DEVELOPMENT OF VIRTUAL ENVIRONMENT TO ENHANCE USER EXPERIENCE WITH THE HELP OF ELECTROENCEPHALOGRAPHY

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ABSTRACT

The use of virtual reality (VR) has made significant advancements, and now it's widely used across a range of applications. However, consumers' capacity to fully enjoy VR experiences continues to be limited by a chronic problem known as cybersickness. This issue is caused by the stark discrepancy between the self-motion the visual system perceives through immersive displays and the real motion the vestibular system detects. According to the sensory conflict theory, this mismatch between visual and vestibular cues leads to feelings of sickness and discomfort. This paper presents an initial techniques and framework to reduce the visually induced self-motion in virtual scenes using geometric simplification approaches. The primary goal is to reduce the amount of optic flow experienced by user during the interaction with the virtual environment in a controlled laboratory setup. The proposed framework combines EEG neurofeedback with virtual reality, allowing users' brain wave activity and cognitive states to be monitored and assessed throughout VR encounters. The empirical evidence amassed from our investigation delineates a significant correlation between the manifestation of cybersickness and enhanced neural activation within the parietal and temporal lobes. These findings were consistently manifested under two experimental conditions—non simplification and geometrical simplification within the virtual reality (VR) environment. Notably, the observed decrement in activation intensity when employing geometrical simplification substantiates the effectiveness of our VR environment simplification strategy in the attenuation of cybersickness.

Keywords: Geometrical Simplification, Cybersickness, Virtual Reality, Electroencephalography.

1 INTRODUCTION

Virtual Reality (VR) technology has gained significant traction in diverse domains, including entertainment, art, education, social interactions, and professional applications [1], [2]. VR enables users to immerse themselves in interactive digital environments, fostering shared experiences accessible to a wide audience. However, the individual experiences Cybersickness, a phenomenon shares similarities with motion sickness and typically manifests as symptoms like headaches, eye strain, nausea, and dizziness [11]. Interestingly, CS can be triggered solely by visual stimuli, even in the absence of actual physical movement. Theoretical evidence points to conflicts between visual and vestibular stimuli as the primary culprits behind CS, "Fig. 1" shows the related area of auditory and visual cortex located at the petitory lobe. This theory gains credibility from the observation that more lifelike virtual environments can provoke more severe symptoms [12]. The heightened visual stimuli in such environments furnish users with a greater wealth of environmental information, making it more challenging to ignore the conflicting sensory cues. CS can significantly diminish user comfort and pose barriers to accessing VR applications designed for therapeutic, rehabilitative, or educational purposes [13], [14]. While there are practices that can alleviate CS within virtual environments, such as narrowing the field of view [15] or incorporating background images [16], it's essential to exercise caution when deploying these measures. Their constant utilization can have adverse effects on the overall user experience. Therefore, it is advisable to apply these techniques only when cybersickness occurs or, even better, when it is anticipated.

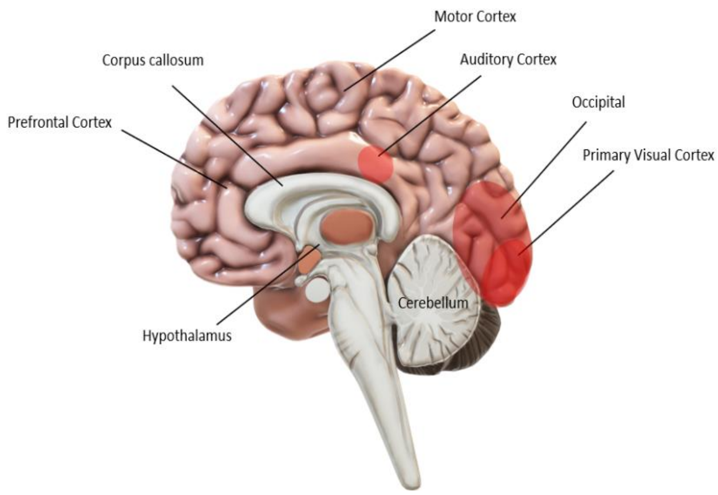

Fig 1. The Neuroanatomy of The Brain Related to Cybersickness.

