Analysis of the capability of EEG technology to discriminate between stressful and non-stressful situations and its sensitivity over time

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Introduction

Stress is ubiquitous in daily life, and manifests in a myriad of ways. In 1908, the relationship between stressors and mental arousal was established through the Yerkes-Dodson Law. Modern research has focused on the collection of neurofeedback to quantify the arousal level for optimal task performance (Faller et al., 2019).

Virtual reality (VR) allows a user to experience full visual and auditory feedback through a head-mounted display (HMD). Previous studies have explored the potential of virtual reality as a method to measure stress reactions, especially in combination with neurological feedback (Brouwer et al., 2011). In the field of exposure therapy, a method implemented to aid in the treatment of anxiety disorders, VR, in conjunction with neurofeedback, has provided a more accessible medium of therapy (Donker et al., 2019). The trends provided by the neurofeedback over time give a perspective on the patient's stressors and their response to the treatment.

Electroencephalography (EEG) is a process through which brain activity is recorded in a non-invasive manner, providing neurofeedback available for analysis (Beniczky & Schomer, 2020). Electrodes are placed on the scalp and measure the electrical activity—resulting from excitatory and inhibitory postsynaptic potentials between neurotransmitters—in the extracellular region of the brain, revealing the activations underneath.

This project aimed to determine how EEG technology was able to discriminate between non-stressful and stressful VR situations. This project simultaneously intended to detect how its sensitivity was altered over time.

Materials and Methods

The purpose of this project was two-fold: to determine if EEG technology had the ability to distinguish between non-stressful and stressful situations and if the sensitivity of the EEG technology changed over time.

To determine if EEG technology had the ability to distinguish between non-stressful and stressful situations, a group of subjects (n = 15) was tested. The HTC Tobii Vive Pro Eye HMD was attached to Wearable Sensing's DSI-VR300 headset with seven electrodes (Figure 1) and collected EEG data while the participant was immersed in a VR experience.

Figure 1: The HTC Vive Pro Eye and the DSI-VR300.

The data collection procedures outlined in Figure 2 were used. The data from the DSI-VR300 was collected in Lab Streaming Layer (LSL). Two laptops were used throughout this experiment: one recorded the data, and one was responsible for running the VR simulations. Each simulation lasted three minutes, with a two-minute break between simulations.

Materials and Methods (continued)

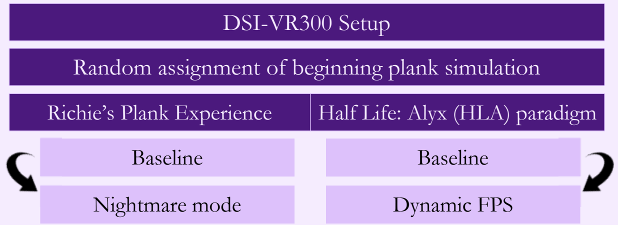
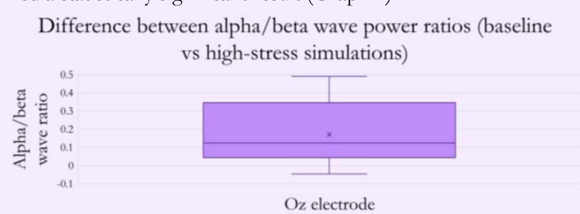


Figure 2: The procedures for data collection within this project. These procedures took approximately 35 minutes to complete, including the time taken to set up.

To determine if the sensitivity of EEG technology altered over time, presumably as habituation occurred, a group of subjects (n = 2) was tested, using similar procedures outlined in Figure 2. These procedures were repeated over the course of four months.

Results

The data collected from the DSI-VR300 was saved in an .xdf file format, alongside other data streams from LSL. From there, the EEGLAB package within the application MATLAB was employed, in conjunction with a script that extracted the data from the .xdf file to provide the amount of power returned from a specific frequency across the seven electrodes from 0–150 Hz. The amount of power for 8–12 Hz and 12–30 Hz was recorded for each of the electrodes, correlating to alpha/beta wave band power. These values were used to calculate the alpha and beta ratio, with a higher value indicating relaxation and a lower value indicating stress. The baseline simulation stress ratio was compared to the high-stress simulation ratio with paired t-tests. Fourteen paired t-tests were run, though only one returned a statistically significant result (Graph 1).

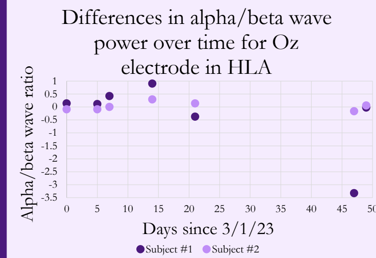


Graph 1: A paired t-test showed there was a significant difference in alpha/beta wave power ratios between the baseline (M = 1.400, SD = 0.221) and stressful simulations (M = 1.230, SD = 0.176), $t(15) = 3.89$, $p = .002$. The mean increase of alpha/beta wave power ratios was 0.170 with a 95% confidence interval ranging from 0.076 to 0.264. The null hypothesis was rejected, suggesting the Oz electrode could discriminate between the simulations.

To determine the sensitivity over time, values for each electrode in each simulation were correlated to the same electrodes at different times.

Results (continued)

A linear regression on the differences between the wave power ratios for each participant revealed no statistically significant correlation (Graph 2).



Graph 2: For subject #1, there was no statistically significant correlation between date and difference between the baseline and high-stress alpha/beta wave power ratios, $r(7) = 0.3995$ and $p = .128$. Furthermore, the relationship between date and difference between the wave power ratios of subject #2 did not have a statistically significant correlation, $r(7) = 0.0058$ and $p = .871$.

Conclusions

The purpose of this study was to determine how EEG technology was able to discriminate between non-stressful and stressful VR situations, as well as to determine how its sensitivity changed over time. The null hypothesis was able to be rejected for the Oz electrode in the Half Life: Alyx paradigm, indicating that the electrode was able to distinguish between stressful and non-stressful situations. In evaluating the capability of EEG technology and its sensitivity over time, there was not a statistically significant relationship found between the alpha/beta wave power over time, meaning that the null hypothesis could not be rejected. These results could be attributed to potential noise with electrode data collection and equipment limitations. Further research could analyze the capabilities of different EEG technologies or experiment with more electrodes on the head in different locations. Furthermore, the trend of the Oz electrode potentially being an indicator could be explored.

References

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