



Research paper

Effectiveness of Brainwave Entrainment in Alpha Band on Working Memory, Anti-Saccade and Anxiety Level of Anxious Participants

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Abstract

The aim of this study was to determine the effect of Brainwave Entrainment in alpha band on working memory, anti-saccade and anxiety level of anxious participants. The present study is a quasi-experimental project of pre-test-post-test with control group. In this regard, 30 anxious participants were selected by Beck anxiety inventory and randomly replaced in 2 experimental and control groups (15 groups each). The Corsi Blocks Tapping test, Anti-saccade Task and Beck Anxiety inventory were used to collect data. Participants in the experimental groups received 10 Hz binaural beats. Data were analyzed using multivariate analysis of covariance. The findings showed that 10 Hz binaural beats significantly improved participant's working memory, increased anti-saccade and decreased anxiety level. Therefore, brainwave entrainment in the alpha band is recommended as a non-invasive intervention method to reduce the level of anxiety and improve cognitive functions.

Keywords: Anxiety, anti-saccade, brainwave entrainment, working memory

Introduction

Anxiety and fear are normal responses to potential or actual threats. They can become repetitive, excessive and prolonged, disrupting normal functioning and leading to pathological anxiety (Koskinen & Hovatta, 2023). Attentional control theory (ACT) assumes that attentional control deficits play a major role in the development of anxiety. The attentional control theory proposes that there are two attention systems: a bottom-up stimulus-driven system and a top-down goal-directed system similar to the central executive in working memory. Thus, when a threat is present, threatening stimuli grab attention. Cognitive dysfunctions may be ameliorated through brainwave synchronization via binaural beats. In this auditory perceptual phenomenon, two sinusoidal sounds are presented individually to each ear, where the frequency of the sound presented to each ear slightly varies from the other, with this variation being equal to the intended frequency of stimulation. Loong, et al. (2022) demonstrated that binaural beats in the alpha frequency band can have

therapeutic effects. Therefore, the primary research question examines whether brainwave synchronization in the alpha band impacts working memory, anti-saccade performance, and anxiety levels in anxious individuals. Therefore, the present study was conducted with the aim of investigating the effect of alpha band brainwave entrainment based on the following hypotheses:

- brainwave entrainment in the alpha band on working memory is effective
- brainwave entrainment in the alpha band on anti-saccade is effective
- brainwave entrainment in the alpha band on anxiety is effective

Method

The present study utilized a quasi-experimental pretest-posttest design with a control group. The sample consisted of undergraduate students at Tabriz University. The independent variable was binaural beats in the alpha frequency band. Dependent variables were working memory, anti-saccade, and anxiety level. After screening 250 university students, a convenience sample of 30 students scoring 16 or above on the Beck Anxiety Inventory (indicating moderate to high anxiety) were randomly assigned to either the experimental or control group (15 each). Pretest measures included the anti-saccade task and Corsi block tapping test. Beck anxiety inventory scores were recorded as pretest anxiety level. The experimental group then received 30 minutes of 10 Hz binaural beats via headphones 5 days per week for 4 weeks (based on the intervention protocol of Le Scouarnec, et al., 2001). Afterwards, both groups were re-evaluated with the same pretest measures constituting the posttest. Inclusion criteria were normal heart conditions, and no other psychiatric disorders. Exclusion criteria were any hearing problems, palpitations, or unpleasant sensations/dizziness during the intervention. Prior to implementation, an informed consent form approved by the university's ethics committee was provided emphasizing confidentiality. Multivariate analysis of covariance (MANCOVA) utilized SPSS version 24 for statistical analyses.

Tools

Beck Anxiety Inventory (BAI): This 21-item questionnaire utilizes a 4-point Likert scale (Beck, et al., 1988). The anxiety score range is from 0 to 63. The Cronbach's alpha of this questionnaire has been reported to be 0.92. Cronbach's alpha in this study was 0.89.

Corsi Block Tapping Test: This computerized task presents 9 blocks lighting up in a specific sequence. (Arce & McMullen, 2021). The test-retest reliability of this test has been reported to be 0.73. Test-retest reliability in this study was .81.

Anti-saccade Task: In this task a visual cue appears to one side, followed by a target stimulus on the opposite side. (Miyake, et al., 2000). The test-retest reliability of this task has been reported to range from 0.50 to 0.80. Test-retest reliability was .86 for the present study.

Brainwave Entrainment: The auditory stimulus followed the protocol used by Cooper (2021) to generate alpha band binaural beats for anxiety treatment. The base and offset frequencies of 400Hz and 410Hz respectively were selected using Gnaural software to produce a 10Hz frequency. The output file format is WAV which was presented to the participants for 30 minutes via stereo headphones.

Results

The descriptive findings presented in Table 1 indicate an increase in working memory and anti-saccade scores and a decrease in anxiety scores of the experimental group in the post-test stage.

Table 1. Mean and standard deviation of dependent variables of two groups

variable	Pre test				Post test			
	Experimental group		Control group		Experimental group		Control group	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Working memory	4.83	0.55	4.76	0.70	6	0.59	5.06	0.65
Anti-saccade	0.77	0.03	0.78	0.03	0.82	0.03	0.78	0.03
Anxiety	32.93	5.52	34.33	5.83	30.20	3.85	33.53	5.57

Examining the assumptions of multivariate variance analysis showed that all assumptions have been fulfilled. As shown in Table 2, after controlling for pretest scores, significant between-group posttest differences emerged across all three dependent variables - working memory, anti-saccade, and anxiety (all $P < .05$).

Table 2. Results of Covariance Analysis for Alpha Band Brainwave Synchronization on Dependent Measures

Source	Variable	MS	df	F	sig	Eta
Group	Working memory	5.90	1	21.85	0.0001	0.46
	Anti-saccade	0.01	1	34.61	0.0001	0.58
	Anxiety	33.97	1	4.88	0.03	0.16
Error	Working memory	6.75	25			
	Anti-saccade	0.008	25			
	Anxiety	173.83	25			
Total	Working memory	936	30			
	Anti-saccade	19.50	30			
	Anxiety	31192	30			

Discussion and Conclusion

Results demonstrated alpha band brainwave synchronization improved working memory capacity, anti-saccade performance, and reduced anxiety in anxious students. These findings may be explained by binaural beats facilitating decreased sympathetic nervous system

activity, thereby reducing anxiety and promoting calmness. Alpha wave activity may also suppress distracting inputs. Anxiety has been shown to impair anti-saccade performance; thus, increased alpha waves directly or indirectly (through anxiety reduction) may improve task performance. Given alpha waves play an important role in working memory, increased alpha waves via brainwave synchronization may have enhanced working memory functions. A limitation was the inability to select clinical participants. Future research should examine such brainwave synchronization interventions among clinically anxious patients.

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Conflicts of interest

There is no conflict of interest for the authors of the article.



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