Regrettably, the limitations of human physiology and perception act as a barrier to the widespread adoption of VR technology, especially as our world increasingly blurs the lines between virtual and real-world interactions. An effective strategy to mitigate CS involves the utilization of predictive or detection tools. These tools must be both automated and objective to facilitate preemptive measures, timely warnings, and clinical interventions, such as resistance training. Presently, the assessment of CS is confined to subjective reports relying on verbal confirmation or questionnaires. These methods not only lack predictive capabilities but also prove time-inefficient, relying on manual input. Leveraging existing technology, objective biomarkers associated with cybersickness can be obtained through wearable devices. These biomarkers can then be integrated into machine learning algorithms, enabling streamlined and automated prediction and/or detection of CS events [17]. Although several models for predicting and detecting CS severity have been proposed [17], [18], there remains a gap in effectively collecting CS data while continuously advancing our understanding of the condition through machine learning-assisted approaches. The detection of cybersickness can be accomplished using physiological signals acquired through various sensors such as Electrocardiogram (ECG) and Galvanic Skin Response (GSR) [19].

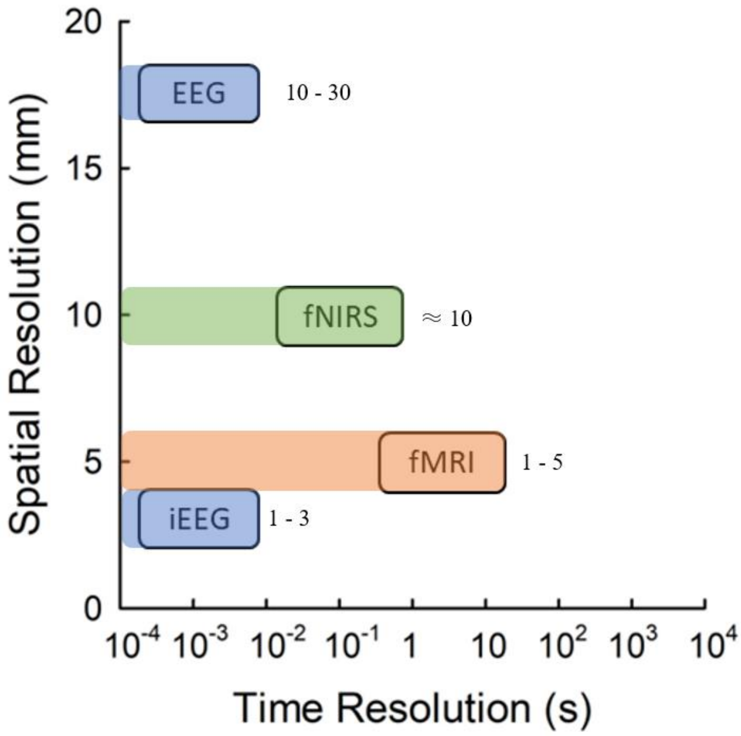

Fig 2. Physiological Devices in Term of Time and Special Resolution

The integration of machine learning techniques and wearable technology in healthcare has the potential to significantly benefit society [20]. Neurophysiological devices, which utilize techniques such as electromyography (EMG), electroencephalography (EEG), and Evoked potential (EP), are utilized to gain a deeper understanding of accurate and unobtrusive information in psychiatry. Other commonly used physiological devices include functional magnetic resonance imaging (fMRI), and functional near-infrared spectroscopy (fNIRS). “Fig. 2” shows the difference between special resolution and time resolution of each of these physiological techniques. In this work, a brief examination of various emerging experiments, issues, and themes will be presented. The proposed work is divided into five sections, the first of which introduces the topic of mitigating motion sickness using geometrical simplification and optic flow with the help of EEG. The second section presents the related work of recent research on cybersickness, third section, entitled methodology highlights the steps and experiment protocols, The fourth section” Results and discussion” presents a discussion of findings and outcomes. The final section,” Conclusion,” summarizes the proposed project.

