Effectiveness of Binaural Beats in Music from The TENG Ensemble in Relieving Stress in Singapore University Students: A Randomized Controlled Trial

Final Report

The TENG Ensemble
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Author Contributions

Peter Kay Chai TAY was the Principal Investigator (PI) of the study. Student researchers, Jia Lin Cherie CHIA, Yeow Hing Bradley LAM, Soo Inn Fidessa NG, and Chu Hui PANG were the co-Investigators (co-Is) and contributed to the development of the questionnaire, collected data, and wrote the initial drafts of this report.

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Executive Summary

Binaural beats therapy is an emerging form of sound wave therapy with a range of reported psychological benefits. In the current study, musicians from the TENG Ensemble produced a novel audio track by incorporating a dynamic progression of binaural beats from theta to delta waves in instrumental music and the researchers investigated the effect of this music on psychological stress and physiological arousal. We predicted that listening to TENG music with binaural beats leads to beneficial psychological and physiological changes compared to listening to the same piece of music without binaural beats or an audiobook.

One hundred and fifty-one university students participated in the study and were randomized to listen to TENG music with binaural beats (n=52), TENG music without binaural beats (n=52), or audiobook (n=47) for thirty minutes. Of which, thirty-two participants underwent physiologic measurement; they listened to TENG music with binaural beats (n=10), TENG music without binaural beats (n=12), or an audiobook (n=10). All participants answered sociodemographic and psychologic questions before and after listening to the soundtracks.

The current study revealed that participants who listened to TENG music with binaural beats reported lower state-anxiety compared to those who listened to the audiobook. Further analyses on a segment of the sample revealed that these observations may be specific to participants who reported the highest state anxiety at the beginning of the session. Similarly for physiological measurement, increased arousal as indicated by skin conductance and greater heart rate variability was observed among high state anxiety participants when they listened to TENG music with binaural beats. This pattern was also observed among participants who reported low positive affect before listening to the soundtracks. One caveat being that the sample sizes for the physiological data were small. In addition, we found that participants who listened to TENG music with binaural beats reported that they were more likely to listen to Chinese music to relieve stress related to studying compared to those who listened to TENG music without binaural beats, and several participants indicated that the headphones were uncomfortable.

Taken together, the current study suggests that TENG music with binaural beats may have some anxiolytic effect in terms of lowering subjective perception of anxiety and stimulating physiological changes as indicated by skin conductance reactivity at least among individuals who initially experienced high levels of state anxiety. In addition, experience associated with listening to binaural beats music could potentially be enhanced by using headphones that are more comfortable (e.g., less bulky) and listening to binaural beats music in an environment that facilitates the lowering of anxiety while heightening positive affect.

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Background

Binaural Beats Therapy

Binaural beats therapy is an emerging form of sound wave therapy (Chaieb, Wilpert, Reber, & Fell, 2015). Two tones with different frequencies are presented separately to each ear but the brain perceives these tones as a single tone, known as binaural beats (BB). BB frequency is the difference between frequencies of the two presented tones (Draganova, Ross, Wollbrink, & Pantev, 2007; Wiwatwongwana et al., 2016). Thus, when tones of 410Hz and 400Hz are presented to the left and right ear respectively, a 10Hz BB is perceived (Wahbeh, Calabrese, & Zwickey, 2007). If this tone is sustained, it influences the brain via brainwave entrainment (Wiwatwongwana et al., 2016), which produces a brainwave response corresponding to the stimuli frequency (Huang & Charyton, 2008). BB frequency can be selected to produce a particular electroencephalogram-associated state (Wiwatwongwana et al., 2016), eliciting its associated effects (Table 1) (Puzi, Jailani, Norhazman, & Zaini, 2013). Brainwave types and associating emotional and behavioral effects in italics indicates brainwaves incorporated in the current study.

