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Effects of theta-binaural beats auditory stimulation on creativity, psychological well-being and mood states of university students: Pilot study

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Abstract

This study investigates the impact of theta-frequency binaural beats (BB) on creativity, mood, and psychological well-being in university students, addressing the growing interest and controversy surrounding this auditory stimulation technique. A quantitative, correlational, quasi-experimental design was employed, involving 26 university students aged 18–54 (96.2% female, 3.8% male). Participants listened to theta BB (6-Hz beat frequency on a 250 Hz carrier) for 20 minutes daily using the Binaural Beats App. Instruments included a sociodemographic questionnaire, the reduced Creative Personality Scale (EPC), the short Profile of Mood States Questionnaire (POMS), and the Psychological Well-Being Manifestation Scale (EMMBEP). Results revealed significant improvements in creativity, psychological well-being, and reduced total mood disturbance after exposure to theta BB. Significant differences in total mood disturbance across assessment moments highlighted the intervention's time-sensitive benefits. The study highlights the potential of theta-frequency BB to enhance psychological well-being, mood, and creativity among university students. These findings contribute to the growing body of evidence supporting the utility of BB as a non-invasive tool for improving mental and emotional states. Theta BB may serve as an accessible and cost-effective method for promoting mental health and fostering creativity in educational and therapeutic settings.

Keywords: Binaural beats, Theta frequency, Creativity, Educational approach, Mood states, Psychological well-being, University students.

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1. Introduction

Binaural beats (BB) are a type of auditory illusion that involves the presentation of two sound waves with very similar or slightly different frequencies, presented dichotomously in each ear separately [1, 2]. The brain perceives a single sound (if you hear only one frequency instead of two) that oscillates in the difference between the two tones, creating the phenomenon of the perception of a rhythmic beat (or double auditory illusion), both being lower than 1000 Hz and having a difference between them of less than 30 Hz [3]. For example, if an individual hears a 250 Hz sound in the left ear and a 256 Hz sound in the right ear through stereophonic headphones, the perception of the sound will be 253 Hz, i.e., the average frequency of both sounds heard, oscillating in amplitude at a frequency of 6 Hz, the difference between both frequencies. In recent years, the study of the potential benefits of auditory beat stimulation on brain states and behavior, including mood, relaxation, and creativity, has gained interest from the scientific community in various areas, such as Psychology, Education, and the Arts.

2. Literature Review

2.1. Benefits of Theta-Binaural Beats

Before we delve deeper into the benefits of Theta-BB, it is important to understand the relationship between brain waves and our mental states. The author Oster [3] in 1973 was a pioneer in studying BB and its effects on brain waves. Brain rhythms, also known as brain waves, are synchronized neural activities with variable amplitudes and frequencies, and in healthy adults, brain waves change depending on their state, whether awake or asleep. There are five main types of brain waves categorized by their frequency bands: delta, theta, alpha, beta, and gamma. These frequency bands range from low to high frequencies and are differentiated as 0.5-4 Hz (delta), 4-8 Hz (theta), 8-13 Hz (alpha), 13-30 Hz (beta), and >30 Hz (gamma). Delta waves occur mainly during deep sleep, severe brain disorders, and wakefulness. Alpha waves are mainly observed in the occipital lobe with eyes closed or in a relaxed state and are typically associated with intense mental activity, stress, and tension. Beta waves appear when the brain is more active and concentrated, or when the individual is engaged in solving problems or carrying out activities that require attention. Gamma waves are related to cognitive and motor functions. Finally, theta activity is associated with emotional stress, creative inspiration, hypnosis Siuly, et al. [4], and deep meditation [5]. When we experience theta waves, we often feel a sense of calm and tranquility, and it is easier for us to access our subconscious [6].