2 RELATED WORK

2.1 Virtual Reality Environment

Virtual Reality (VR) has the potential to be a useful tool for studying the effects of optic flow on the user experience. In a VR environment, researchers can create scenarios that simulate real-life scenarios, a verity of studies found that VR can be used to successfully mimic real-life situation and elicit physiological responses like those seen in real-world situations. This allows researchers to study the effects of optic f low on the user experiance in a controlled and repeatable manner. Pooladvand et al. in [21], used a 3D model created with Maya (Maya 2020.4) to simulate a suburban environment. Five VR trackers were used to track the subjects’ body movements and sync them with a virtual avatar in real-time. The subjects wore an HTC VIVE Pro Eye VR headset and experienced the virtual environment as if they were the avatar. The virtual environment included a simulated arc flash with visual and audio representations, as well as wind and sound effects to increase the subjects’ sense of presence [21]. Other study by [22] explores the effects of environmental cues in virtual reality (VR), specifically virtual reality deformation and simplification, on cybersickness among users of head mounted displays (HMDs). Through the analysis of self-reported discomfort using SSQ form, it was discovered that cybersickness was mitigated when using more simplified VR environment [23]. The study by [24] involved participants experiencing a roller coaster simulation in a virtual reality (VR) environment at three different speeds using the HTC Vive HMD and Unity graphics engine, with their brain activity recorded via a 14-channel adhering to the international 10 20 system for EEG electrode placement. They found that exposure to a visually disturbed environment in virtual reality led to a damping effect in the alpha band across almost all EEG channels and at all speed levels, with the most significant attenuation observed in the” O” and ”P” channels associated with the visual cortex.

3 EXPERIMENT SETUP

3.1 Study Flow

As shown in “Fig. 3”, the proposed paper comprises two key objectives centered around neurophysiological measurement of motion sickness during virtual environment interactions. The first aim entails using an electroencephalography (EEG) device to monitor brain activity. Following data collection, a crucial step involves preprocessing to eliminate artifacts and extraneous data. Subsequently, feature extraction and selection techniques, such as Independent Component Analysis (ICA) which are employed in this study. With a selection of features derived from EEG signals, a time frequency analysis methods are applied to ensure optimal results. This can be achieved through well-established methods such as complex morlet wavelet and power spectral analysis. The second aim of this research involves the geometric design and analysis of the virtual environment. Prior research has concentrated on simplifying and deflecting optic flow to reduce motion sickness and enhance user experiences. Nevertheless, existing work requires further development, with the integration of EEG and VR headset to improve real-time user experiences “Fig. 3” shows the flowchart for the experiment and signal processing pipeline.

