Mixed Reality for PTSD/TBI Assessment

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Abstract. Mixed Reality (MR) refers to the blending of virtual content into the real world. Using MR, we create contextually meaningful scenarios in which users carry out tasks encountered in the presence of visual and aural distracters. Visual distracters can include subtle ones – people walking; and more abrupt ones – cartons falling. Aural distracters can include gentle ones – fans whirring; and more aggressive ones – automobiles backfiring. The intensity of these distracters can be dynamically controlled by a therapist or software that takes into account the patient’s perceived level of stress. Intensity can also be controlled between experiences. For example, one may increase the stress level in a subsequent session, attempting to improve a person’s tolerance. Assessment of progress includes psychophysical metrics (stress indicators) and the performance of tasks (accuracy and adherence to time constraints). By accurately capturing a patient’s interaction with the environment in the context of simulation events, we can use MR as a tool for assessment and rehabilitation planning for individuals with stress-related injuries. This paper reports on the MR environment we have developed and its efficacy (realized and potential) for the assessment of post-traumatic stress disorder (PTSD) with or without traumatic brain injury (TBI).

Keywords. Mixed reality, post-traumatic stress disorder, psychophysical metrics, traumatic brain injury

Introduction

Virtual reality (VR) technologies afford the therapist an ecologically valid research environment while still maintaining therapeutic benefit and have fostered over fifteen years of research supporting these assets \cite{1-2}. The flexibility of VR to deliver both safe and programmable rehabilitation protocols allows for more personalized environments that can match the disability level of the patient. From a basic research perspective VR-based rehabilitation also has the potential to advance our understanding of how the brain functions when persons perform real-world tasks \cite{3}. These advances are major steps forward in creating standardized efficacy measures and designing successful rehabilitation protocols \cite{4}.

For some rehabilitation applications, VR’s intentional attribute of isolating participants from the real world is inappropriate. Specifically, our goal is to use Mixed Reality (MR), the blending of virtual content into the real world \cite{5}, as a way to create

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contextually meaningful scenarios that can trigger responses indicative of subjects suffering from post-traumatic stress disorder (PTSD). The study on which we report was carried out with a group of healthy controls, with the objectives of testing the system’s ability to capture baselines, stress indicators and performance data, and of the scenario’s ability to induce levels of stress and distraction found in a chaotic work environment.

1. Determining MR Efficacy using Psychophysiological Measures

An MR-based experience refers to one that occurs in the context of virtual objects that are integrated into the real world. At a minimum, this involves the user’s visual sense, and commonly includes mixed synthetic/real aural content. Other senses (touch, smell and taste) are often provided by the real world only. This combination of real and virtual content can create a very intense, personalized experience. For instance, an MR-enabled rehabilitation experience could take place in a transitional learning center, where MR is used to give a patient the sense of being in his or her own home [6]. Here, physical objects required for the patient to carry out desired tasks are real. Thus, in a kitchen, objects like the counters, cabinets, utensils, dinnerware, refrigerator, required food items, microwave and coffee maker may be real. Some of these real objects would be augmented by virtual textures that simulate the appearances of the patient’s actual kitchen, e.g., the cabinets, counters and floor. Moreover, objects with which the patient never interacts, like a stove or a dining area, could be entirely virtual. The expected sense of touch is provided by real components, e.g., one can put coffee grounds into the real coffee maker. The smell of food, e.g., the coffee brewing, and its taste are real.

Figure 1 provides a visual tour of the MR Kitchen referenced in [6]. The left column shows three instances of the subject with his therapist. On the top, we see them standing in front of a real refrigerator, with a virtual counter and virtual cabinets; in the middle pane, we see them talking in front of a portion of the physical space containing a real coffee maker and real cabinets; in the lower pane, we see his therapist watching him make coffee in view of a virtual version of his dinette set in the background (demonstrating the immersion of a participant into a much larger environment than the physical space he or she is in.). The large right pane shows some of our staff testing the system. The top part shows the real setting. The bottom presents three monitors. The left monitor displays the scene as observed through a video see-through head-mounted display (VST-HMD). The middle monitor displays the output from a program that records the participant’s movements. The right monitor is running a video of the patient in his home kitchen.