In this sense, and with regard to theta-BB, some studies have found that the most significant benefits are their ability to promote positive emotional experiences Aftanas and Golocheikine [7] to reduce stress Gantt, et al. [8] as well as inducing a meditative state or reducing alertnessJirakittayakorn and Wongsawat [1] and relaxation [9]. Other potential benefits of theta-BB are improving sleep quality Lee, et al. [10] and relieving insomnia or inducing drowsiness [11, 12]. Regarding cognitive performance, such as memory and attention, recent studies reveal some controversy regarding the effectiveness of theta-BB and beta-BB in these cognitive processes [13-16]. While other studies highlight the concrete benefits of auditory beat stimulation theta on verbal memory [17]. These inconsistencies in results require further investigation. Although the mechanisms underlying the neurophysiological processes of BB are known in current scientific literatureSchwarz and Taylor [18] an answer has not yet been clearly presented, whether binaural auditory stimulation generates a frequency following the response of the presented frequencies, or whether evokes different responses in the brain [19]. Despite these doubts, it appears that the induction of these non-invasive and easily administered auditory stimuli can modulate behavior and cognitive processing, by altering functional connectivity patterns between brain regions or networks, and through the synchronization of neural activity [20, 21]. Overall, research on BB suggests their potential for therapeutic applications for a variety of conditions and real-world contexts.

2.2. Effects of Using BB on Creativity, Mood States and Psychological Well-Being

Auditory beat stimulation has been gaining attention from the scientific community as a potential instrument to improve creativity, psychological well-being, and mood states. It is now important to understand whether BB in general and theta-BB in particular have any influence on these variables.

Creativity is a cognitive process or the ability to generate new ideas or useful solutions for solving problems Wiseman, et al. [22] which involves the combination of convergent thinking (the ability to evaluate and select the best solution/idea for a problem) and divergent thinking (the ability to generate multiple solutions/ideas for a problem). Creative thinking, or critical thinking, is fundamental in multiple domains, including in business, in the technological context, in education and learning, in professional performance, in science, in the arts and in society [23-25] . With regard to university students, Wang and colleagues Wang, et al. [26] suggest that the Extraversion and Perceiving personality type is positively associated with academic creativity. Furthermore, it appears that individuals who possess creativity tend to exhibit certain cognitive abilities, which include, for example, being highly observant, having high intellectual abilities and an excellent memory (to store and compare multiple ideas), having a unique perspective on a given problem, are independent in their opinions, work tirelessly to acquire new knowledge and exhibit greater emotional intelligence or emotionality [27].

With the aim of evaluating the impact of BB on creative performance, and how these auditory stimuli would have an effect on convergent and divergent thinking, Reedijk, et al. [28] and collaborators Reedijk, et al. [28] developed a study in which 24 university students were asked to attend three sessions with different conditions. In the first session they were exposed to a binaural alpha auditory stimulus (10 Hz), in the second to binaural gamma stimuli (40 Hz), and in the last, the control condition, participants were asked to listen to a constant sound (340 Hz). Before completing the two tasks proposed in the experiment, convergent and divergent thinking, participants listened to the BB for 3 minutes. The results showed that BB had an impact on divergent thinking, as opposed to convergent thinking, regardless of the frequency presented, perhaps due to the short duration of exposure to BB (3 minutes). However, no studies were found on the influence of theta-BB on creativity. We point out some possible reasons: because there is no coherence in a single definition of creativity; due to the possible existence of other cognitive processes involved, in addition to divergent and convergent thinking Reedijk, et al. [28] or because the underlying neural mechanisms of creative thinking are not fully understood [29].

Although the mechanisms through which theta-BB can influence people's creativity need to be studied, we put forward the hypothesis that this type of auditory stimulation at the theta frequency induces a state of relaxation and increases concentration, allowing individuals to have a greater flow of ideas and inevitably influence their creativity [24]. Additionally, the study by Müller and collaborators (Müller, et al. [30]) demonstrated that creativity can be improved after engaging in meditation sessions. Since this technique involves concentration on breathing and awareness of one's emotions and the environment, it is plausible that similar results can be achieved with theta-BB if the listener is properly concentrated and aware of its presence. Another hypothesis is that theta-BB influences the synchronization of neural activity, leading to greater communication between brain regions, facilitating the integration of new information and the creation of ideas.

