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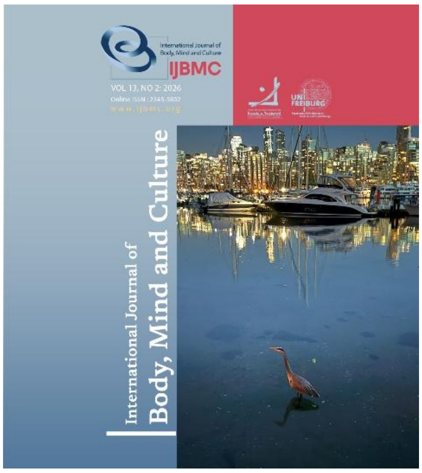

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The Effect of Binaural Beats on Mood and Emotional Self-Regulation in Individuals with Generalized Anxiety

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ABSTRACT

Objective: This study examined the effectiveness of binaural beat stimulation on mood and emotional self-regulation in individuals with generalized anxiety disorder.

Methods and Materials: This quasi-experimental study used a pretest–posttest–follow-up design with a control group. Participants were individuals with generalized anxiety disorder who referred to Behjou Clinic in Tehran, Iran, in 2024. 36 eligible participants were selected and randomly assigned to a binaural-beat intervention group or a control group. The intervention consisted of 15-Hz beta-range binaural beat stimulation using 240-Hz and 255-Hz carrier tones, delivered through headphones for 20 minutes per session, three sessions per week, over four weeks. Data were collected using the Penn State Worry Questionnaire, Positive and Negative Affect Schedule, and Cognitive Emotion Regulation Questionnaire. Data were analyzed using repeated-measures ANOVA and MANOVA in SPSS-27.

Findings: Binaural beat stimulation significantly improved mood state, with significant time ($F = 180.5$, $p = 0.001$, $\eta^2 = 0.891$) and time × group effects ($F = 34.3$, $p = 0.001$, $\eta^2 = 0.610$). Positive affect increased from 20.7 ± 2.73 to 32.4 ± 1.62, while negative affect decreased from 43.4 ± 4.85 to 31.3 ± 4.94. Emotional self-regulation also improved significantly, with significant time ($F = 715.2$, $p = 0.001$, $\eta^2 = 0.970$) and time × group effects ($F = 30.4$, $p = 0.001$, $\eta^2 = 0.580$). Improvements were maintained at follow-up.

Conclusion: Binaural beat stimulation improved mood and emotional self-regulation in individuals with generalized anxiety disorder.

Keywords: Generalized Anxiety Disorder, Acoustic Stimulation, Affect, Emotion Regulation, Anxiety, Auditory Perception.

Introduction

Individuals with generalized anxiety disorder (Cipric et al.) show heightened sensitivity to danger and negative stimuli and often exaggerate the likelihood and severity of adverse outcomes. This leads to a pattern of anxiety, rumination, and avoidant behaviors. In this regard, neurocognitive assessments have frequently revealed attentional biases toward threatening stimuli, difficulties with cognitive flexibility, and impairments in attention and memory, especially under stressful or threatening conditions (Gkintoni et al., 2017). Under such conditions, altered performance in favor of emotion-related stimuli—mainly negative or disorder-related—is referred to as *cognitive bias*.

In people with GAD, connectivity between the prefrontal cortex and the amygdala is also reduced; the prefrontal cortex is thought to help regulate emotional responses. Other brain structures related to anxiety, threat, and fear include limbic areas and the thalamus. The thalamus, in particular, plays a role in behavioral control and emotional processing, and its contribution to anxious behavior appears to be that of a regulatory structure; activation of certain thalamic regions can induce anxiety and aversive states. Therefore, both the dorsal medial prefrontal cortex and the thalamus appear to play important roles in regulating emotional processing in anxious individuals (De la Peña-Arteaga et al., 2022).

Previous studies have also reported that patients with anxiety-related disorders may show an imbalance between right and left dorsolateral prefrontal cortex (DLPFC) activity, with hypoactivation on the left side and hyperactivation on the right. It has been suggested that left-sided hypoactivity of the DLPFC is associated with negative emotional judgments, whereas hyperactivity is related to attentional bias (Stein et al., 2020).

