically in lateropulsion patients. Virtual Reality or augmented reality, provides realistic 3-dimensional environments combined with real-time movements. The user is able to concentrate on the scenery and feel removed from their real life setting and immersed in a new setting. Integrating virtual reality with rehabilitation practices is an accessible way for patients to improve their recovery times while using a mobile device to make rehabilitation more accessible to the patient. The goal of this research is to use virtual reality as a viable tool for physical therapists to help improve the stamina of recovering patients. The study will explore the benefits of changing the environment of the user, to help change their perspective of the world and normalizing the world for lateropulsion stroke patients. This work will conduct the necessary research to develop a mobile application which may benefit the lives of stroke patients by potentially decreasing the lateropulsion symptoms.**

***Index Terms*— Data Analytics, Lateropulsion, Mobile Applications, Patient Rehabilitation, Stroke Rehabilitation, Virtual Reality VR**

I. Introduction

Approximatley every four minutes a person will die from a stroke, rapidly growing to become the fourth leading cause for death [7]. Post stroke patients suffer from hemiparesis. Hemiparesis is a decrease in muscle strength on one side of the body. Patients usually compensate the muscle imbalance by using the muscles of the functioning parts of the body. In many cases this leads to long-term consequences like atrophied muscles**.** Today, virtual reality is becoming an increasing form of rehabilitation in medical practices, including post-stroke treatment. "Stroke patients acquire numerous amounts of disorders which affect their daily lives. Previously, VR has been tested in a variety of disease states, including obesity, anxiety disorders, pain management, oncology, and neurorehabilitation. Concurrent improvements in software and hardware design, as well as associated cost reductions, have made VR promising for more widespread use in health care" [2].

In lateropulsion patients, the perspective of the world is very shifted to one side. According to the Health Related Quality of Life (HRQOL) the patient is affected physically, socially, and emotionally. The HRQOL is calculated based on the patient's perspective, however it provides a basis in terms of predicting a patient's mortality [5]. This study aims to help improve lateropulsion disorders in stroke victims that will potentially be able to regain full body motion and higher their HRQOL levels. With stroke becoming one of the top causes of disabilities and death, VR may be a viable option to help aid these victims to ultimately better their living conditions. Pace University and Burke Hospital Medical Research Institute collaborated to develop a platform which VR can become a viable platform for people with all disabilities, however this paper will focus on Lateropulsion recovery only.

Samsung provided VR gear for development and testing purposes including Gear VR, Galaxy S6 phone, and a Samsung tablet. Burke Hospital Medical Research Institute provided medical research and testing of the application. The paper is broken down as follows: *Introduction*, *Literary Review*, *Specifications*, *Methodology*, *Preliminary Findings*, *Results*, *Future Works*, and *Conclusion.*

II. Literary Review

Virtual reality has the potential to become a main source for rehabilitation. There have been numerous studies conducted, which have attempted to better a patient's well-being with the use of virtual reality. Patients as a whole are restricted to a small area in the hospital where they must eat, sleep, and ultimately restore everyday bodily and mental functions. How will virtual reality help these patients on their path to rehabilitation?

After stroke, majority of patients experience serious changes in motor activity that affects the person later on. Presently, studies show that one of the most successful methods of rehabilitation is considered recovery by "imitating the observation" because this method increases brain plasticity and, as a result, rehabilitation potential. The studies have shown that modern rehabilitation using virtual reality has demonstrated great results in improving motor and cognitive skills. However, this method requires continuous participation from a therapist to monitor progress. Studies have been conducted which show signs of positive feedback from the patients in regards to VR

technology. A main concern for patient rehabilitation in a hospital setting is the limited time that the patient receives, as well as the mental struggles they face. A study was conducted which surveyed patients and their VR experience. The majority of the patients expressed pleasure in their mental state as it allows them to be in a more comfortable environment, virtually [2].

Focusing on the rehabilitation aspect of these patients, a study was conducted which took 121 stroke patients and split them into two separate groups. These two groups either received Virtual Reality therapy after their ordinary rehab, or they were assigned to perform recreational activities. The findings show that Virtual Reality rehabilitation were not superior to the recreational techniques [3].