Regarding the relationship between creativity and mood, results from meta-analysis studies show that positive mood states linked to a promotion motivation approach (e.g. happiness) increase creativity, unlike negative moods (e.g. sadness) and of mood states associated with an avoidance motivation approach (e.g. fear and anxiety) that exhibit a negative correlation with creativity [31, 32].

One's mood can be described as existing on a spectrum that extends from positive and pleasant emotional states to negative and unpleasant emotional states [33]. Furthermore, as suggested by Kuang and colleagues (Kuang, et al. [34]), positive emotional contagion increases positive mood and decreases negative mood. These transient and fluctuating characteristics of mood states reflect how individuals feel at a given moment. In the case of university students, they face several mental health problems, and mood disorders are just one of them [35].

Based on the assumption that anxiety is one of the mood state dimensions of the POMS (Profile of Mood States Questionnaire, Viana, et al. [36]), some studies have evaluated the effects of binaural beats (BB) on this same dimension. For example, randomized experimental studies report the benefits of this type of auditory stimulation at the delta frequency in reducing pre-surgical anxiety (Padmanabhan, et al. [37]) and at the alpha frequency (10 Hz) during surgery, including the reduction of heart rate [38]. These results are consistent with those of the study by Le Scouranec, et al. [39], who, for one month and five times a week (approximately 30 minutes per session), tested 15 people with mild anxiety using BB at the delta/theta frequency. The results of the pre- and post-test assessments indicated a significant reduction in participants' anxiety. Studies by authors Wahbeh and collaborators (Wahbeh, et al. [40]) can also confirm that BB technology has an effect on psychological measures of anxiety. The same authors conducted two studies to investigate the impact of BB on theta (7 Hz) and delta (0–4 Hz) frequencies on mood. One study exposed participants to delta-frequency BB daily for 60 days, while the other study presented theta-BB for 30 minutes. The researchers used the POMS as a measure of changes in mood states before and after auditory stimulation. The results showed that delta-BB stimulation led to a reduction in total mood disturbance, as well as a decrease in tension, anxiety, confusion, and fatigue, but an increase in depression and vigor. On the other hand, theta-BB stimulation caused an increase in the POMS depression subscale in the experimental group compared to the control group after 30 minutes of auditory stimulation. In turn, Lane and colleagues (Lane, et al. [41]) conducted a study to examine the effects of BB on vigilance tasks and mood by comparing beta and theta/delta frequencies. A total of 29 participants completed a 30-minute visual vigilance task over three days while listening to single-tone pink noise, BB at the beta frequency (16 and 24 Hz), or theta/delta frequency (1.5 and 4 Hz). The results showed that beta-BB stimulation favored greater accuracy in detecting correct targets and fewer false alarms compared to theta/delta frequency BB. Additionally, beta-BBs have been found to have a more positive impact on mood (assessed by POMS).

Very recently, Mallik and Russo [42] developed a randomized experimental study, with the purpose of evaluating the potential of combining calm music with theta-BB (4-7Hz) in reducing anxiety. A total of 163 participants taking anxiolytics were randomly divided into four groups namely, (1) which included a combination of music and theta-BB, (2) music only, (3) theta-BB only, (4) or pink noise. (control group). The results showed that, for participants with moderate anxiety, in the music and theta-BB combination conditions, and music alone, there was a greater reduction in somatic anxiety than in the pink noise condition. In turn, the reduction in cognitive anxiety was more evident in the music and theta-BB combination condition, than in the conditions without combinations (music only, theta-BB only, pink noise). Thus, these authors concluded that the combination of calm music with theta-BB can reduce anxiety.