Given the high rate of comorbidity between mood and anxiety disorders, research has increasingly focused on the shared mechanisms of these conditions (Newman et al., 2023). Studies on the impact of comorbidity between GAD and other psychiatric disorders have shown that, compared with individuals without any disorder, those with both anxiety disorders and other medical or psychiatric conditions experience greater difficulties in recalling past events and performing cognitive tasks involving planning, problem solving, and decision-making (executive functions). The presence of comorbid psychiatric disorders, such as mood disorders, can therefore affect the neuropsychological functioning of these individuals (Gkintoni & Ortiz, 2023).

Mood and anxiety disorders are among the most common and disabling conditions and frequently occur as comorbid diagnoses. For example, almost 90% of patients with an anxiety disorder experience at least one episode of major depression during their lifetime. In fact, mood and anxiety disorders share symptoms such as tension, anxious arousal, anhedonia, melancholia, and dysphoria. More recently, disrupted connectivity within functional networks involved in emotion regulation has been demonstrated in anxiety disorders, and there is evidence of dysfunction in brain structures such as limbic regions, the anterior cingulate cortex, amygdala, insula, and prefrontal cortex in patients with mood and anxiety disorders (Chivu et al., 2024).

Previous studies indicate that individuals with GAD, at the behavioral level, show poorer emotion regulation, defined as "cognitive and behavioral processes that influence the occurrence, intensity, duration, and expression of emotions." Unsurprisingly, prior research has found that GAD patients exhibit reduced recruitment of the dorsal anterior cingulate cortex, lateral frontal cortex, and parietal cortex, which are involved in explicit emotion regulation and attentional control tasks. Indeed, limitations in attentional functioning—such as reduced capacity to focus and attentional bias—are thought to generate maladaptive emotion-regulation strategies that facilitate the emergence and maintenance of anxiety symptoms. Conversely, emotion-regulation difficulties can exacerbate anxiety symptoms and contribute to greater distress in individuals with GAD (Li et al., 2023).

Therefore, the present study sought to examine whether binaural beat stimulation affects mood state and emotional self-regulation in individuals with generalized anxiety disorder.

Methods and Materials

Study Design

The present research was applied in nature and used an experimental design with a pretest–posttest–follow-up structure and a control group. The follow-up phase was conducted one month after the posttest for all groups. The statistical population in this study consisted of all individuals with generalized anxiety disorder (Cipric et al.). The target population included all patients with GAD who were referred to Behjou Clinic in Tehran in 2024. A systematic random sampling method was used. Since a list of patients with anxiety disorders was available at this center, and given the likelihood of sample attrition and the sample size calculated using G*Power software, 36 people were invited to participate. If a clinic visitor declined to participate, another patient was selected systematically as a replacement. These 36 participants were then randomly assigned using Excel software to three groups (13 participants in each group).

The required sample size was determined to be 33 participants using G*Power, based on α = 0.05, statistical power of 85%, the number of groups, and the experimental design. With an additional 10% added to account for attrition, the final sample size was set at 36 participants.

Inclusion criteria were: scoring above the cut-off on the Pennsylvania State Worry Questionnaire, no history of neurological disorders or epilepsy, not being under treatment for an anxiety disorder or similar conditions, not taking psychiatric medication, and no substance abuse, and normal bilateral hearing as confirmed by an audiologist (audiometrist). Exclusion criteria were: absence from more than two intervention sessions and unwillingness to continue collaboration with the research team.

Instruments

Demographic questionnaire: Demographic information was collected using a short questionnaire, which included basic data such as age, education, occupation, and gender.

