Can Brain Stimulation Reduce VR motion sickness in Healthy Young Adults During an Immersive Relaxation Application? A Study of tACS

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Abstract

This study marks the first exploration of whether a non-invasive transcranial alternating current stimulation (tACS) on the left parietal cortex can reduce VR motion sickness (VRMS) induced by a commercial VR relaxation app. Two VRMS conditions were examined for 36 healthy young adults: 1) pure VRMS without a moving platform; 2) VRMS with a side-to-side rotary chair. Participants underwent three counterbalanced tACS protocols at the beta frequency band (sham, treatment, and control). Contrary to our hypothesis, the treatment protocol did not significantly reduce VRMS in either condition. Given the protocol's prior success in our previous tACS study, we discussed potential factors hindering the replication of our earlier achievement.

Keywords: motion sickness, EEG, brain stimulation.

Index Terms: motion sickness, cybersickness, neurostimulation.

1 Introduction

Our recent electroencephalogram (EEG) studies in vestibular cortical areas revealed that there is a significant correlation between VRMS ratings and the phase-locking values in beta frequency band [1]. To assess the casualty between our EEG findings and the severity of VRMS, we previously designed a transcranial alternating current stimulation (tACS) protocol to disrupt that EEG-VRMS correlation and successfully validated its feasibility in mitigating VRMS in healthy young adults (*see attached Supplementary Materials*). VRMS in this previous study was induced by a visual motion stimulus eliciting linear self-forward vection, with motion sickness susceptibility of participants being well controlled (10<MSSQ<36; Motion Sickness Susceptibility Questionnaire [2]). In the current study, we replicated the successful beta-tACS protocol developed in our previous work to answer the following research question: Does the beta-tACS stimulation mitigate VRMS caused by a commercial immersive VR relaxation application under stationary and dynamic environments in a non-MSSQ-controlled randomly-recruited student population?

2 Methods

2.1 VRMS Stimulus

The VRMS stimulus was a relaxation VR app named Fairy Forest developed by SyncVR Medical, as seen in Fig. 1. This application features the participant moving on an animated and mild-curved country road through a fairy-tale forest. This application was originally developed for pediatric patients undergoing chemotherapy. This application consisted of a 7-minute relaxation journey with audio-guided breathing exercises based on the principles of mindfulness. Traveling along the mild-curved country road can elicit a sensation of self-forward motion which in turn has the potential to trigger VRMS given the absence of matched vestibular response to the visual self-motion stimulus.

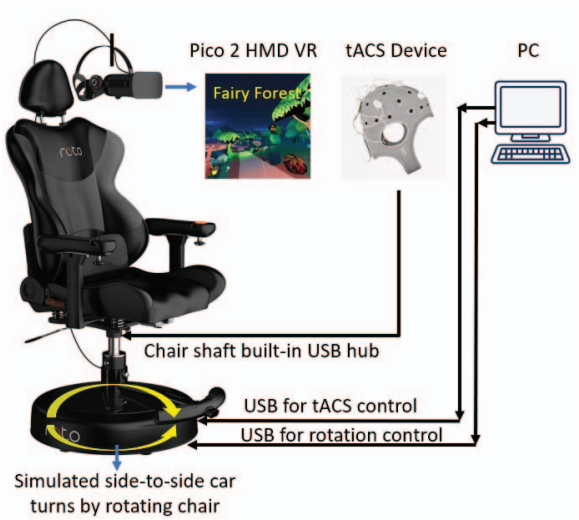

Figure 1: The system architecture of our simulated dynamic environment for VRMS induction

2.2 Experimental Procedure

This study replicated the previous use of beta-tACS to mitigate VRMS which involved three protocols: treatment, control and sham (the baseline). The order of the three protocols were fully counterbalanced and applied to each participant with a 5-min break between each protocol. During the implementation participants reported their experience of dizziness and nausea on two scales ranging from 0 (min) to 20 (max) every minute. Both the stationary and dynamic conditions implemented the same experimental procedure. This procedure was approved by the ethics committee of the University of Glasgow (No. 200220374). All participants gave informed consent prior to participation. The tACS device used in this study is StarStim8 (Neuroelectrics, Spain).

