Rehab-Track: Mixed Reality Obstacle Course for Physical Post-Stroke Rehabilitation

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ABSTRACT

A stroke affects the motor and cognitive skills in a person. Post-stroke patients not fully engage and felt frustrated with conventional rehabilitation therapy because it became monotonous and boring after a few repetitions. Rehab-Track is an augmented reality (AR) system developed in Unity and displayed in HoloLens 1. This AR system has different cognitive and physical exercises for post-stroke patients to strength their physical and cognitive abilities.

1 INTRODUCTION

The brain needs to receive oxygen and nutrients through blood flow to work properly. When a stroke occurs, there is an obstruction of the blood flow in an area of brain, thus the brain cells does not received oxygen and begin to die [1]. A cause of this, there is brain function lost which impact the cognitive and motor abilities controlled by the affected area of the brain. Therefore, post-stroke patients need effective and intensive therapies to increase their motor and mental strength and restore mental connection of functional abilities [2].

Conventional physical therapy is high-priced, slow, inefficient, monotonous, boring, without progress feedback and labour-intense. As a result the patient doesn't fully engage in the rehabilitation process [2]. Thus, creating an Mixed Reality (MR) system will allow post-stroke patients to have a more intensive, repetitive, better movement feedback therapy and have fun while they get better. Virtual Reality (VR) and Augmented Reality (AR) are part of MR continuum. VR creates an artificial environment where the users suspends their beliefs and accepts this new environment as their real. On the other hand, Augmented Reality (AR) is a system that combines digital information into user's real environment. VR systems has challenging training situations, and the diversity of physical exercises is limited [3]. Therefore, we proposed an AR obstacle course (Rehab-Track) to guide post-stroke patients through a series of trials, and allow them to work in cognitive and motor rehabilitation exercises. The whole track and trials are displayed in a optical see-through head-mounted display (OST-HMD).
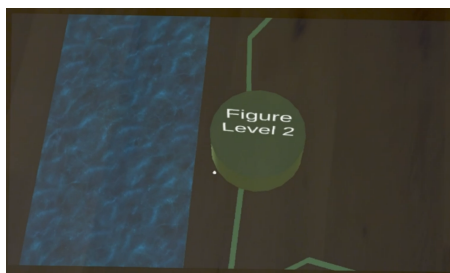

Figure 1: Rehab-Track path and checkpoint

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The different exercises are distributed in a path of 3x3 meters. While the patient walk thru the path, she will find different checkpoints (See Fig. 1), which mention the level and type of game that will be display in the OST-HMD (HoloLens 1). When the patient pass through each checkpoint, the exercise mentioned will be activated.

We developed various physical and cognitive therapy exercises to strength the patient skills:

- **Physical Therapy**: Balance Exercises
    - Heel-to-Toe walking between games
    - Hole in the Wall game
- **Cognitive Therapy**
    - Memory: Simon Says
    - Spatial Awareness: Sonification

In "*Hole in the Wall*" (HITW) game, the patient has to imitate the figure that is showing the wall that is in front and moving towards her (See Fig. 2). All the poses presented in the wall are related with balancing exercises, which will help the patient to restore and improve her balance and motor skills [4]. In addition, besides the balancing exercise, HITW game includes a concentration exercise, called "Stroop Game". While the wall is coming towards the patient, there are 3 buttons near, where she has to choose the button that describe the color of the wall. For instance, in Fig. 2b the patient has to choose the left button as the wall is green, and the text in the button says *Green*. Hence, with HITW game the patients can improve and work in their motor and cognitive skills at the same time.

(a) Level 1 - Arms Up   (b) Level 2 - Single leg standing

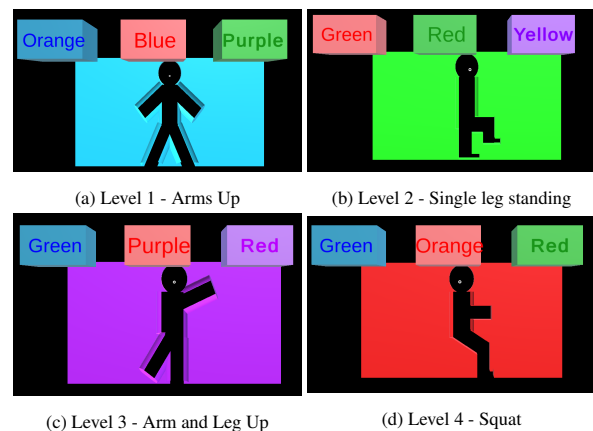(c) Level 3 - Arm and Leg Up   (d) Level 4 - Squat

Figure 2: Hole in the Wall Visualization

There are 4 different levels (See Fig. 2) and the difficulty of the balance exercise is increased while the patient walk thru the path. The HITW game also have auditory feedback, where the patient can hear a different sounds for selecting the correct or incorrect button. Also, when the wall pass thru the patient, she can hear a windy noise

(*"WHOOSH"*) that indicates that the pose is over and can continue walking in the path to the next game. To track the patient pose and give a better feedback, it is necessary to use Azure Kinect.