In summary, there is little evidence on the effects of theta-BB on other mood states including anxiety, assessed by the POMS. Furthermore, the effects of theta-BB on the mood states of university students remain unknown, specifically, the duration of the effects, the total duration of each session and the total duration of the intervention. Still, given the relaxation characteristics induced by the theta frequency, we speculate that this type of auditory stimulation may reinforce or increase positive mood Razali, et al. [43] and have an influence on the mood states of university students. For example, McConnell, et al. [9] and colleagues McConnell, et al. [9] carried out an experimental study with 21 university students, with the aim of evaluating the effects of theta-BB on heart rate variability during post-exercise relaxation, that is, study participants first they exercised for 20 minutes and post-exercise, they heard BB at a theta frequency; while the placebo group listened to pink noise without BB for 20 minutes, in a silent environment with low light. Compared to the placebo group, the group in the experimental condition that benefited from theta-BB auditory stimulation reported greater perceived relaxation after exercise.

In addition to positive mood states, it appears that psychological well-being is also related to creativity [44]. In turn, individuals with higher levels of creativity reported greater satisfaction with life Fiori, et al. [45], i.e., creativity has a positive relationship with subjective well-being [46].

The author Huppert [47] states that psychological well-being is both related to positive emotions (e.g. happiness, interest, affection) and negative emotions (e.g. sadness, failure) that are part of a person's normal life. Although individuals are not expected to constantly experience positive emotions, psychological well-being is also related to living a satisfying life, feeling good, and functioning effectively. When negative emotions are experienced in an exaggerated and prolonged way, they can compromise your psychological well-being. Ryff [48] adds six central dimensions and components of well-being, namely self-acceptance, positive relationships with others, autonomy, mastery of the context, life goals and personal growth.

In the case of university students, they face a series of challenges throughout their academic career that can affect their psychological well-being, namely anxiety, anguish, stress, depression Bewick, et al. [49]; Liu, et al. [50] and Morales-Rodríguez, et al. [51] financial problems Ludban [52] among others. This means that universities need to recognize the vulnerabilities of their students in terms of psychological health problems or reduced psychological well-being, providing psychological treatment alternatives. Digital psychological interventions are a promising tool for psychological well-being in this population, but their effectiveness and validity inevitably need to be tested Ferrari, et al. [53] as is the case with BB. Despite the scarcity of studies that relate theta-BB or BB with improved psychological well-being, and similar to mood states, we propose that the meditative and relaxing characteristics arising from theta waves have an influence on this variable in university students.

Given the discrepancy between some studies on the effectiveness of theta-binaural beats on creativity, mood, and psychological well-being, additional studies must be carried out to allow a better understanding of the effects of this technology and to design new and effective applications. The present investigation, therefore, aims to provide an overview of the potential benefits of theta-binaural beat auditory stimulation.

The main objective of this study is to investigate how binaural beats at theta frequency can be used to improve creativity, reduce overall mood disturbance, and increase psychological well-being. Regarding the specific objectives, the aim is to: (1) characterize the sample under study in terms of gender, age, and year of school attended; (2) analyze the relationship between theta-binaural beats auditory stimulation and the improvement of psychological well-being and mood states of university students; (3) understand the effects of theta-binaural beats auditory stimulation on the creativity of university students.

Regarding the possible contributions of this research, the analysis of the effects of theta-BB on creativity, mood states, and psychological well-being in university students appears to be an innovative aspect, as the research analyzed tends to focus only on one of these variables within the same population. Furthermore, understanding how this easily available, free, and downloadable technology for mobile phones can be applied in the university or educational context, and its contribution as a promising tool for psychological intervention, aims to improve the cognitive and emotional functioning of these individuals.

3. Methodology

3.1. Kind of Study

This is a pilot study, quantitative, correlational in nature, with a quasi-experimental design.

3.2. Participants and Sampling Techniques

The sample collected in this study is convenience-based. Twenty-six university students, aged between 18 and 54 (M = 21.42, SD = 8.91), included 25 (96.2%) female and 1 (3.8%) male. These students attended the TAP (Theatre and Performing Arts - UC Music for Theater and Cinema) and LLC (Languages, Literatures and Cultures - UC Cultura Teatral) classes at a university in the North of Portugal. The majority attended the 1st year of the degree (n = 24, 92.3%), while only 2 (7.7%) attended the 2nd year of the degree.