Table 1. Brainwave types and associating effects

Brainwave Type	**Associating emotional and behavioral effects**
Beta (15Hz – 30Hz)	Awake, normal alert consciousness
Alpha (9Hz – 14Hz)	Relax, calm, meditation, creative visualization
Theta (4Hz – 8Hz)	*Deep relaxation and meditation, problem solving*
Delta (1hz – 3Hz)	*Deep, dreamless sleep*

Note: Italics indicates brainwaves incorporated in the current study.

Binaural Beats Effect on Anxiety, Affect, and Memory

In the current study, anxiety is operationalized as the experience of physiological and psychological responses to one's perception of having inadequate resources to meet situational demands effectively, where physiological changes include increased heart rate and arousal while psychological changes include perceived stress and anxiety (Lazarus, 1966).

Existing studies demonstrated that binaural beats (BB) may reduce stress and anxiety in participants (Gantt, Dadds, Burns, Glaser, & Moore, 2017; Gkolias et al., 2020; Isik, Esen, Büyükerkmen, Kilinç, & Menziletoglu, 2017; Parodi et al., 2021; Wahbeh et al., 2007). Music embedded with BB significantly reduced post-employment chronic stress in military service members over four weeks (Gantt et al., 2017). Gkolias and colleagues (2020) also found a significant reduction in perceived stress at 30 minutes with the effects lasting a week. Furthermore, studies suggested that BB exposure can significantly reduce preoperative anxiety in those undergoing elective caesarean section (Parodi et al., 2021) and dental surgery (Isik et al., 2017). Healthy participants also showed reduced anxiety following exposure to BB sounds for sixty days (Wahbeh et al., 2007).

BB has also demonstrated effects on working memory, long-term and verbal memory (Beauchene, Abaid, Moran, Diana, & Leonessa, 2017; Derner, Chaieb, Surges, Staresina, & Fell, 2018; Garcia-Argibay, Santed, & Reales, 2019). For instance, beta-frequency BB facilitated correct recall for words (Garcia-Argibay et al., 2019). Given that the theta and delta brainwave states promote relaxation but attenuates verbal memory performance (Garcia-Argibay et al., 2019), we aim to investigate its effect on false memory (i.e., recalling a word that is related to a word list but did not appear on the list) and the number of words recalled using the Roediger and McDermott (1995) paradigm.

Significance of Current Research

To date, no studies have investigated the effects of BB in reducing stress, enhancing affective state, or examined verbal memory (including false memory) in Singapore university students. Organization for Economic Cooperation and Development reported that Singapore university students suffer from high stress levels (Davie, 2017). Furthermore, the students encounter stressful events like challenging school projects and higher education examinations (Asif, Mudassar, Shahzad, Raouf, & Pervaiz, 2020). High stress levels among students can negatively impact their academic performance, physical and mental health (Maajida Aafreen, Vishnu Priya, & Gayathri, 2018). Hence, investigating BB effects on relieving stress and enhancing affective state among Singapore university students and the subsequent influence on students' perception of academic performance and student role competency was of interest in the current research.

BB has been administered over varied media including soft meditative music (Gkolias et al., 2020), instrumental music (Le Scouranec, Poirier, Owens, & Gauthier, 2001), pink noise overlay (Wahbeh et al., 2007) or no background sound (Isik et al., 2017). However, BB has yet to be incorporated into Chinese instrumental music. As Singapore is a multi-racial country with 74.3% of the population being Chinese (Department of Statistics Singapore, 2020), Chinese instrumental music is a suitable BB medium.

Based on these knowledge gaps, the current research aimed to investigate the effectiveness of incorporating BB in Chinese music to relieve anxiety and its impact on verbal memory (including false memory) among Singapore university students. BB frequencies of the theta and delta types were incorporated because these tones are associated with relaxation and positive affective states.

Methods and Materials

A double-blind randomized control trial (RCT) involving an intervention group (TENG music with BB), a placebo control group (TENG music without BB) and an active control group (audiobook) was implemented.