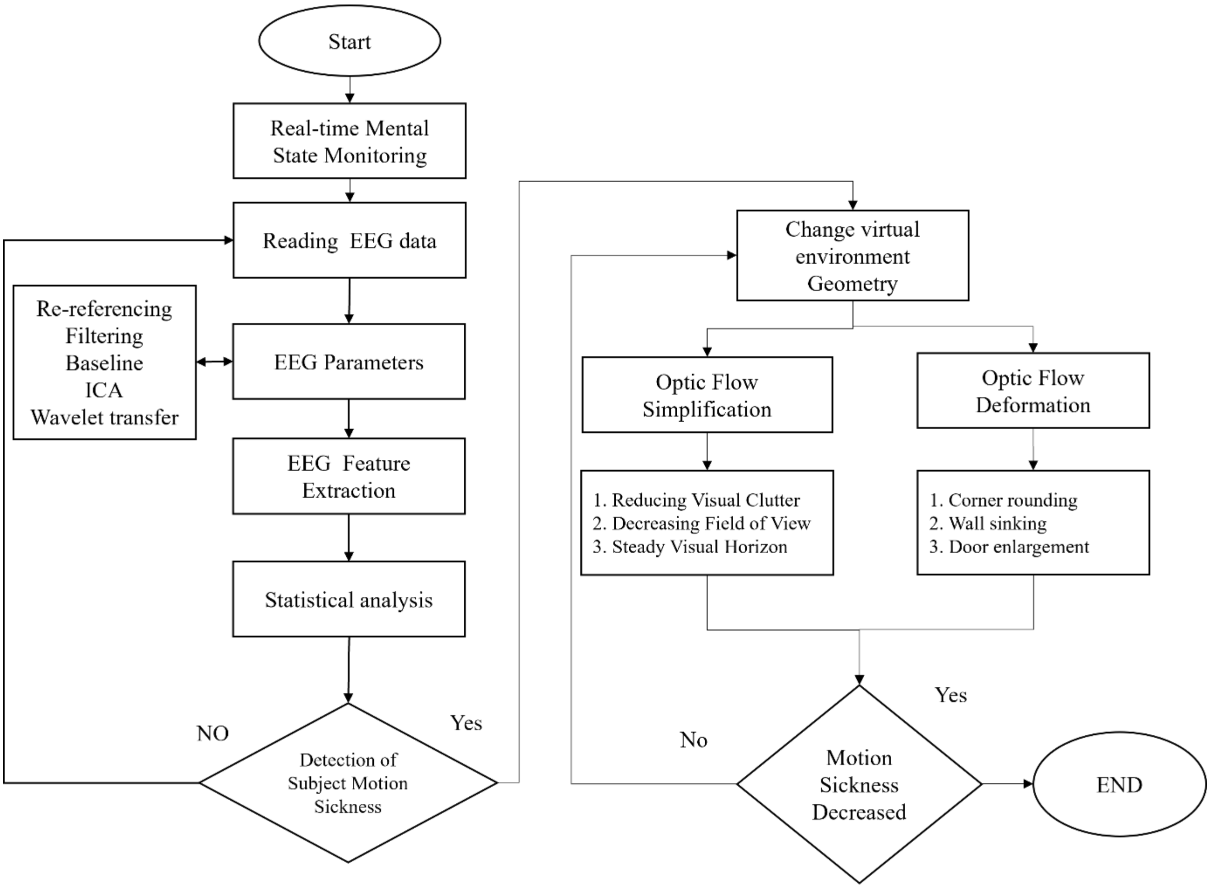

Fig 3. Flow chart of the user experience and neurofeedback measurement

3.2 Participants

The study engaged two healthy male participants, both aged 28 years (± 2 years), free from ophthalmologic conditions, following the acquisition of their written informed consent. Prior to the experiment, participants abstained from consuming substances such as alcohol, drugs known to induce nausea or headaches, and caffeine. To ensure the integrity of EEG data, participants were instructed to minimize head movements and remain silent during the EEG recording sessions, which were challenged by some technical difficulties associated with EEG data acquisition.

3.3 Apparatus

Electroencephalogram (EEG) recordings were conducted using the eegosports system, equipped with gel-based electrodes. This setup allows for configurations of either 32 or 64 electrodes; for the purposes of this study, a 32-electrode montage was employed, adhering to the international 10-20 system for electrode placement. Virtual reality (VR) experiences were delivered through the Oculus Meta Quest 2, which was securely mounted to the front of the EEG cap, facilitating the simultaneous recording of EEG data and exposure to VR content as depicted in “Fig. 4”.

3.4 VR environment

The virtual environment was meticulously crafted to induce the participants cybersickness, incorporating two distinct settings, each subjected to two different conditions. The inaugural environment is modeled as a tunnel, wherein the virtual