Inclusion criteria are: age greater than or equal to 18 years old up to 55 years old; know how to read and write in Portuguese; have access to an electronic device to fill out the assessment questionnaires online and to install the Binaural Beats – study music App; have stereo headphones; who voluntarily agreed to participate in the investigation; and be able to give their consent. Once data collection is complete, incomplete forms, dropouts or participants who do not meet the defined inclusion criteria will be automatically excluded.

3.3. Tools

Data were collected through a sociodemographic questionnaire, the reduced form of the Creative Personality Scale (EPC), the reduced version of the Profile of Mood States Questionnaire (POMS), and the Psychological Well-being Manifestation Measurement Scale (EMMBEP).

As for the reduced form of the Creative Personality Scale (EPC), by Pocinho, et al. [54] containing 9 items and to be used in the present study, it was developed based on its long version by Garcês, et al. [55] consisting of 30 items. It is a self-response questionnaire whose respondents are invited to indicate the degree to which they agree or disagree with each of the following statements: 1. I appreciate new ideas; 2. I like to question and make suggestions; 3. I am open to receiving new ideas; 4. I discover problems in my surroundings and ideas come to mind to resolve them; 5. When I fail, I don't give up and continue to try new solutions; 6. I enjoy solving problems in an unusual way; 7. I enjoy activities that allow me to have lots of ideas; 8. I love perfecting my ideas until they are well defined; 9.I can find several solutions to the same problem.

Participants in this study gave their response using the following 5-point Likert scale: “1-Strongly Disagree”; “2- I disagree a little”; “3- I neither disagree nor agree”; “4- Moderately Agree”; “5- Totally Agree”.

The total score on the scale varies between 9 and 45. The rating is made by adding up the points attributed to each item and interpreted according to three ranges: from 9 to 34 the subject presents “Little Creativity”, between 35 and 40, “Average Creativity” and from 41 to 45 “Much/High Creativity”. The average score is 36.38 (SD = 5.11), indicating “Average Creativity”. According to Pocinho, et al. [54] the scale presents good psychometric characteristics for the 9 items, with good internal consistency (Cronbach's alpha of .86). In the present study, the scale revealed good internal consistency in the two assessments carried out, with a Cronbach's alpha value of .87 and .91 for the first and second assessment, respectively.

In the shortened version of the Profile of Mood States Questionnaire (POMS) by McNair, et al. [56] adapted to the Portuguese population by Viana, et al. [36] answers are given according to a 5-point Likert scale (0=Not at all; 1=A little; 2=Moderately; 3=Quite a lot; 4=Very much). In the response instructions, the participant was asked to say how they felt over a certain period of time. This period usually corresponds to one day or one week. To carry out the present study, participants were asked to evaluate their mood states in the last week, but once a week, over the course of 4 weeks (1 month).

The reduced version of the POMS consists of 36 items, with a total of 6 items for each of the six scales – Tension, Depression, Hostility, Vigor, Fatigue, and Confusion. More specifically, the Tension-anxiety dimension or factor (T) is composed of adjectives that describe increases in musculoskeletal tension and worry: tense, restless, nervous, anxious, calm, and impatient. The Depression-melancholy dimension or factor (D) represents an emotional state of discouragement, sadness, unhappiness, and loneliness, and is composed of the following adjectives: sad, discouraged, alone, downcast (depressed), and unhappy. The dimension or factor Hostility-anger (H) corresponds to a mood state of anger and antipathy towards others and is composed of the adjectives: irritated, bad-tempered (grumpy), annoyed, furious, and enervated. The Fatigue-inertia dimension or factor (F) represents a state of tiredness, inertia, and low energy and is composed of the adjectives: exhausted, fatigued, without energy, and tired. The dimension or factor Confusion-disorientation (C) is characterized by a state of confusion and low lucidity and is composed of the adjectives: confused, bewildered, effective, competent, and insecure. The Vigor-activity dimension or factor (V) is related to a state of energy and physical and psychological vigor and is composed of the following adjectives: lively, active, energetic, full of life, full of good humor, and cheerful. The total result (Total mood disturbance-PTH) is obtained by adding the five subscales with a negative sign (T+D+H+F+C) and subtracting the result from the Vigor scale, and adding 100. The following formula is used: PTH = [(T+D+H+F+C) - Vigor] + 100.