Research Participants

One-hundred and fifty-one university students were recruited by email mailers in their student emails and signed informed consent approved by the Institutional Review Board at the Singapore Institute of Technology (SIT). Participants (and co-investigators) were blinded to the true nature of the study; they were told that the study aimed to explore "emerging relaxation techniques on reducing stress in university students" and they would be "randomized to listen to one of three audio files."

All RCT sessions were held at SIT@Dover. Session allocation was based on the randomized grouping. All participants (n=151) were administered psychological measures before and after listening to the audio files and a subset of students (n=32) where monitored for their physiological indicators as they listened to the audio files. Participants were reimbursed with S$30 Starbucks vouchers at the end of the session. Table 2 shows the recruitment schedule by day. Figure 1 summarizes the process from enrollment to data analysis.

The following are the inclusion and exclusion criteria for the study.

Inclusion Criteria:

1. University students in Singapore, aged 18 to 35 years old.

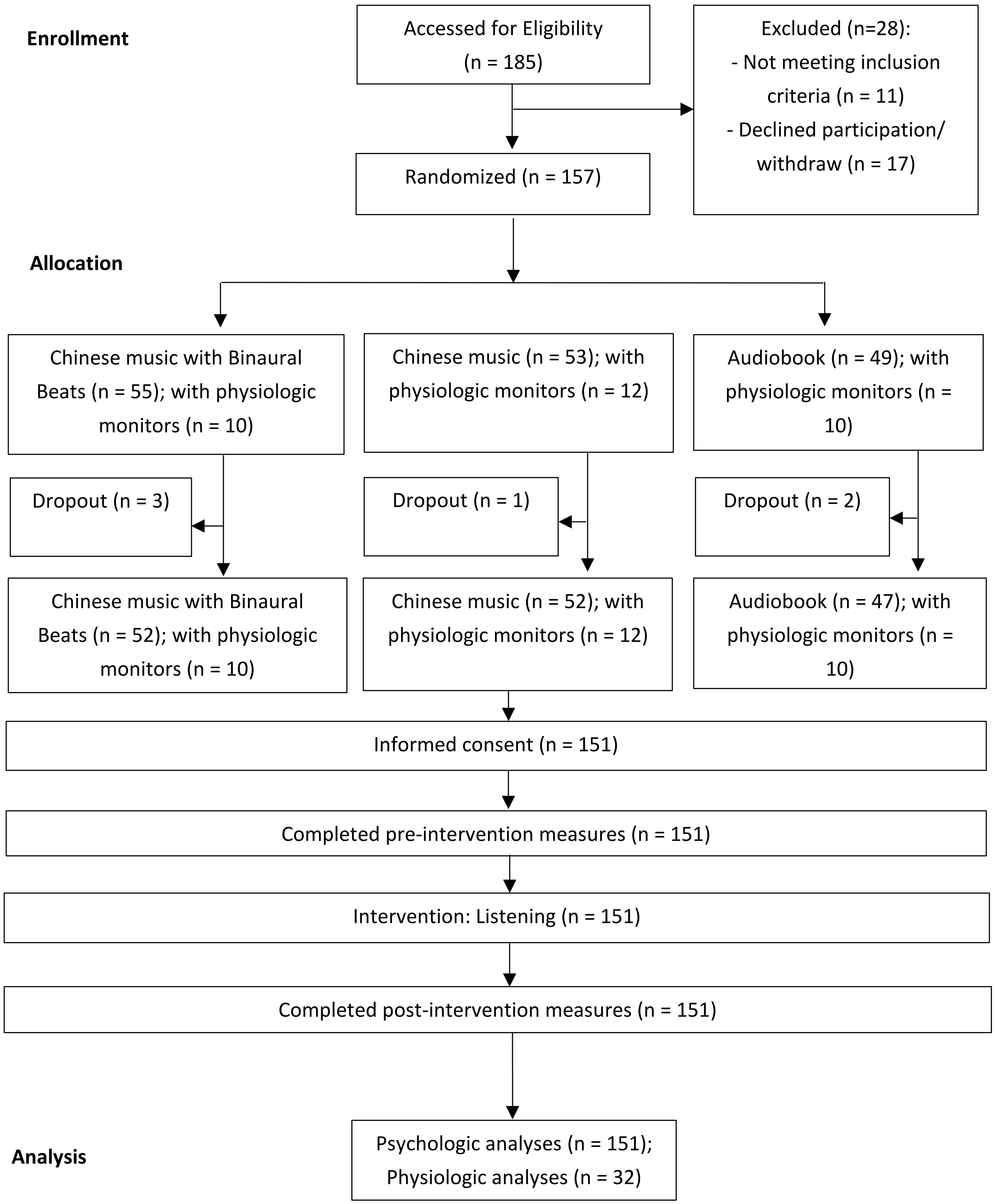
Exclusion Criteria:

1. Students with a history of epilepsy and profound hearing loss due to the nature of study.
2. Students with cardiovascular disorders and a history of diagnosed mental health conditions as the study's current focus is on healthy participants.

Table 2. Participant Recruitment Schedule

Date	**Number of participants**
Round 1:	Total: 79
24th Aug 2021	12
25th Aug 2021	10
26th Aug 2021	11
27th Aug 2021	3
30th Aug 2021	14
31st Aug 2021	10
1st Sep 2021	12
2nd Sep 2021	7
Round 2:	Total: 72
28th Oct 2021	3
29th Oct 2021	7
8th Nov 2021	12
9th Nov 2021	12
10th Nov 2021	14
11th Nov 2021	13
12th Nov 2021	11

Figure 1. CONSORT Flow Chart

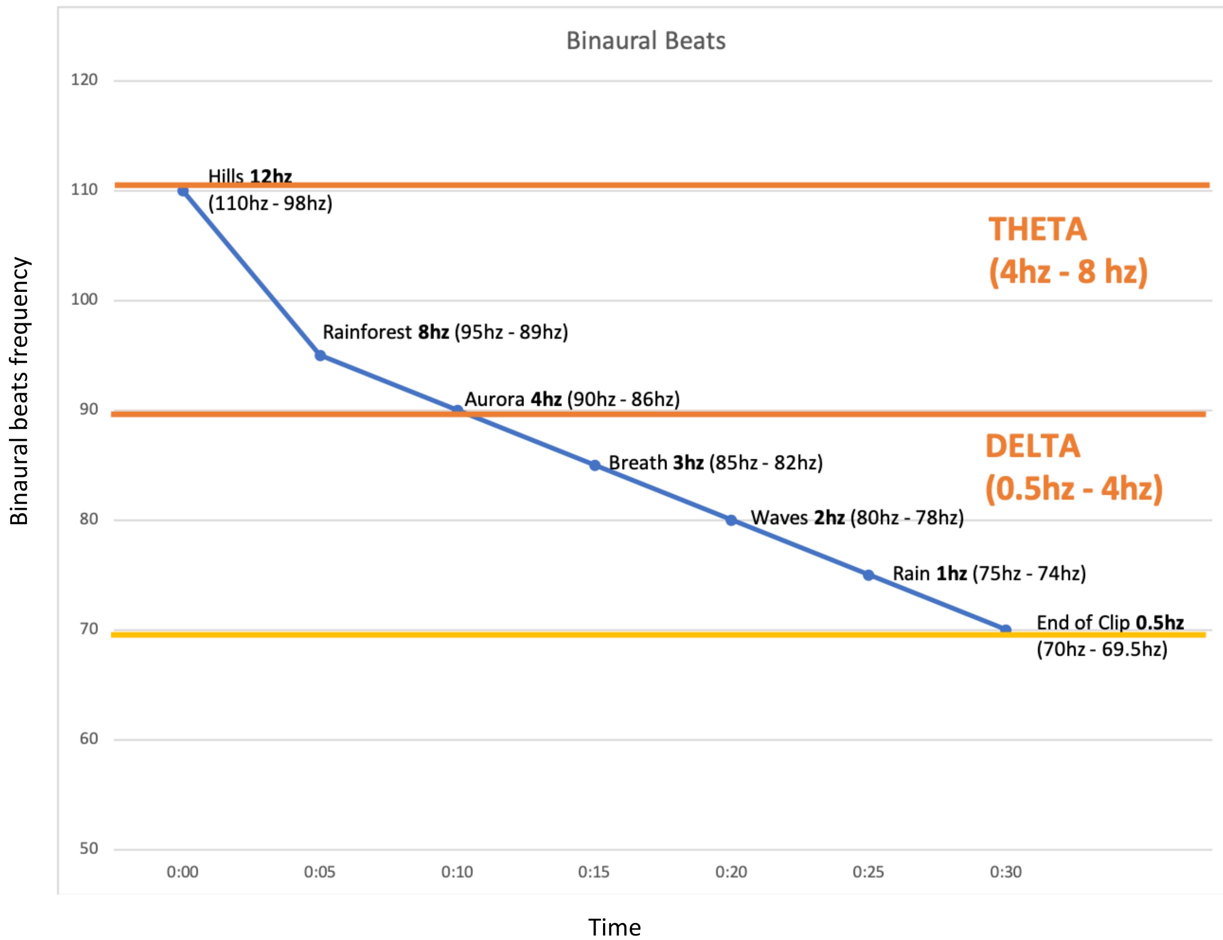


Audio Files

TENG music with and without Binaural Beats (BB) were produced by the Teng Ensemble. The music included instruments like Chinese flute, plucked lute, Chinese fiddle, zither, guitar and piano. BB incorporated in TENG music will flow dynamically from theta to delta brainwaves in 30 minutes with the first 10 minutes occupied by theta wave (see Figure 3 below). The audiobook file (history of Chinese instrumental music) was provided by the researchers. To ensure double blinding, the audio files were labelled by Teng Ensemble with alphabets A to C and researchers did not know the contents until the end of the data collection phase. Each session took an average 1.5 hours, consisting of pre-study responses to the questionnaire, audio file listening segment, and post-study responses to the questionnaire. Participants listened to these audio files through headphones provided by the Teng Ensemble. Before putting on the headphones, the participants were told "for the next 30 minutes, you will be listening to an audio track through the headphones in front of you. After you put on the headphones, please focus on the track that is playing and avoid all forms of distractions such as using your mobile phone. You may adjust the volume in front of you using the laptop if you find the volume too low or high. Do you have any questions before we begin?" Considering the COVID-19 situation, all equipment were sanitized after every use. The following photos show the researchers with the headphones sitting in the trial center.

Figure 2. Headphones and trial set up for the listening task.

Figure 3. Soundwave flow chart for audio file for Chinese music with binaural beats.