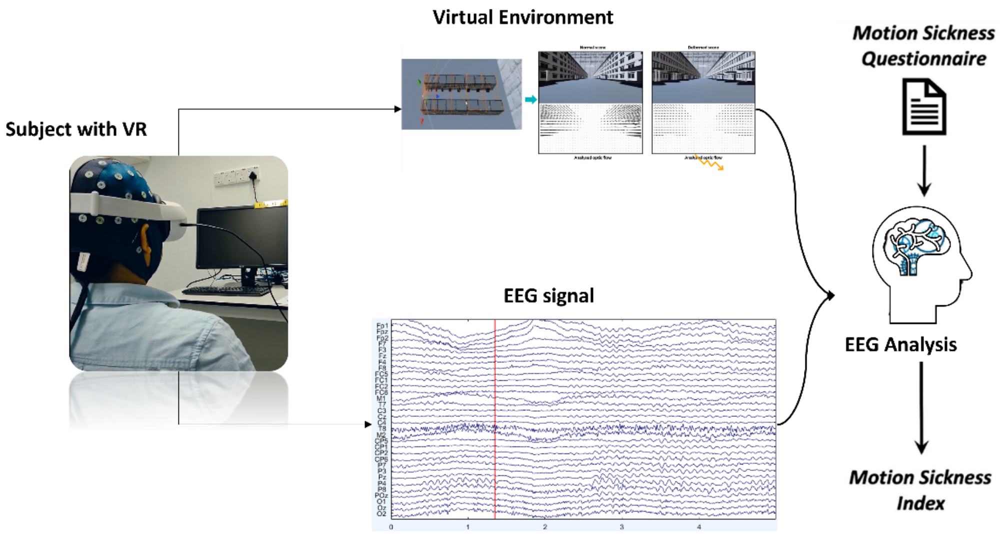

Fig 4. Configuration of the experimental equipment on a participant (EEG & VR).

reality (VR) simulation progresses in a straight trajectory at a uniform velocity. The first condition within this environment is characterized by a condensed, high degree of visual information, hypothesized to exacerbate cybersickness. Conversely, the second condition employs geometric processing techniques aimed at diminishing the density of virtual reality features, potentially mitigating cybersickness. The second environment is designed around a zombie shooting scenario, implementing experimental conditions analogous to those described for the tunnel environment, to further examine the effects of environmental manipulation on the incidence of cybersickness "Fig. 5".

Fig 5. The virtual reality design for the first and second task

3.5 Data Collection Protocols

Following the establishment of the experiment protocol's validity and reliability, alongside the integration of EEG with virtual reality (VR) technologies, and after receiving ethical clearance, an EEG apparatus was employed to capture the neural activities of two participants subjected to cybersickness-inducing stimuli. The experimental procedure commenced with a baseline recording of 60 seconds, succeeded by the first task of 20 seconds duration, a subsequent rest period of 10 seconds, a second task lasting 20 seconds, and a final rest interval of 10 seconds. This sequence was repeated across ten trials, culminating in a total duration of ap proximately 660 seconds, as depicted in "Fig. 6". The second scenario involved a zombie shooting simulation, comprising two tasks each of 60 seconds with a 10-second interlude and an initial 60-second baseline, across five trials amounting to 760 seconds in total. Prior to the commencement of EEG recording, participants underwent training to familiarize themselves with the VR environment, including trial runs. Participants were instructed to sit comfortably and minimize blinking and movement as much as feasible during the EEG recording sessions to ensure the accuracy and reliability of the data collected. All procedural conditions, alongside potential effects and the participants' autonomy to withdraw at any moment, were thoroughly communicated. The entire experimental session, inclusive of EEG electrode placement, was conducted within a time frame of less than one hour.