High PTH scores indicate a worsening of mood and, on the contrary, a low score indicates an improvement in mood. All items are rated in the same direction, with the exception of one item on the Tension scale (Calm) and two items on the Confusion scale (Effective and Competent), for which the response to the item must be reversed. In the present study, the total scale showed good internal consistency in the two assessments carried out, with a Cronbach's alpha value of .93 and .92 for the first and second assessment, respectively.

To complete the Measure of Manifestation of Psychological Well-being (EMMBEP), adapted to the Portuguese population by Monteiro and collaborators (Monteiro, et al. [57]), participants were asked to respond taking into account the last month. This scale consists of 25 items, divided into 6 subscales, namely: self-esteem (4 items), "I felt that others liked and appreciated me"; balance (4 items), "My life was well balanced between my family, personal, and academic activities"; social involvement (4 items), "I had goals and ambitions"; sociability (4 items), "I related easily to the people around me"; control of oneself and events (4 items), "I was able to face difficult situations in a positive way"; and happiness (5 items), "I felt good, at peace with myself." The higher the value achieved through the combination of all the items that constitute it, the higher the perceived psychological well-being. The questions are associated with a 5-point Likert scale, where 1 corresponds to "Never" and 5 to "Almost always." The total scale score varies between 0 and 125, the corrected item-total correlation varies from .36 to .78, and there is homogeneity between the items that are part of the scale. Most of the Cronbach's alpha values obtained are appropriate, ranging between .67 (social involvement) and .89 (happiness). In the present study, the total scale revealed good internal consistency in the two assessments carried out, with a Cronbach's alpha value of .97 and .96 for the first and second assessments, respectively.

3.4. Procedure

The original authors of the Psychological Wellbeing Manifestation Measurement Scale (EMMBEP), the reduced version of the Profile of Mood States Questionnaire (POMS) and the Creative Personality Scale (EPC) were contacted via email, in order to give authorization to use the same instruments in the present study.

After authorization from the authors and after the favorable opinion of the Ethics Committee of the University of Trás-os-Montes and Alto Douro (Ref. Doc28-CE-UTAD-2023), the instruments were made available in full on Google Forms, and the link corresponding to this file was subsequently shared with study participants. Participants were required to complete the Informed Consent, in which the main objectives of the investigation were described, as well as the guarantee of anonymity, as no identifying data from the participants were requested. The responses were encrypted, and only the responsible researcher had access to them, with the commitment to destroy them five years after the study was completed. In addition, the email address of the responsible researcher was available for any clarifications, questions, or requests for additional information about the study. Participants were also informed that the data collected was for exclusive use for research and that it was not permitted to be published or disseminated in any other way. Data collection was carried out between April (pre-test) and July (post-test) 2023, and March (pre-test) and May (post-test) 2024, which was conducted online via the Google Forms platform. Completing the protocol took approximately 10 minutes for each participant. In order to maintain the anonymity and confidentiality of the participants, each one was assigned a five-digit code. It is pertinent to highlight that no rewards were offered for participation in the study.

In terms of study procedure, firstly (pre-test phase), each participant was then asked to complete the sociodemographic questionnaire, the EMMBEP, the POMS and the EPC, giving their informed consent to participate in the study. Secondly, participants were instructed that every day after class, they would listen to theta-binaural beats (6-Hz beat frequency on 250 Hz carrier frequency in both ears - Figure 1) with their stereo headphones for 20 minutes. After installing the App on their cell phone Binaural Beats – study music available on Google Play, we explained to the students how they should program theta-binaural beats (6-Hz beat frequency on 250 Hz carrier frequency) on the App and, later, they were invited to comfortably listen to the music, reducing the volume to a comfortable level so as not to disturb them. Finally, participants were instructed to complete the POMS questionnaire once a week, always at the end of the week (on Friday), for a total of four times. For the purposes of carrying out the post-test, the same assessment procedures designed for the pre-test were followed.