Pennsylvania State Worry Questionnaire (PSWQ; 1990): A 16-item self-report scale developed by Meyer et al. (1990). The authors report that this questionnaire correlates predictably with several psychological measures of worry and shows no significant association with more distal constructs. Responses are not affected by social desirability (Meyer et al., 1990). The PSWQ measures severe and uncontrollable worry and is used as a screening tool for generalized anxiety disorder. Items are rated on a 5-point Likert scale (from 1 = not at all typical of me to 5 = very typical of me). Eleven items are positively keyed, and the remaining five require reverse scoring. The total score is obtained by summing the item scores; higher scores indicate greater pathological worry, and the total score ranges from 16 to 80 (Rodríguez-Biglieri & Vetere, 2011).

Positive and Negative Affect Schedule (PANAS): The Positive and Negative Affect Schedule (PANAS) is a self-report questionnaire developed by Watson et al. (1988). It consists of two subscales, each containing a list of 10 positive and 10 negative affects. Respondents rate the extent to which they have experienced each emotion using a 5-point Likert scale (from 1 = very slightly or not at all to 5 = extremely). The minimum and maximum possible scores on each subscale are 10 and 50, respectively. Validity for the PANAS has been reported via correlations of the positive and negative affect subscales with the Beck Depression Inventory (0.36 and 0.58, respectively) and with the State Anxiety subscale of the State–Trait Anxiety Inventory (−0.35 and 0.51, respectively. In Iran, construct validity and reliability of the PANAS were examined using exploratory factor analysis and principal components analysis. Two factors were extracted, accounting for 43.631% of the total variance, and internal consistency for the scale was 0.771. The PANAS has acceptable validity and reliability and is suitable for use in the Iranian population (Pasha Sharifi & Najafi Zand, 2012).

Cognitive Emotion Regulation Questionnaire (CERQ) (Garnefski & Kraaij, 2006): The *CERQ* was developed by Garnefski & Kraaij (2006). It is a multidimensional self-report instrument consisting of 36 items, with separate forms for adults and children. The CERQ assesses nine cognitive emotion regulation strategies: self-blame, acceptance, rumination, positive refocusing, refocusing on planning, positive reappraisal, putting into perspective, catastrophizing, and blaming others. In this questionnaire, respondents are asked to indicate how they typically think in response to threatening experiences or stressful life events they have recently encountered by answering items assessing emotion regulation strategies and cognitive processes. The CERQ uses a 5-point rating scale from "almost never" to "almost always." Each of the four items assesses one factor, resulting in nine factors overall: self-blame, other-blame, catastrophizing, rumination, refocusing on planning, acceptance, positive refocusing, and positive reappraisal (Sanagouye Moharer et al., 2020).

Binaural beat stimulation.

The binaural beat frequency used in this study was defined as the difference between the two carrier tones, set to 15 Hz in the beta range. A 240-Hz tone was presented to the right ear and a 255-Hz tone to the left ear, generated using G-Neural software and delivered via wireless headphones. Participants received stimulation 3 times per week, for 20 minutes per session, over a total intervention period of 4 weeks.

Procedure

The study was implemented as follows. After coordinating with the relevant treatment centers and obtaining the necessary permissions, individuals with a DSM-5 diagnosis of GAD aged 18 to 50 years who met the other inclusion criteria were identified. Among the clients of Behjou Clinic and its branches in Tehran, purposive sampling was used: volunteers who met the inclusion criteria and did not meet any exclusion criteria during the clinical interview and medical assessment were invited to participate.

After obtaining written informed consent, participants completed the study questionnaires—including the Spitzer GAD questionnaire, the PANAS, the Emotion Regulation Questionnaire, and other relevant instruments—in a safe and quiet setting in the presence of the researcher or a research assistant. Eligible individuals were then randomly assigned to experimental (receiving the intervention) and control groups, with the experimental group receiving binaural beat stimulation according to the predefined protocol and the control group receiving no intervention.

During the intervention sessions, participants' status was regularly monitored and documented; if participants met exclusion criteria, they were withdrawn from the study. After completion of the intervention sessions, all participants again completed the questionnaires. Three months later, the same questionnaires were administered as a follow-up. Data were then collected for statistical analysis. Ethical considerations such as confidentiality and the option for the control group to receive treatment after the study, upon request, were observed throughout, and all procedures complied with research ethics guidelines and were carried out with informed consent.

