Virtual Reality Mirror Therapy Rehabilitation For Post-Stroke Patients

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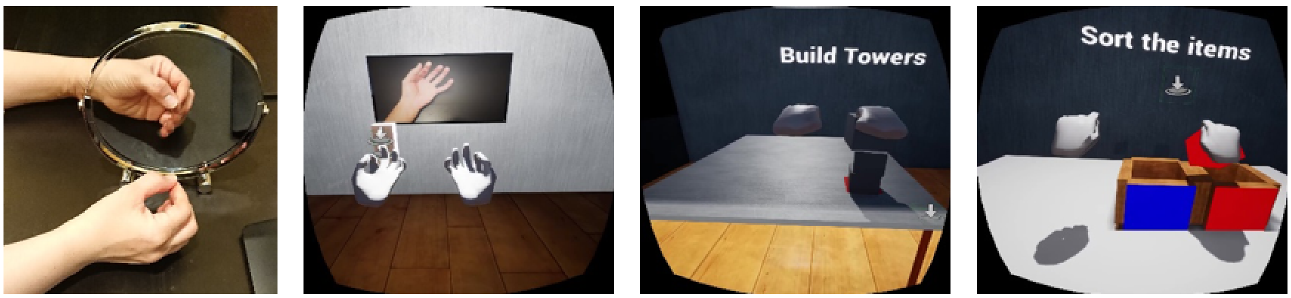

(a) (b) (c) (d)

Figure 1: (a) Traditional mirror therapy, where the patient's unaffected limb is mirrored, which sends motor imagery impulses to the brain that promote movement in the affected limb. (b) Intro level that introduces gameplay mechanics to the patient. (c) Level for user to exercises grab motions and hand coordination/focus. (d) Third level that enhances patient's stretch and promotes horizontal hand movements.

CCS CONCEPTS

• **Computing methodologies → Virtual reality**; *Graphics input devices*; • **Applied computing → Consumer health**.

KEYWORDS

stroke, rehabilitation, therapy, virtual reality

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1 INTRODUCTION

Strokes have a wide range of occurrence among people of all races and genders. The consequences of a stroke often include significant muscle weakness on one side of the body that must be physically exercised to attempt to restore its previous strength and mobility.

In traditional mirror therapy, the partially disabled hand or leg is hidden by a mirror. The patient sees a reflection of the healthy side of their body where the disabled limb should be, in order to stimulate brain to operate the partially disabled hand/leg in the proper way. The patient will interact with mirror using unaffected hand and observe its reflection.

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In this work, we recreate the techniques of Mirror Therapy in Virtual Reality (VR) video game environment. This approach provides completely unique sets of therapy uses with new capabilities that include richer exercise approaches and atmospheric customization. In contrast with physical environment, patients in Virtual Reality can use unlimited number of objects and other therapeutic resources for exercises, and proceed with abundant set of exercise movements. These features create both economical and usability advantage. Different environments with custom physics can now be presented to Mirror Therapy's users and it can provide new rehabilitation techniques and practices.

Prior work in VR mirror therapy has focused primarily on pain management, using either sensors placed on the unaffected limb or a cyberglove [Ambron et al. 2018; Sato et al. 2010].

2 OUR APPROACH

We begin by modeling patient's unaffected hand in the VR environment using Unreal Engine 4 (UE4) with a Leap Motion for tracking. The implementation was done using UE4 Blueprints and a Leap Motion plugin [Kaniewski 2018]. We reflect the transformations from the unaffected hand to the skeletal mesh for the reflected hand, and place both in the VR world space. The choice of which hand would be reflected is selected in advance according to patient needs. Standard pinch and grab motions are only supported for the affected hand, forcing the patient to make the actions with the mirrored hand.

Our VR setup consists of an Oculus Rift with infrared (IR) head tracking sensors and the Leap Motion sensor mounted to the front of the VR headset. Wearing the headset, patient will experience three level designs that we chose as a starting point for rehabilitation exercises. The first exercise introduces game mechanics

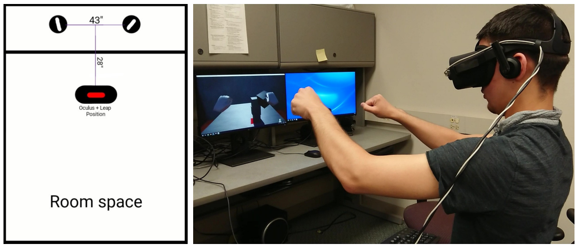

Figure 2: The VR mirror therapy system in use

and hand mirroring through exercises similar to traditional mirror therapy. The second attempts to redevelop hand's grab motions together with coordination and focus, and third aids with overall hand rotation and side-to-side motion.

The patient's healthy hand is captured by Leap Motion sensor, and the unhealthy hand is replicated and simulated to repeat all of the healthy hand's movements in unison. This approach allows patients to be fully immersed into the process with no mirrors involved, allowing exercises with larger motions that would not be possible with a physical mirror in the way. Patients are now able to cross their hands when needed, use objects in the play and interact with them in every direction.

Most of therapeutic exercises are focused on large arm motions and thus Leap Motion provides sufficient hand tracking while being attached to the headset. However, for accurate and precise tracking, the cases when hand is located parallel to patient's view, we plan on changing the location of Leap Motion from headset to static mounted metallic stand that will be located over patient's hands on the appropriate distance. In addition to current mirroring technique, it was suggested that instead of mirroring movements, hands should move in parallel and only finger motions should remain mirrored. Thus, when healthy hand would be moving right the reflected/injured hand would also be moving right, while finger actions will remain reflected from healthy hand onto affected.

Physical setting for rehabilitation procedure does not require complex preparation: there needs to be an Oculus Rift headset with two IR sensors connected to PC, Leap Motion, table for patient, and adjustable chair, in order to adjust user's height in Virtual Reality. See Figure 2.

3 RESULTS

The current state of the project is as a research prototype, that has not yet been tested with stroke patients. It has been tried by multiple non-stroke users at an Undergraduate Research Presentation at UMBC, and by doctors and nurses at the University of Maryland School of Medicine Stroke Rehab Unit. From this feedback it was found that current attachment of Leap Motion to the VR headset limits parts of the exercises where patients need to place a virtual object near the limit of the affected hand's reach. When they turn their head to see the mirrored hand, the non-mirrored hand can go out of the Leap Motion's capture range, losing tracking and mirroring. This has limited the exercises to ones using motions centered directly in front of the user. Before we advance to patient testing, we will need to modify and test the system with the Leap Motion mounted on a static stand.

Hand transposition through Leap Motion into VR environment was perceived as natural for users as they wore the headset. From the initial testing it was seen that users constantly tried to move the hand that played role of an injured limb and this in turn gave promising forecast that brain indeed is being stimulated extensively by such VR approach and in turn causes involuntary movements in hand that undergoes therapy treatment. Similar results were met when demo was presented at University of Maryland Rehabilitation and Orthopaedic Institute, where orthopedists and medical staff were able to try out the demo exercises.

In future work, we also plan adding customized hands to better match the look of the patient's hands for improved immersion. In collaboration with stroke rehabilitation doctors at the University of Maryland School of Medicine, we plan to create additional rehabilitation layers and start patient trials.

ACKNOWLEDGMENTS

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