2 RELATED WORK

There are a number of papers that had work on AR rehabilitation for post-stroke patients. Xinyu Song et al. [2] designed different games based on ARKit toolbox to run on an iPhone 7. The AR system is mainly designed to patients that need to gain strength in the upper body. After validating the AR system on different patients, the authors could observe that there is high interest from patients in using AR systems for their rehabilitation process. Moreover, they concluded that around 75% of the patients are more engage on the recovery process as they felt happy and relaxed during the training and the games.

Held J et al. [3] developed an AR obstacle course rehabilitation system focus on gait and balance exercises. It was developed by using HoloLens 2 as OST-HMD device, and Xsens MWN as a sensor-based motion capture system. This rehabilitation system consist on visualizations of real-life obstacles and a trail pointing to the walking direction. In addition, it forced the patient to perform specific leg movements. The AR system was tried by a right-hemispheric ischemic stroke patient. After the trial, the patient show to adapt his gait performance and improvement in the knee flexion angle. Furthermore, the patient showed a high interest in the system, and to use it to complement his conventional therapy program.

3 METHOD

To display the AR obstacle course to the patient, we needed an OST-HMD (HoloLens 1). Additionally, we needed a tracking device, Azure Kinect, to follow patient's movement, body and gestures.

The AR system and HITW game was developed using the following two platforms:

1. **Blender**: Design and creation of the wall with different poses.

2. **Unity**: Complete system development, and design of the path and games.

   - Use the object created in blender, create the checkpoints with a cylinder object, and the buttons with a cube object.
   - Apply visual rendering into the walls, buttons, and checkpoints. See the material properties in Table 1.
   - Add text object as a child object into the checkpoints and buttons objects.
   - Create scripts to:
     - Trigger each level in the respective checkpoint
     - Move the wall: Apply in the *Update()* class: *transform.Translate(Vector3.forward * Time.deltaTime)*
     - Create the buttons: Use the class: *OnTap()*
     - Add sound to the objects
   - Integrate MRTK Toolkit: To develop the AR system in Unity, and be able to use it in the HoloLens 1.

Table 1: Material Properties

Property	Value
Albedo	Different RGB for each level checkpoint, button, wall
Metallic	0
Roughness	0.5
Rendering Mode	Transparent

4 EXPERIMENT AND RESULTS

It wasn't possible to validate the demo on doctors, physiotherapists, or post-stroke patients. However, the work was presented to a few doctors through a video demonstration. The doctors look interested in the developed AR system. They also mentioned that it includes some additional features than other similar systems, like the Simon Says and the Stroop game,

In addition, a cause of calibration issues between the Azure Kinect and Unity, it was not possible to generate a feedback about the patient balance pose.

5 DISCUSSION

It was possible to develop an MR obstacle course with different cognitive and motor exercises for post-stroke patients rehabilitation. Rehab-Track and previous work show that AR rehabilitation games for post-stroke patient is a promising idea, where the patient could have more engagement in the rehabilitation process. However, AR rehabilitation process needs further research and development. In Rehab-Track, we need to work closer with experts physiotherapists in post-stroke patient rehabilitation to obtain a feedback about the the track and the HITW poses.

Additionally, prior testing the system in patients, it is necessary to improve the obstacle course. Add deeper validation measurements, cosmetics, and scoring. With respect to the HITW game it is recommended to add more walls with the same pose in sequence for each level. The repetition will help to rewire the mental connection and restore balance. Additionally, automatically adjust the size of the wall with respect to the height of the patient. Furthermore, to give better feedback to the patient in the balance exercises and measure their pose accuracy, we'll need to further integrate and calibrate properly the Azure Kinect with the AR system .

At last, it is required to validate the system in post-stroke patients. Obtain objective measurements by evaluating patients performance and improvement in their rehabilitation process. Also, acquire subjective measurements thru a questionnaire and get a feedback about how good is the system for the rehabilitation and what could be improved.

6 CONCLUSION

Post-stroke patients need cognitive and physical rehabilitation to strength and promote neurological restoration of functional abilities. Conventional physical therapy is expensive, monotonous, and frustrating for a lot of patients. Rehab-Track is an AR system built-in in HoloLens 1 and developed in Unity and Blender. This system will help to post-stroke patients to gain their cognitive and physical strength through a series of games and exercises. Our system and other AR rehabilitation systems has shown a positive response from doctors and patients. For further results and measurements, it is required to validate the system in different post-stroke patients.

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