Data analysis

Data analysis was conducted using both descriptive and inferential statistics. Descriptive statistics (frequency, mean, and standard deviation) were used to describe the characteristics of the sample. For inferential statistics, after checking the assumptions of linearity, multicollinearity, homogeneity of variances, homogeneity of covariance matrices, homogeneity of regression slopes, and normality of variable distributions, a repeated-measures analysis of variance with Bonferroni post hoc tests was conducted. SPSS version 27 was used for data analysis. The significance level was set at $\alpha = 0.05$ and the effect size at 85%.

Ethical considerations

Observance of ethical principles constitutes an essential part of any research. In this study, all participants were assured that their personal information would remain confidential and would not be disclosed publicly. The study was conducted after obtaining written informed consent, and participants were informed about the nature and different stages of the research. Prior to data collection, ethical approval for the study was obtained with an ethics identification code, and all procedures were carried out in accordance with ethical standards and with respect for participants' autonomy and informed choice.

Findings and Results

The mean ± standard deviation of age in the binaural beat group was 38.5 ± 7.21 years, and in the control group, 38.0 ± 6.19 years. In terms of gender, the binaural beat group included 6 men (50%) and 6 women (50%), and the control group included 5 men (41.7%) and 7 women (58.3%). As indicated by the statistical tests (table not shown), there were no significant differences between the groups on demographic variables.

Table 1

Means and standard deviations of mood variables in the two groups at pretest, posttest, and follow-up

Variable	Group	Pretest M	Pretest SD	Posttest M	Posttest SD	Follow-up M	Follow-up SD
Positive affect	Binaural beat	20.7	2.73	32.4	1.62	31.1	1.33
	Control	23.08	3.84	23.5	3.42	23.2	3.25
Negative affect	Binaural beat	43.4	4.85	31.3	4.94	31.6	4.69
	Control	41.7	3.69	41.4	3.67	41.5	3.75
Adaptive emotion regulation	Binaural beat	24.3	1.23	30.08	0.996	29.4	1.24

	Control	23.0	1.34	24.3	1.96	23.8	1.69
Maladaptive emotion regulation	Binaural beat	49.0	3.10	48.5	3.08	50.9	4.20
	Control	50.5	3.91	49.0	3.78	49.4	4.31

To examine the normality of the variables and select appropriate statistical tests, the Shapiro–Wilk test was used (Table 2). As shown, for most subcomponents the significance level was greater than .05, indicating that the distributions did not deviate significantly from normality.

Table 2

Shapiro–Wilk test for normality

Variable	Group	Pretest W	Pretest p	Posttest W	Posttest p	Follow-up W	Follow-up p
Positive affect	Binaural beat	0.942	0.200	0.961	0.393	0.953	0.274
	Control	0.976	0.495	0.929	0.210	0.948	0.212
Negative affect	Binaural beat	0.977	0.813	0.961	0.432	0.897	0.190
	Control	0.966	0.799	0.979	0.507	0.931	0.298
Adaptive emotion regulation	Binaural beat	0.971	0.308	0.945	0.619	0.959	0.116
	Control	0.956	0.089	0.981	0.665	0.947	0.200
Maladaptive emotion regulation	Binaural beat	0.919	0.183	0.891	0.083	0.984	0.812
	Control	0.943	0.428	0.972	0.861	0.961	0.267

The significance level of the obtained F for the covariance matrix was less than .05, indicating that the assumption of homogeneity of covariance matrices was not met. However, given the equality of group sizes, this violation was considered acceptable. Because Mauchly's test of sphericity was not supported, the Greenhouse–Geisser correction was used in the repeated-measures ANOVA. With pretest scores controlled, Wilks' lambda was significant at the .01 level, indicating a significant difference between the experimental and control groups in the dependent variables. The partial eta-squared of .883 indicated that 88.3% of the joint variance in the dependent variables was attributable to group membership.