2.3 Participants

Thirty-six 20–30-year-old university students participated in this study, with half of them participating in the stationary (N=18,

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which is the same sample size as our previous tACS study) and the other half participating in the dynamic condition. All participants had normal or corrected-to-normal vision and were self-reported free from tACS/tDCS contraindications. They all reported playing less than 2 hr of PC or VR video games per month; this was done to ensure that participants prior experience with video games did not affect the findings of this study. All participants were paid £10/hr for their participation. In the stationary environment, each participant experienced the VRMS stimulus on a normal non-rotary office chair. They were instructed to sit as still as possible on the chair without moving their head. In the dynamic environment, each participant experienced the VRMS stimulus on a side-to-side rotary chair (RotoVR, Hertfordshire, UK, as shown in Fig. 1). The rotation frequency of the chair was random but less than 0.2Hz [3]. All participants were required to sit still relative to the chair without performing additional head movements.

2.4 Statistical Analyses

Analyses of repeated VRMS ratings utilized Generalized Linear Mixed Model (GLMM) with treatment (treatment/control/sham tACS), time (the 1st to 7th minute) and their interaction as fixed factors as well as time and participant as random factors (if random factors were not significant, $p<0.05$, then only fixed factors were used). Among these analyses, as dizziness and nausea ratings were non-normal integers, negative binomial distribution was used as the target distribution. The basic first-order autoregressive was set as the covariance structure for all repeated measurements. These GLMM settings are the same as our previous tACS study.

3 Results

3.1 Stationary Condition

Ten (55.6%) out of the 18 participants in the stationary condition experienced VRMS. Among them, 100% reported very weak dizziness per min (0.39±0.78 out of max: 20) and 50% (that is, 5 out of the 10 participants) reported very weak nausea per min (0.18±0.49 out of max: 20). However, we did not replicate the success of our previous tACS study, with no statistically significant treatment effect for treatment tACS protocol.

3.2 Dynamic Condition

Nine (50%) out of the 18 participants in the dynamic condition experienced VRMS, which is even lower than that in stationary condition. All of them reported very weak dizziness per min (M=0.59±0.80 out of max: 20) and 66.7% (that is, 6 out of the 9 participants) reported very weak nausea per min (M=0.80±0.59 out of max: 20). However, we did not replicate the success of our previous tACS study in dynamic condition either.

4 Discussion

Table 1 shows the similarities and differences between the current study and our previous study.

Table I Comparisons of the present work and the previous study

	The present work	The previous work
Sample Size	18	
tACS protocol	Counterbalanced 3 protocols: sham, control and treatment	
VR stimulus	self-forward visual motion	
Statistics	GLMMs	
Duration of VR stimulus & tACS	7 mins	30 mins
Prevalence of VRMS	50-55%	100%
Timing of observed mitigations	N/A	The 10th min during the tACS session

We speculate that the primary reason why we could not replicate the success of the beta-tACS on VRMS mitigation is that VRMS just did not occur as often with this VR relaxation app. Regardless of whether it was the stationary or dynamic condition, the VRMS prevalence rate was only around 50%, while in our previous work 100% of participants experienced VRMS. The results of this study suggest that the treatment beta-tACS protocol encountered a floor effect and thus cannot reduce very weak VRMS symptoms caused by a commercial VR relaxation app. It is also possible that we did not find an effect of our treatment protocol due to inadequate brain stimulation time. It is especially pertinent given that in the prior work the effectiveness of the beta-tACS could not be observed until the 10th minute after the tACS started. Since in our previous work, our observation points were 4, 10, 16, 22, and 28 mins after the onset of brain stimulation, we do not know the exact time point at which the mitigation effect begins. Based on previous findings, it could happen before the 10th min and at some point between the 5th and 9th mins. The present study did not find any mitigation effects between the 5th and 7th mins, meaning that future study can increase the duration of tACS from 7 min to 10 min to check if the VRMS mitigation effect can be observed.

5 Conclusion

This is the first study to investigate if a non-invasive brain stimulation technique (tACS) can reduce VRMS caused by a commercial VR relaxation app. Although our investigation did not show any significant results, we found that no participants dropped out or complained of any symptoms associated with tACS, regardless of whether it was treatment, control or sham protocols and regardless of whether it was stationary or dynamic conditions. This is a meaningful exploration on mitigating VRMS caused by VR healthcare apps per se using the current state-of-the-art VRMS mitigation technology that does not involve changes in VR content.

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