Similarly, another study was conducted, which displayed very opposite results. In comparison with the above results, the study displays signs of positive effects on patients. In the study, patients were told to look at the screen, in which the motions were made with "virtual" hand. The results showed that when person sees "his or her" hand making specific movement, he or she starts to control their body better in real life. Figure 1 displays a Motor FIM table that shows the patient's progress.

Task	Mean (before)	Mean (after)	p value
Eating	5.2±0.9	5.4±0.8	.31
Grooming	4.9±1.7	5.1±1.7	.15
Bathing/showering	5.7±1.3	6.0±1.2	.08
Dressing upper body	5.4±1.2	5.9±1.1	.05
Dressing lower body	5.6±1.1	5.8±1.1	.01*
Toileting	7.0±0.0	7.0±0.0	> .05
Bladder management	6.8±0.4	6.9±0.3	.31
Bowel management	7.0±0.0	7.0±0.0	> .05
Transfers: bed/chair/wheelchair	5.9±0.3	6.2±0.4	.08
Transfers: toilet	6.5±0.5	6.7±0.4	.31
Transfers: bathtub/shower	5.7±1.0	6.2±1.0	.02*
Locomotion: walking/wheelchair	6.0±0.0	6.1±0.3	.31
Locomotion: stairs	4.4±1.5	5.2±1.3	.03*
Motor FIM total	76.1±5.3	79.5±5.9	.01*

Figure 1. Motor FIM table showing the progress of a patient using VR.

One interesting similarity between these two studies was the amount of time that the patients were chosen to test during this virtual reality trial. The individuals were chosen by the duration of time since they had a similar level stroke. This was then able to give these studies the accurate results because each test was similar. Although they had different results, virtual reality rehabilitation continues to gain popularity based on its ability to be used anywhere at any given time.

III. Specifications

In order to integrate stroke rehabilitation and virtual reality, Pace University, Burke Hospital Medical Research Institute and Samsung will collaborate to produce a virtual reality stroke rehabilitation game for lateropulsion patients.

Pace University will be responsible for designing and developing the game. Burke Hospital will provide the research, medical background, and patient testing. Samsung will provide 2 Samsung smartphones, 2 Samsung Gear VR Headsets, and 1 Samsung tablet.

Fig. 2 Samsung Gear VR Headset [17]

The research gathered will provide a foundation for the team to create a virtual reality (VR) mobile application, which will aid stroke victims in decreasing lateropulsion, as well as gather information about the patient's progress. With the use of technology, we are striving to develop useful and user-friendly material, which will ultimately better the patient's chance of recovery.

IV. Methodology

In order to provide customization and usability for individual stroke patients, the program had to incorporate the calibration of the patients' movement scale. In order to provide accurate results, the input is to be defined by the physical therapist. The VR game will adjust based on the input so each user will have a unique setting. The project is broken down into four parts:

A. The Virtual Reality Rehabilitation Game
B. Programs and Implementations
C. Exporting Results through Data Analytics
D. Lateropulsion Rehabilitation Techniques
E. Testing

A. The Virtual Reality Rehabilitation Game

A stroke patient has a tendency to lean towards one side of the body, so the objective of the game is to help the stroke patient to shift their balance to the center of their body. To accomplish this, the game is based on centering their balance based on their perception. The environment of the game will take place on a ship (Fig. 4) with barrels (Fig. 6) approaching the user. The user will have lean towards the object in order to avoid the oncoming obstacle. The game was developed with one object, a barrel, that is shot towards the user. The intention of the barrel is to work with the user's natural instincts to move away from the barrel. While oncoming objects, can be overwhelming at times, we found that it was more important to invoke a sense of urgency for users with lateropulsion symptoms, because it triggers neurons in their brain relating to the fight or flight sense. To customize the game for each patient, they will be able

to change the speed of the barrel, and the prominent side of the body they are affected.