Table 3

Summary of simple ANOVA: within- and between-subjects effects for mood state

Source	Sum of Squares	df	Mean Square	F	p	η^2
Between-subjects						
Group	11307.2	1	11307.2	32.08	0.001	0.534
Error	1140.6	22	40.7			
Within-subjects						
Factor (time)	7352.06	1.52	4826.8	180.5	0.001	0.891
Factor × Group	1398.5	1.52	918.1	34.3	0.001	0.610
Error (factor)	895.8	33.5				

The Greenhouse–Geisser–corrected repeated-measures ANOVA showed that the main effect of time was significant at the .01 level (F = 180.5, p = .001), indicating significant differences in mood scores across pretest, posttest, and follow-up irrespective of group. The interaction between time and group was also significant (F = 34.3, p = .001), meaning that the pattern of change over time differed between the experimental and control groups. To determine between which measurement points these differences occurred, within-subject pairwise comparisons were conducted (Table 4).

Table 4

Within-subject contrast tests for mood state

Source	Pairwise comparison	Sum of Squares	df	Mean Square	F	p	η^2
Time (factor)	Pretest vs. posttest	5002.5	1	5002.5	234.5	0.001	0.914
	Posttest vs. follow-up	477.3	1	477.3	94.4	0.001	0.811

Time × Group	Pretest vs. posttest	650.01	1	650.01	30.4	0.001	0.581
	Posttest vs. follow-up	431.7	1	431.7	38.5	0.001	0.795
Error	Pretest vs. posttest	469.1	22	21.3			
	Posttest vs. follow-up	111.2	22	5.05			

As shown in Table 4, the main effect of time was significant for both the pretest–posttest (F = 234.5, p = .001) and posttest–follow-up (F = 94.4, p = .001) comparisons. The time × group interaction was also significant in both comparisons (pretest–posttest: F = 30.4, p = .001; posttest–follow-up: F = 38.5, p = .001). Comparison of means indicated that mood scores in the experimental (binaural beat) group improved from pretest to posttest relative to the control group, suggesting that binaural beat stimulation effectively enhanced mood. Furthermore, the significant time and time × group effects from posttest to follow-up mean that differences between groups remained significant over time; the experimental group maintained its gains, whereas the control group showed little change. Thus, binaural beat stimulation appears to have a lasting positive effect on mood state in individuals with GAD. ئA MANOVA was conducted to examine the simultaneous effect of the intervention on the multiple dependent variables.

Table 5

Multivariate tests (MANOVA) for the study groups

Effect	Test	Value	F	df1	df2	p	η^2
Group	Pillai's Trace	0.750	10.8	5	18	0.001	0.750
	Wilks' Lambda	0.250	10.8	5	18	0.001	0.750
	Hotelling's Trace	3.000	10.8	5	18	0.001	0.750
	Roy's Largest Root	3.000	10.8	5	18	0.001	0.750

With pretest scores controlled, Wilks' lambda was significant at the .01 level (Λ = 0.250, F(5,18) = 10.8, p = .001, η^2 = 0.750). In other words, there was a significant multivariate difference between the experimental and control groups across the dependent variables, and 75% of the combined variance of the dependent variables was attributable to group membership—a similar repeated-measures ANOVA was conducted for emotional self-regulation (adaptive and maladaptive strategies).

Table 6

Summary of simple ANOVA: within- and between-subjects effects for emotional self-regulation

Source	Sum of Squares	df	Mean Square	F	p	η^2
Between-subjects						
Group	309.1	1	309.1	11.6	0.003	0.346
Error	585.09	22	26.5			
Within-subjects						
Factor (time)	18785.8	1.94	9677.1	715.2	0.001	0.970
Factor × Group	799.4	1.94	411.8	30.4	0.001	0.580
Error (factor)	577.8	42.7	13.5			

The Greenhouse–Geisser–corrected ANOVA again showed a significant main effect of time (F = 715.2, p = .001), indicating significant changes in emotional self-regulation across pretest, posttest, and follow-up. The interaction between time and group was also significant (F = 30.4, p = .001), indicating different patterns of change between the experimental and control groups. Pairwise within-subject contrasts are presented in Table 7.

