Audio-Visual Entrainment and Episodic Memory

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Abstract

Roberts et al. (2018) found that theta brainwave oscillations induced by audio-visual entrainment (AVE) improved episodic memory in a recognition paradigm. The current study attempted to replicate and extend Roberts et al. using episodic memory recall in both male and female participants, whereas Roberts et al. used only females. In our study, participants rated two different word lists, either for pleasantness or frequency, then engaged in 5.5 Hz (theta), 13-18 Hz (SMR/Beta), or sham AVE. A free-recall task assessed episodic memory for words in the pleasantness rating task. The current study replicated the basic findings of Roberts et al. with episodic recall, but the improvement in episodic recall accuracy in the theta AVE condition occurred only in female participants.

Introduction

Audio-Visual Entrainment (AVE) is a technique for synchronizing EEG activity to a particular rhythm by presenting light flashes and sound pulses at the desired rhythm, through headphones and special goggles (See Figure 1). The frequency and intensity of the tones and flashes is identical, and can be controlled so as to be slow (e.g., 5.5 pulses per second (Hz) or faster (e.g., 14 pulses per second). Each pulse or tone generates a "wave" of brain activity, which because of the interconnectivity of the cortical and subcortical structures, pervades the brain. These waves of activity match the input frequency; thus, the brain becomes "entrained" to the presented frequency. Entrainment continues while the stimuli are presented, and for a period of time after the stimuli cease. Audio-visual entrainment can be used to create EEG patterns that can potentially affect the quality of performance on cognitive tasks (Budzynski et al., 1999; Joyce & Siever, 2000; Huang & Charyton, 2008).

Episodic memory is memory for a specific event ("what", "when", and "why" information), and can be tested using either a recognition ("Have you seen this item before?") or a recall ("List the items you have seen") format. Roberts, Clarke, Addante and Ranganath (2018) found that a brief session of 5.5 Hz AVE between learning a list of words and a test of the words led to improved source memory using a recognition paradigm. From their results, however, it is not clear whether AVE would improve one's ability to recall the information.

Roberts et al. used neutral valence words, but episodic memory has been shown to be better when the words have a stronger emotional valence (Pause, Zlomuzica, Kinugawa, Mariani, Pietroswky, & Dere, 2013). Using emotionally-charged words, the current study was conducted to provide a partial replication of Roberts et al. to determine if theta (5.5 Hz) training through AVE would lead to an increase in episodic recall.

Method

Forty-five participants (21 female and 24 male, M_{age} = 19.4 years) from an introductory psychology class at a university in the Northeastern U.S. were randomly assigned to one of three experimental conditions: a single AVE session that enhances brain wave patterns in the SMR/beta range (13-18 Hz), one designed to increase theta waves (5.5 Hz), or a sham condition (0.1 Hz).

All participants completed two word-rating tasks, then a session of AVE, followed by a recall task (see Figure 2). Each of the word lists was comprised of 30 words selected from the Bradley and Lang Affective Normalized English Word (ANEW) list to be either negative (10 words), positive (10 words), or neutral (10 words) in emotional valence. For both lists, each word was shown on a computer screen for 1.5 s. For the "pleasantness" rating task, the participants were asked to rate how pleasant they judged each word to be on a 7-point scale. For the "frequency" rating task, participants rated each word based on how frequently they encounter the word. The order of the two lists was counterbalanced between-subjects. The participants were not informed that their memory would later be tested, nor encouraged to try to study the words.

Following the rating tasks, each participant was randomly placed in one of the three AVE conditions. For the memory task following the AVE exposure, the participants were asked to think about the pleasantness rating task that they previously completed, and in 5 min, recall as many of the 30 words from that list as they could. They were told to only write down the words from the pleasantness rating task, not the frequency task. The entire procedure took about one hour.

The study used a 3 (AVE) x 2 (Sex) x 2 (List Order) between-subjects design. The dependent variable was episodic recall accuracy, as measured by the number of words recalled correctly minus the number of false alarms.

Figure 1. The AVE Apparatus

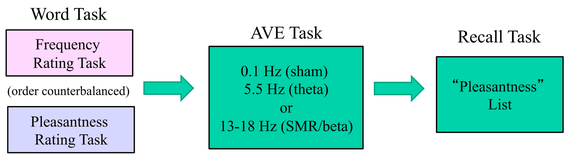

Figure 2. Task Order

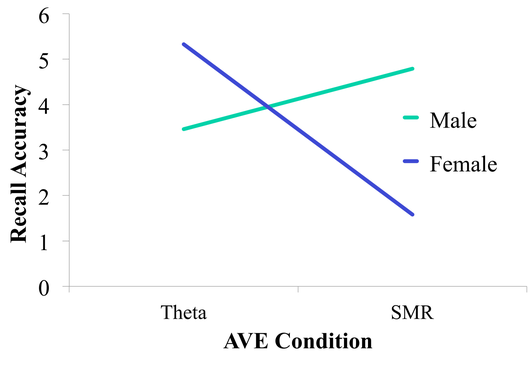

Figure 3. Recall Accuracy as a Function of Sex and AVE Condition

Results

A 3 (AVE) x 2 (Sex) x 2 (List Order) between-subjects ANOVA was computed using recall accuracy (the number of correct minus the number incorrect) as the dependent variable. No significant main effects nor interactions were found. The analysis did reveal a marginally significant effect of List Order, $F(1, 34) = 3.43$, $p = .073$. As might be predicted, recall tended to be more accurate when the pleasantness rating task was presented more recently. The means for List 1 and List 2 were 2.89 ($SD = .77$) and 4.70 ($SD = .80$), respectively. There was also a marginally significant interaction effect between Sex and AVE, $F(2, 34) = 2.62$, $p = .088$. It was discovered through this analysis, however, that no female participants were in the sham AVE condition with the pleasantness task second. Given the trend for performance to be better when the critical list was second, this lack of participants in that condition is problematic. To further explore the interactions between Sex, List Order and AVE, analyses were run omitting the sham condition.

A 2 (AVE) x 2 (Sex) x 2 (List Order) between-subjects ANOVA was computed using accuracy as the dependent variable. The analysis revealed a significant effect of List Order, $F(1, 23) = 4.38$, $p = .048$. Overall, memory was more accurate when the pleasantness rating task was more recent. The means for List 1 and List 2 were 2.71 ($SD = .749$) and 4.88 ($SD = .714$), respectively. There was also a significant interaction between AVE and Sex, $F(1, 23) = 6.03$, $p = .022$. No other main effects nor interactions were significant. Follow-up analyses showed that for female participants, accuracy was higher in the theta condition, $F(1, 13) = 6.74$, $p = .022$, but for male participants AVE did not have a significant effect on accuracy, $F(1, 10) = .815$, $p = .388$. See Figure 3 for the means.

Discussion

This study was a partial replication of the work of Roberts et al. (2018), but focused on episodic recall rather than recognition, using both male and female participants, and used words with a greater emotional valence. Consistent with Roberts et al., female participants demonstrated improved episodic memory in the theta AVE condition. This extends the previous findings to include episodic recall. The findings of Roberts, et al., using only female participants, do not appear to generalize to male participants. We found that AVE condition did not impact the recall accuracy for the male participants in our study.

This study raises interesting questions about why AVE frequency exposure appears to impact the episodic recall of female, but not male participants. Future studies will examine whether this sex difference is a robust phenomenon. If so, additional research is needed to determine the cause of the differential effect.

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