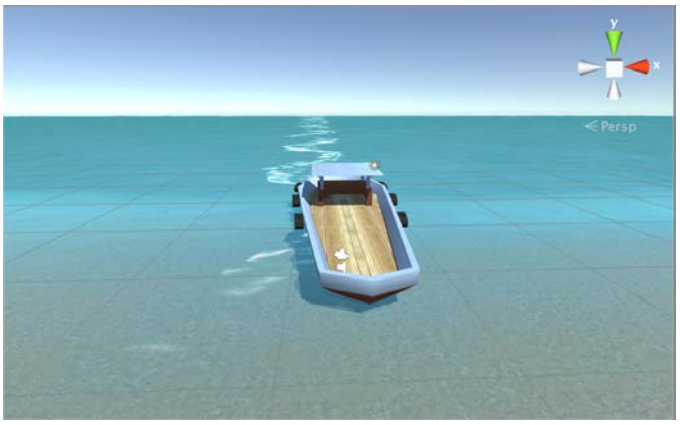

Fig. 3 Starting Environment of the game.

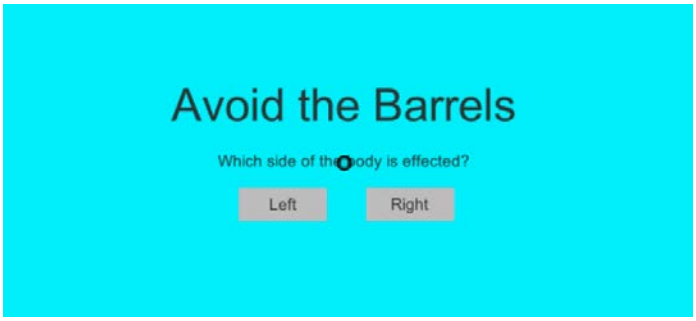

Fig 4. Settings menu for the game, specifying the which side of the body was effected by the stroke.

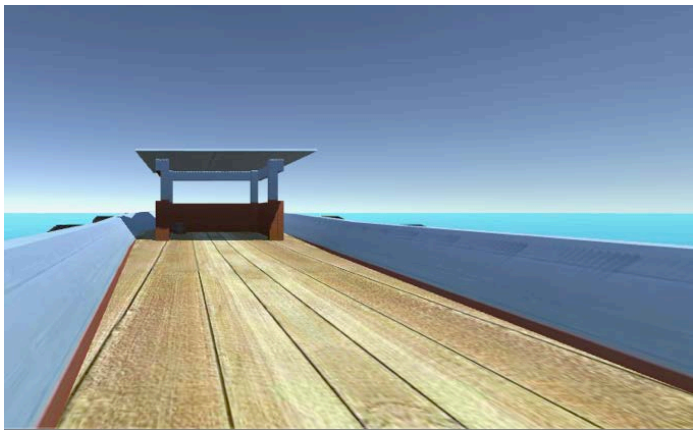

Fig 5. View of the boat.

Fig 6. Barrel Design.

The limits of the calibration will be defined by the physical therapist based on the Burke Lateropulsion Scale. By avoiding the incoming objects, the user will be given points, but if the user collides with the object points will be reduced. Once the user has gained enough coins, they will advance to the next level. The next level will have an increased speed and the calibration will be adjusted slightly.

A similar project was conducted by Janet Eyre, a professor of pediatric neuroscience at Newcastle University. The game developed showed that continued movement of the affected area, will slowly generate strength and regain mobility to perform everyday activities [6].

In our Alpha version of testing, we found that it was important to add a hatch into the game to provide stability.

B. Programs and Implementations

Unity was the main program used to develop the game. The game was developed specifically for Android use with the potential to translate into other platforms like the X-Box Kinect, or other operating systems including IOS. The game was developed using C# as the dominate scripting language. Both Unity and C# were chosen because of the accessibility among computer operating systems, open source scripts, online support, and the ease of translating across platforms for potential growth. The game was built with the intentions of being published in the Android App Studio for accessibility for patients.

When building with Unity, we first had to set up our project so that it supports Virtual Reality. To do so, we must import the Oculus SDK along with Android's SDK so that the game will work on both platforms. A minimum API (Application Program Interface) must be selected so that the game will be restricted to the latest Android updates. The texture compression is set to ETC2(GLES 3.0) as it works with Android most efficiently. There are many functions that must be utilized in order for Virtual Reality to be able to begin. These functions include using a Physics Ray caster, Buttons, and a User Interface, which allows the creation of a menu. The environment was built from scratch with a few free assets from Unity's asset store.