This combination of real and virtual content makes for a rich experience that can trigger old memories, and build multiple pathways to new and existing ones. When coupled with portable, noninvasive, unobtrusive neurosensing devices (e.g., encephalography, EEG), MR-based rehabilitation provides a means to study the brain in action. Uncovering the retuning and the reorganizing properties of the human brain is necessary for determining therapeutic efficacy, appropriate prognoses, and long-term care needs. In previous work, the UCF team has shown that EEG measures of engagement and workload can assist in determining the efficacy of an MR-based rehabilitation environment within the feasibility stage [7].
To obtain these classifications, 20-minute baseline tasks consisting of a 3-choice vigilance task, eyes open rest task, and eyes closed task are performed. The results of these tests were used to fit an attention and distraction algorithm to obtain the proper classifications for each construct during data collection. The strength of this approach is that data from each participant can then be processed per individual or in aggregate, thus maintaining the individual effects while highlighting overall sample trends. More importantly, therapists can obtain objective, quantitative response variables instead of potentially unreliable after-the-fact surveys or patient reports.

2. Multiple Distracter Study Overview

The goal of this feasibility study was to measure the amount of distraction a healthy participant would experience while performing a multi-task occupation as follows. The primary task was to scan warehouse items. The worker also performed two secondary tasks, filling incoming orders and alerting the manager when a truck entered the bay. The scenario we developed (Figure 2, left side) shows a participant in a virtual warehouse setting, involving a real counter with printer, order forms and a parts tray; an open cabinet with parts trays containing a variety of small parts; and a surrounding area with boxes. In addition to the virtual surround, the counter has a virtual texture associated with it. Virtual sounds are added to those associated with the real printer in order to increase the participant’s awareness of new orders arriving. Additional audio enhancements include the sounds of a fan, trucks arriving, doors opening/closing, a supervisor giving out orders and the forklift moving around the warehouse in order to stack newly arriving palettes.

Figure 2. Warehouse worker performing sequencing tasks: Real setting on left; Mixed Reality on right.
The worker is wearing a VST-HMD [8] that has stereo cameras on the outside to capture the real world and a pair of LCD displays on the inside to present the visual component of the MR world (Figure 2, right side). The participant is also wearing a wireless B-Alert EEG cap and a vest that contains sensors for respiration and electrodermal response (galvanic skin response) [7]. The baseline tasks were performed in a quiet room outside of the scenario presentation area before the participant entered the mixed reality setting. The participant was then escorted to the experiment site still wearing the cap and performed the experiment overview and baseline for the other physiological measures. Separate EEG data files were created for each of these stages of the experimental procedure.

Twelve healthy participants (6 males and 6 females) performed the mixed reality warehouse tasking. Data analysis performed for this paper was on data collected during the participant’s performance within the mixed reality scenario only. While analysis for the full EEG dataset is ongoing, we report results for 5 participants (3 females and 2 males) for which there is a full EEG dataset of high data quality.

3. Results

Overall, participants showed a mix of high and low EEG engagement with frequent distraction. Distraction was mostly associated with the audio stimuli from the printer. Spikes ranging from 50 to 70% distraction were classified within 10 seconds of one or more printer audio cues. Some participants were so distracted by the secondary task of filling orders that they did not respond to the trucks entering the bay after the first observation. Figure 3 displays the means for % Engagement 30 seconds prior to the truck entering the bay area. When the truck entered the bay, the worker needed to alert the manager by pressing a button on the wall. The high percentage of low engagement and distraction suggests that the participants were not able to sustain attention or maintain vigilance when performing this task.

![Figure 3. Average % EEG Engagement 30 seconds prior to the truck entering bay](image)

Additionally, participants demonstrated phases of high and low workload levels. Figure 4 shows the % EEG Workload changes 30 seconds prior to the truck entering the bay. The high workload percentages suggest that the warehouse tasking is cognitively demanding during periods where the worker may have to shift their attention to another task. The Workload measures coupled with the Engagement measures suggest that the warehouse tasking is challenging even for healthy controls. Further analysis of individual performance, including task strategy, may show distinct associations
between tasks that demand more cognitive resources than others. Based on the outcomes described here, we believe that this EEG-based workload and engagement assessments have promise as comparators between healthy controls and their head-injured counterparts.

Figure 4. Average % EEG Workload 30 seconds prior to the truck entering the bay

4. Conclusions

The results show that EEG measures of Engagement and Workload are good indicators of how the tasks affected the healthy participants. A person with head trauma would not be able to complete these vocational tasks as scripted. However, the EEG measures allow for a means to modify the environment to support successful use of the mixed reality scenario as a rehabilitation tool. More specifically, EEG data can be analyzed individually and in aggregate to obtain an understanding of cognitive aspects of the task that may pose challenges to head injured patients. The EEG measures also show how distracters within the scenario affected performance from a cognitive processing perspective. This information is critical for virtual rehabilitation therapy protocols.

References