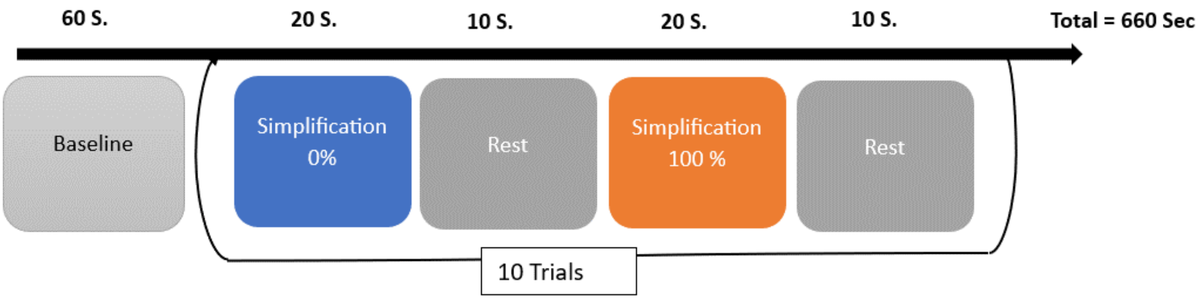

Fig 6. Data collection timeline and the number of trials

4 Results and Discussion

4.1 Event Related Potential (ERP)

From "Fig. 7", if we interpret that the no simplification represents condition1 and the gematrical simplified environment represents condition2, and the lower amplitude (closer to the baseline) is associated with fewer symptoms of cyber sickness, it appears that condition2 might be associated with less ERP activation, potentially indicating a reduction in cybersickness symptoms. However, condition1 seems to exhibit higher variability and possibly greater amplitude fluctuations, which might suggest a stronger response to the stimulus and potentially more pronounced cybersickness symptoms.

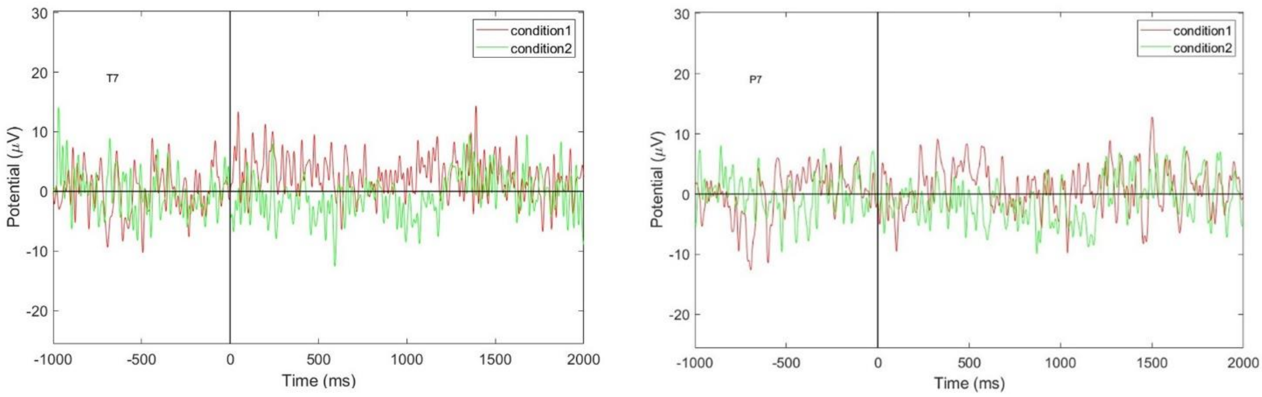

Fig 7. ERP Data from The T7 And P7 Electrode Placement Over the Left Temporal And Parietal Area Of The Scalp.

4.2 Time Frequency Analysis

From "Fig. 8", In the time-frequency topography graph provided for P7 corresponding to the parietal region of the brain, we observe the Event-Related Spectral Perturbation (ERSP) for two different conditions, Condition 1 related to no simplification and Condition 2 for geometry simplification. ERSP illustrates changes in the brain's power spectrum in response to a stimulus or task over time. The color scale on the right of each plot indicates the power spectral density with warmer colors (reds and yellows) indicating an increase in power, and cooler colors (blues) indicating a decrease in power relative to a baseline. from the graph we have observed that both conditions show a range of activity across different frequency bands. However, the patterns of activation are different between Condition 1 and Condition 2. Condition 1: Appears to have more pronounced power in creases (reds and yellows) in the lower frequency bands, delta (0.5-4 Hz) and theta (4-8 Hz) and some mid-range, alpha (8 13 Hz) and beta (14-30 Hz) frequencies. There is also notable activity in the higher frequency, gamma bands (30-100 Hz). Condition 2: Shows more sustained and less fluctuating activity throughout the observation period, with less pronounced peaks of activation. Since Condition 1 is meant to simulate a scenario inducing cybersickness, the increased power in the lower frequencies indicate that this condition elicits a stronger cognitive response, or a more pronounced disorientation reflected in the EEG. Condition 2 appears to be more stable, which might suggest that the brain is not reacting as strongly as in Condition 1. This could be interpreted as indicative of less cybersickness or a more tempered response to the VR environment. The difference in power levels across the conditions, condition 1 is higher power, could suggest that Condition 1 is more stimulating and stress-inducing than Condition 2. In the context of cybersickness, increased power in alpha 8 13 HZ frequency bands could relate to discomfort or disorientation, while more stable, lower power levels in beta and gamma bands could indicate mitigation. However, it's critical to consider taking more subjects for the future results. It would also be essential to compare these results with subjective reports of cybersickness SSQ form to see if the EEG data aligns with the participants' experiences.