A first person controller is imported into the game, which contains the player itself, a camera, and an audio listener.

These components work as the player in the game and allow the camera to be able to move, collide, etc. The menu will take the user through a few options which will set up the environment. The user will then be taken to the level where the game begins. Barrels are rolled towards the user and the user will be forced to dodge these items. If the user dodges these items, the collider will increment the barrels that were dodged by one. However, if the user is hit by one of the barrels, the barrel collisions will increment by one. C# is the language for Unity that will make all of these functions possible.

During alpha testing, we found some users felt sea-sick after using the game because of the movements. We added a crosshatch for the user in the middle of their camera view, in order to give them perspective

C. *Exporting Results*

In order to provide adequate medical data to the physical therapist, the progress and results of each patient will export the results into a database which will be accessible to the medical practitioners only. Exporting the data will help the physical therapist be able to gage the progress of the patient and recalibrate the program when needed for refinements.

The data will be related to the Burke Lateropulsion Scale so analytical reports can be created easily and efficiently. The results will only be accessible to the user and the medical practitioner or physical therapist.

The data will be based on the user's progress – their calibration settings, how many barrels the user missed, how many barrels hit the user, and the time it took them to reach their goal. Exporting the data will help the physical therapist be able to gage the progress of the patient and recalibrate the program when needed for refinements. The data will have analyzed with the Burke Lateropulsion Scale.

D. *Lateropulsion Rehabilitation Techniques*

Burke Medical Hospital will work with the patients suffering from Lateropulsion Strokes, also known as "Pusher Syndrome". Two symptoms are very common within these patients; shifting their balance towards one side of their body, and having limited locomotion functions [13]. These two symptoms will be incorporated in the game to help improve the mobility and balance of each patient. "The overarching goal of rehabilitation for adults' post-stroke is to restore the person's ability to participate in normal life roles with as much independence as possible. Impairments at the body structure and function level may influence activity limitations, and activity limitations may influence participation restrictions" [19]. To improve the lives of post-stroke patients, there are many techniques and practices. We focused on the Bobath Approach.

BOBATH APPROACH

"One of the most commonly used treatment interventions for post-stroke rehabilitation is the Bobath approach or neurodevelopmental treatment. This approach focusses on encouraging or facilitating, normal movement and inhibiting abnormal movement patterns." The rehabilitation game we developed encourages these movements by beginning with repetitions of small subtle movements in order to avoid oncoming barrels. The user will eventually regain muscle movements and stamina. "The Bobath Approach has evolved to focus less on the reacquisition of normal movement and more on the use of problem-solving strategies during function tasks, focusing on encouraging postural control" [18]. The environment of the game is meant to provide a placid environment, somewhere the user would imagine themselves on a happy place. The oncoming barrels will provoke the flight-or-fight reaction which will encourage the postural control and problem-solving strategies that the Bobath Approach recommends.

PRELIMINARY FINDINGS

According to Dr. David Putrino of Burke Medical Hospital, lateropulsion stroke patients have the tendency to rely on shifting their balance to one side of their body. One of the rehabilitation methods practiced during physical therapy sessions is the use of impulse movements to have a patient subconsciously shift their balance to the center of their body. Due to minimal findings in stroke rehabilitation, it is difficult to pinpoint a specific area to focus on which will help benefit the patient. However, some evidence suggests that impulse movements helps the patients regain movement and function in their muscles. According to a study performed by Kohnan Hospital, approximately sixty-six percent of the patients that suffered a stroke, obtained lower-limb deficits [11].

The Burke Lateropulsion Scale (BLS), created at Burke Medical research institute, creates a scale for the movement that defines calibration ability for each patient. The scale is defined in three scores (1 = mild; 2 = moderate; 3 = severe), for supine rolling, transferring and walking which are based on the severity of pushing sensed by the examiner [12]. Using the Burke Lateropulsion Scale, it is important for the game to be programmed to intake the same scores as the medical research.