Table 7

Within-subject contrast tests for emotional self-regulation

Source	Pairwise comparison	Sum of Squares	df	Mean Square	F	p	η^2
Time (factor)	Pretest vs. posttest	12644.5	1	12644.5	831.8	0.001	0.974
	Posttest vs. follow-up	206.3	1	206.3	78.2	0.001	0.781
Time × Group	Pretest vs. posttest	570.5	1	570.5	37.5	0.001	0.630
	Posttest vs. follow-up	192.1	1	192.1	34.9	0.001	0.614
Error	Pretest vs. posttest	334.3	22	15.2			
	Posttest vs. follow-up	57.9	22	2.63			

As Table 7 shows, the main effect of time for both pretest–posttest (F = 831.8, p = .001) and posttest–follow-up (F = 78.2, p = .001) was significant. The interaction between time and group was also significant in both comparisons (pretest–posttest: F = 37.5, p = .001; posttest–follow-up: F = 34.9, p = .001). Mean comparisons indicated that emotional self-regulation scores in the experimental group improved from pretest to posttest relative to the control group, demonstrating that binaural beat stimulation effectively enhanced emotional self-regulation. Moreover, the significant differences between posttest and follow-up in the two groups indicated that the experimental group's improvements were maintained over time, whereas the control group showed little change.

Discussion and Conclusion

The results showed that binaural beat stimulation is effective in improving mood state in individuals with generalized anxiety disorder. This finding is consistent with the results of Garakani et al. (2020); Ingendoh et al. (2023); Leistiko et al. (2024); Opartpunyasarn et al. (2022); Sabet et al. (2023); Salemi & Sobhi (2024); Szeremeta et al. (2023) and Baseanu et al. (2024).

This result can be interpreted as follows: there are various methods for altering human brain waves. Some of these stimuli are color, sound, music, or human contact. One emerging technique is binaural beats. The binaural beat phenomenon shows that the brain perceives the difference between two tones presented separately to each ear. Binaural beats require that each ear hear a different tone. This type of rhythmic stimulation can change brain activity and mood and helps the listener relax. Since Oster (1973) first described the potential clinical value of binaural beats, reviews of studies using binaural beats as a therapeutic intervention for health and well-being have found evidence supporting their effectiveness for pain, cognition, and anxiety (Platt & Hammond, 2025). In addition, several clinical trials have reported reduced perioperative anxiety associated with exposure to binaural beats (Isik et al., 2017; Loong et al., 2022).

The findings also showed that binaural beat stimulation is effective in improving emotional self-regulation in individuals with generalized anxiety disorder. This result is likewise in line with the findings of Garakani et al. (2020); Ingendoh et al. (2023); Leistiko et al. (2024); Opartpunyasarn et al. (2022); Sabet et al. (2023); Salemi & Sobhi (2024); Szeremeta et al. (2023) and Baseanu et al. (2024).

In the present study, data were collected using questionnaires, and responses were self-reported. Therefore, the answers depended on participants' honesty and their self-evaluations. This method is inherently subject to limitations, including distraction, inattention, judgment errors, and misinterpretation of instructions, all of which may have influenced the results. Undoubtedly, intervening variables such as the influence of subcultures and social and economic conditions could also have affected the findings. The sample in this study consisted of individuals with anxiety who had been referred to Behjou Clinic in Tehran, which limits the generalizability of the results to other people and settings. Given that this was a cross-sectional study, longitudinal research is needed to obtain more comprehensive information in this area.

To strengthen future results, it is recommended that other data collection methods, such as interviews and observations, also be used. Future studies should take into account potential intervening variables such as the influence of subcultures and socio-economic conditions. It is further suggested that subsequent research include other age groups and samples drawn from different communities and social environments, and that longitudinal designs be employed. Finally, considering the importance of mental health and reducing the impact of anxiety, it is recommended that similar studies be carried out in universities, research centers, and clinical settings.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Declaration of Helsinki, which provides guidelines for ethical research involving human participants. Ethical considerations in this study were that participation was entirely optional.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contribute to this study.

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