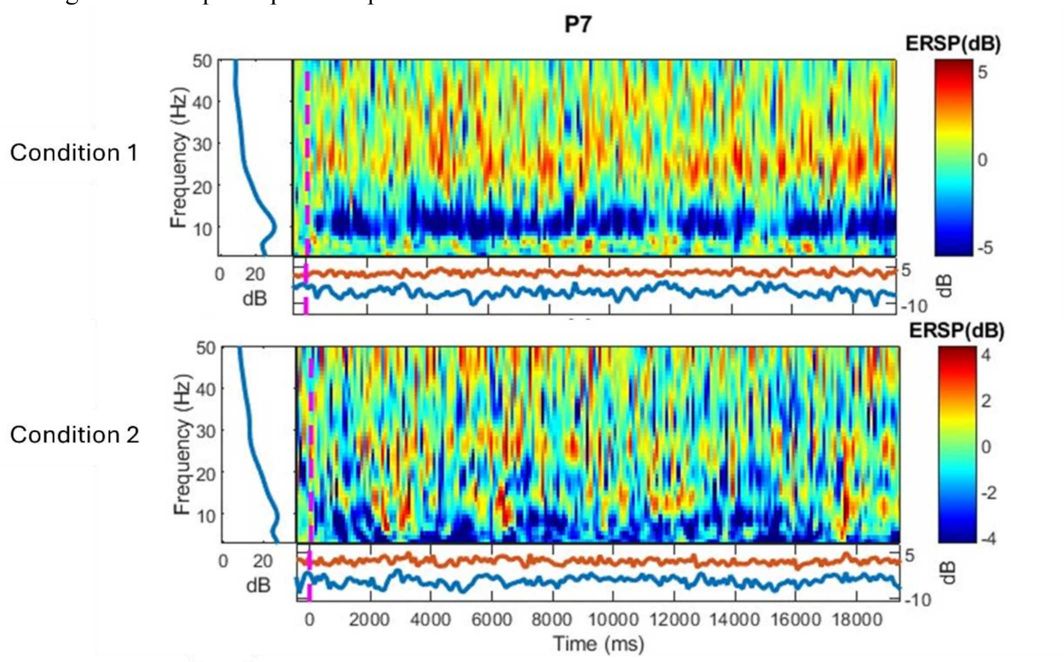

Fig 8. Time-frequency analysis for the tunnel task, depicting the spectral dynamics at the P7 electrode placement, situated in the parietal region on the left side of the brain. This analysis illustrates the variation in power across a range of frequencies over time in response to the task.

5 Conclusion

In conclusion, our study has made strides towards mitigating the prevalent issue of cybersickness in virtual reality (VR) environments. Through the implementation of a framework that integrates EEG neurofeedback with geometric simplification techniques, we have been able to monitor and analyze the cognitive states of users as they engage with VR. Our findings confirm a palpable relationship between cybersickness and increased neural activity in the parietal and temporal lobes, with such activity markedly reduced under the condition of geometric simplification. The decrease in optic flow and the subsequent reduction in sensory conflict validate the proposed approach as an effective intervention for reducing cybersickness. This research not only contributes to the theoretical understanding of cybersickness but also provides practical implications for the design of VR experiences that are more comfortable and can be enjoyed by users with increased longevity.

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