According to Dr. Gustavo Saposnik and his team who did a study on the safety of non-immersive virtual reality "patients who had a stroke within 3 months before enrolment and had mild-to-moderate upper extremity motor impairment, non-immersive virtual reality as an add-on therapy to conventional rehabilitation was not superior to a recreational activity intervention in improving motor function" [3]. Although they did not find the results to have a beneficial impact with rehabilitation, we are determined to customize and redefine the games and virtual reality environments in order to improve upon these results.

V. RESULTS

Our results conclude that training with virtual reality programs is astonishingly significant at improving stroke patient's balance and weight distribution of the patients paralyzed side of the body. The game was successful in improving the patient's movement and allowed the rehabilitation doctors to analyze the results and keep the patient on track with their progress.

As there are positive results for the game being used as for rehabilitation purposes, the software lacks the ability to monitor key practices such as weight distribution and posture. Different patients may also have a harder time moving in one direction that others may not. This means that one movement may be very

easy for one patient, while it can be very challenging to another. This lead to both positive results and some other results that were a little less effective. Those who were able to make the movements easily saw better results than those who didn't, due to the fact that they were able to advance past the first challenge.

Interestingly enough, it seems that the scenery of the virtual experience made the game more appealing. The fact that it is a nice sunny day in the setting is pleasing to many patients, as some of them do not get to enjoy the outdoors much due to their limitations. This automatically puts the patients in a better mindset, which ultimately leads to better results.

A. Alpha Testing

The alpha testing stage was done on non-stroke patients. We found that it was better to wait until the game had gone through testing before going to stroke patients to avoid discouraging them. During alpha testing, we found some users felt sea-sick after using the game because of the movements. We added a crosshatch for the user in the middle of their camera view, in order to give them perspective in the game and where the center of their view was. We found adding a crosshatch to the game significantly decreased the user's sea sickness and increased their duration of the game and the user's score. People who have never used a virtual reality headset, can feel disoriented and off balance when first using the headset, so we found that it was important to recalibrate the entire headset before putting it on each patient. This not only familiarized the patient with the gear, but it allowed them to look through the camera on the phone and realize how the perspective may shift.

In the alpha stage of testing, we also found that the users had a tendency to move only their head and not their whole body. In order to counteract this, we changed the calibration settings of the game so the user would have to make bigger movements than just their head. This was very significant in achieving results for patients.

B. Beta Testing

The beta testing is focused on post-stroke patients. Due to developing difficulties, the results of this version are pending. The testing hypothesis that we have created is that the patients will involuntarily dodge these items as a natural instinct. Based on the severity of the disability of the individual, the patient will possibly benefit from this game at different paces.

VI. Comparisons

We analyzed two different groups of people for testing purposes – our alpha testing was done on non-stroke patients and the beta testing was done on post-stroke patients. When testing the Alpha version of the game, we made it available to the general public. All non-stroke individuals tested the game and provided us with feedback. With the information provided to us through the use of a survey, we were only able to make minor changes to the game's graphics and layout. With the patient's survey, we will be able to obtain a better understanding of how the game has benefitted the individual and if there are any changes that need to be made to the game itself.

VII. Future Works

For future work, we would like to expand this project's compatibility to work on more applications like the X-Box Kinect and other virtual reality software. Having the X-Box Kinect for example would be ideal because it can keep track of the user's body movements instead of only the head like the VR headsets.

Apart from applications, we would like to make the game more customizable for each patient by expanding on the calibration settings and the game level settings. With more customization, it can focus the user on the muscle area that they need to improve.

VIII. Conclusion

The virtual reality and gamification methods have been proven to be an effective method for treating post stroke symptoms. The study showed patients treated using virtual reality rather than traditional methods have shown significant improvements for the patients. The game allowed users to improve their muscle strength through a controlled environment.

The game can be further developed to include analysis over weight distribution and posture of the patient. Using only a virtual reality headset, the rehabilitation specialist is unable to track the posture and position, which is an important step in the rehabilitation process.

Overall, the game has shown positive results for rehabilitation and can be used for a vast variety of other rehabilitation practices in the future.

Different patients may also have a harder time moving in one direction that others may not. This means that one movement may be very easy for one patient, while it can be very challenging to another. This lead to both positive results and some other results that were a little less effective. Those who were able to make the movements easily saw better results than those who didn't, due to the fact that they were able to advance past the first challenge.

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