Figure 1.
Theta-BB de 6 Hz on 250 Hz carrier frequency. Image from freepik: https://www.freepik.com/free-vector/man-with-headphones-silhouette_720852.htm#query=headset%20free&position=32&from_view=search&track=robertav1_2_sidr. For commercial and personal projects.

3.5. Data Analysis

Data processing will be carried out using the IBM SPSS Statistics 28 software. The normality of the distribution of quantitative variables was analyzed through the values of asymmetry, kurtosis, and the results of the Shapiro-Wilk test. Not all variables had a normal distribution, so parametric statistics were used when applicable, and non-parametric statistics otherwise.

For descriptive analysis, absolute (n) and relative (%) frequencies are presented for qualitative variables, and mean (M) and standard deviation (SD) or median (Mdn) and interquartile range (IQR) for quantitative variables, depending on whether normality was fulfilled or not, respectively.

To analyze differences between two moments, pre- and post-test, in relation to quantitative variables with normal distribution, the t-test for paired samples was used, calculating Cohen's d as a measure of effect size. For quantitative variables that did not meet normality and for ordinal qualitative variables, the Wilcoxon test was used to carry out this analysis, with r being presented as a measure of effect size.

To analyze differences between more than two moments in relation to quantitative variables, if the assumption of normality of distribution was not met, the Friedman test was used, followed by pairwise comparisons, with Bonferroni correction, to identify significant differences. As a measure of effect size, Kendall's W was used.

In all tests performed, results with p less than .05 are considered statistically significant, for a confidence level of 95%.

4. Results

4.1. Differences Between Pre- and Post-Test in Well-Being (EMMBEP), Mood State (POMS) and Creativity (EPC)

Table 1 presents the results of the analysis of differences between the pre- and post-test in terms of well-being. There is a statistically significant difference (p = .002), with an increase in scores from pre- to post-test.

Table 1.
Differences between the pre- and post-test in terms of well-being (N = 26).

	Pre ***M* (*DP*)**	**Post** ***M* (*DP*)**	***t*(25)**	***p***	***d***
EMMBEP	85.04 (17.33)	93.69 (15.37)	-3.39	0.002	0.50

Regarding creativity (Table 2), there is also a statistically significant difference between the pre- and post-test (p = .011). Although the medians do not reflect this difference, the test results point to an increase in the level of creativity from pre- to post-test.

Table 2.
Differences between the pre- and post-test in terms of creativity (N = 26).

	Pre ***Mdn* (*AIQ*)**	**Post** ***Mdn* (*AIQ*)**	***Z***	***p***	***r***
EPC	2.00 (1.00)	2.00 (2.00)	-2.53	0.011	-0.35

Table 3 presents the results of the analysis of differences between the pre- and post-test in terms of mood states. A statistically significant difference was found between pre- and post-test (p = .001), observing a decrease in scores from pre- to post-test.

Table 3.
Differences between the pre- and post-test in terms of mood states (N = 26).

	Pre ***Mdn* (*AIQ*)**	**Post** ***Mdn* (*AIQ*)**	***Z***	***p***	***r***
POMS	126.00 (32.50)	99.00 (34.75)	-3.20	0.001	-0.44

4.2. Differences in Mood States Over the Weeks of Using Binaural Beats

Table 4 presents the results of the analysis of differences between the various assessments of mood states, pre- and post-test, and intermediate assessments. There are statistically significant differences between the assessments (p < .001). Pairwise comparisons with Bonferroni correction indicate a statistically significant decrease between the post-test and pre-test, and the first (T1) interim assessment (p < .001 and p = .009, respectively), as well as between the pre-test and the second (T2) and third (T3) intermediate assessments (p = .009 and p = .001, respectively).

Table 4.
Differences in mood states between pre-, post-test and intermediate assessments (N = 26).