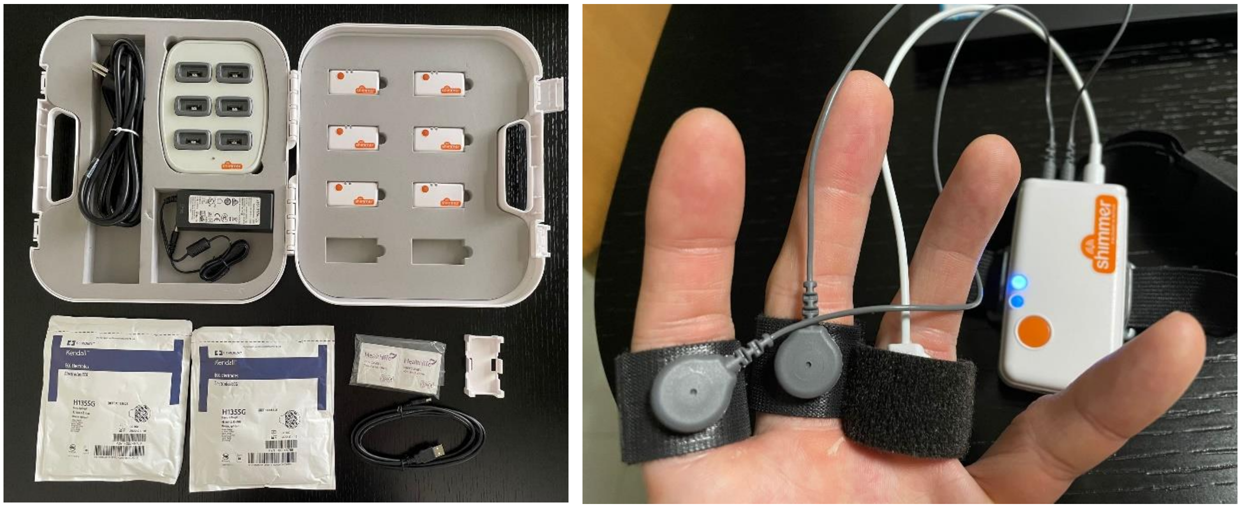
Procedure and Measures

Both physiological and psychological measurements were included in the research. Physiological measures included skin conductance and heart rate while psychological measures included State-Trait Anxiety Inventory, Perceived Stress Scale and Positive and Negative Affect Schedule. The physiological measurements were conducted on thirty-two subset participants throughout the listening task while psychological measurements were administered pre- and post-listening to all participants.

Physiological Measures

Participants' sympathetic responses (skin conductance and heart rate [HR]) were measured throughout the session. The activation of the sympathetic nervous system and inhibition of the parasympathetic system via the autonomic nervous system by emotional arousal influences sweat production (Benedek & Kaernbach, 2010; Fowles et al., 1981) and HR (Taelman, Vandeput, Vlemincx, Spaepen, & Van Huffel, 2011; Taylor & Meeran, 1973). Skin conductance, a physiological signal related to a change in sweat gland activity, was regarded to be a reliable indicator of stress and emotional arousal (Anders, Lotze, Erb, Grodd, & Birbaumer, 2004; Boucsein, 2012; Critchley, 2002). It was also identified as one of the most sensitive and valid markers for arousing or calming music (Kyriakou et al., 2019; Rickard, 2004). Skin conductance will be measured using sensors on hands (see Figure 4 below). HR and HR variability (HRV) has been commonly used as a proxy of sympathetic response, and indicator for both physiological and emotional responses (Appelhans & Luecken, 2006; Kyriakou et al., 2019; Williams et al., 2015). HR refers to the number of times the heart beats in a minute and the HRV refers to the time interval between two heartbeats measured in milliseconds. Higher HRV is postulated as an indicator for cardiovascular fitness and reaction towards stress (Kim, Cheon, Bai, Lee, & Koo, 2018; Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). In addition, HR variability has been found to be associated with repeated exposure to music (Iwanaga, Kobayashi, & Kawasaki, 2005) and affective sounds (Nardelli, Valenza, Greco, Lanata, & Scilingo, 2015). In the current study, HR and HRV were monitored using a wearable HR monitor. The iMotions (https://imotions.com/blog/skin-conductance-response/) software was used to collect the physiological data throughout the listening task.

Figure 4. Biosensors to capture sympathetic nervous system responses including skin conductance, heart rate and heart rate variability.



Psychological Measures

The **State-Trait Anxiety Inventory (STAI Form Y)** was used to evaluate participants' perceived anxiety levels. It is a 40-item self-report measure consisting of 20 items measuring anxiety relating to a situation (STAI-S) and 20 items measuring anxiety associated with personal characteristics (STAI-T) (Spielberger, 1983). Participants will be required to rate themselves on all items on a 4-point Likert scale. A higher score indicates a higher anxiety level (Spielberger, 1983). STAI is the most commonly used, reliable and widely validated scale for anxiety (Bieling, Antony, & Swinson, 1998; Spielberger, 1983; Vitasari, Wahab, Herawan, Othman, & Sinnadurai, 2011). STAI-T and STAI-S subscales will be used pre-listening while only STAT-S will be used post-listening.