	Pre ***Mdn* (*AIQ*)**	**T1** **Mdn (AIQ)**	**T2** **Mdn (AIQ)**	**T3** **Mdn (AIQ)**	**Post** ***Mdn* (*AIQ*)**	X^2	***p***	***W***
POMS	126.00 (32.50)	111.50 (30.50)	104.50 (24.50)	99.00 (30.50)	99.00 (34.75)	31.15	< 0.001	0.30

5. Discussion

The main objective of this pilot study was to investigate the relationship between theta-binaural beats (BB) auditory stimulation and the improvement of creativity, psychological well-being, and mood states of university students. Our significant findings on the relationship between theta-BB auditory stimulation and increased psychological well-being, as well as decreased negative mood states, corroborate the results of other studies. For example, studies by Le Scouranec, et al. [39] and Wahbeh, et al. [40] confirm the effects/impact of BB on theta frequency in significantly reducing anxiety. Research by Mallik and Russo [42] also confirms the reduction in moderate anxiety when calm music is combined with theta-BB. Despite little evidence on the effects of theta-BB and the duration of these effects on other mood states, including anxiety, assessed by POMS, in the university population, our results are encouraging, as we speculate that auditory theta-BB

stimulation may reinforce or increase positive mood, as suggested by Razali, et al. [43] and by McConnell, et al. [9] given the effects of greater relaxation after exposure to theta-BB. We assume that the meditative and relaxing characteristics of theta waves positively influence the psychological well-being and mood of university students.

Our results also indicate a significant increase in creativity with theta-BB auditory stimulation. However, we did not find previous studies investigating the influence of theta-BB on creativity. Possible reasons for this include the lack of a consistent definition of creativity, the presence of cognitive processes other than divergent and convergent thinking, and the lack of understanding of the neural mechanisms underlying creative thinking [28, 29]. It seems that the state of relaxation/meditation Müller, et al. [30] induced by theta-BB auditory stimulation increases concentration on breathing, which in turn influences the synchronization of neural activity, improving communication between brain regions and facilitating the integration of new information, allowing a greater flow of ideas and, consequently, influencing creativity [24]. Given the discrepancy between some studies on the effectiveness of theta-BB (compared to other frequencies, e.g. delta) on creativity, mood, and psychological well-being, additional studies are needed to better understand the benefits of these digital applications in the university population.

6. Conclusion

In general, the results of this study suggest that auditory stimulation at the theta frequency (6-Hz beat frequency on a 250 Hz carrier frequency in both ears), through the Binaural Beats study music app, may have potential health benefits for psychological well-being, including the promotion of positive mood states and the reinforcement of creativity. It can be used in university or educational contexts. Although promising results have been recorded on the effects of theta-BB, more research is needed to fully understand the mechanisms of action and the potential of this widely available, free, and downloadable tool for mobile phones, as well as to investigate its effectiveness in different populations and contexts.

7. Limitations

The present investigation is not without limitations, and it is important not only to mention them but also to leave some indications for future studies regarding this topic. Some of the limitations are related to the fact that it was a study carried out over a month; it would be important in the future to conduct a longitudinal study in order to understand the effects of BB in the long term. The sample size is another limitation and is also one of the limitations commonly highlighted in the literature on this topic. Therefore, it would be relevant in the future to counter this trend by conducting a randomized experimental study with a heterogeneous sample made up of female and male university students, with the aim of achieving more robust results. We know that the effects of auditory stimulation can vary depending on individual differences in brain rhythms; therefore, the optimal parameters for BB stimulation at theta frequency and the potential moderators of the effects should be considered in future investigations. More research is also needed to understand the duration (in minutes), the ideal intensity, and frequency of theta-BB in the variables tested and possibly in others (e.g., anxiety and stress) and using other neurophysiological measures such as EEG. Therefore, more studies are needed to investigate the potential effects of theta-BB compared to other frequencies (e.g., beta and delta) on the creativity, mood states, and psychological well-being of university students, using more rigorous methodological approaches.

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