Perceived Stress Scale (PSS) is a 10-item self-report global stress measure, capturing an individual's perception of how uncontrollable, unpredictable, and overloading the stresses in his/her life are in the past month (Cohen, Kamarck, & Mermelstein, 1983). PSS was shown to be valid and reliable in Singapore context (Archer, Lim, Teh, Chang, & Chen, 2015; Teh, Archer, Chang, & Chen, 2015). Participants responded to the items on a 5-point Likert scale. A higher total score indicates a higher chronic stress. PSS has been shown to correlate to biological markers of stress and disease (Cohen & Janicki-Deverts, 2012). Time-frame was changed from 'last month' to 'current moment' so that it is relevant to assess the effectiveness of the study on current perceived stress. PSS was administered at pre- and post-listening.

The Internationally Reliable Short-Form of the **Positive and Negative Affect Schedule (I-PANAS-SF)** is a 10-item self-report that measures the participants' positive and negative affect (Thompson, 2007). Participants rated the extent to which the 10 adjectives describe them based on a 5-point Likert scale. A higher score indicates a higher frequency that the adjectives describe them. I-PANAS-SF was found to be psychometrically acceptable and reliable in university students (Thompson, 2007). I-PANAS-SF was found to be cross-culturally validated in university students across countries (Karim, Weisz, & Rehman, 2011; Thompson, 2007). The I-PANAS-SF was administered pre- and post-listening.

Potential Covariates

Participants' personality may influence the effect of BB on their stress level. Hence, the **Mini International Personality Item Pool (Mini-IPIP)** (Donnellan, Oswald, Baird, & Lucas, 2006) was used to assess the participants' personality. It is a 20-item self-report measure of the Big Five factors of personality (Extraversion, Agreeableness, Conscientiousness, Neuroticism and Intellect/Imagination). Participants rated themselves on a 5-point Likert scale on how well each item described them. Mini-IPIP was found to be reliable and valid in measuring personality in college students (Donnellan et al., 2006). Mini-IPIP will be administered at pre- listening.

Participants' level of academic stress may also influence the effect of BB on their stress level. **Perceptions of Academic Stress Scale (PAS)** (Bedewy & Gabriel, 2015) is a 18-item self-report measure assessing the perceived academic stress of students and its sources. It consists of four subscales – pressures to perform, perception of workload, academic self-perception, and time restraints. Participants rated each item on a 5-point Likert scale. PAS was reported to be reliable and valid in measuring the perceived academic stress in undergraduates (Bedewy & Gabriel, 2015). PAS was administered at post- listening.

Additional questions elicited included "Do you listen to Chinese instrumental music? (Purely instrumental with no lyrics) [Responses: Yes, No]," "If not, would you consider listening to Chinese instrumental music after this experience?" [Response: Yes, No]," "If yes, how often do you listen to Chinese instrumental music? [Response: Everyday, 2-3 times a week, Once a week, Once a month, Once a year]," and "Do you have any music background (i.e., had taken official music lessons for at least one year)? [Response: Yes, No]."

Memory Test

Before listening to the audio file, the participants were shown a list of fifteen words individually presented for three seconds each (Roediger & McDermott, 1995). This was followed by a filler task requiring the participant to rate ten faces for the level of perceived emotional negativity and positivity. This task is included to reduce recency effect (better recall for the most recent words seen). The participants were then told to recall as many words as they can. The same process is repeated immediately after they completed listening to the audio file using a different word list. In each list, the list of words was semantically related such that it induced false recall of an associating word ('mountain' for the first list and 'sweet' for the second list) which did not appear on either lists. The memory task was administer pre- and post- listening.

All measures (except for skin conductance and HR) were administered via Qualtrics online on tablets for participants to respond. In Table 3, the physiological and psychological measures administered are summarized.

Table 3. Summary of physiological and psychological measures administered

Pre-study	1. Questionnaire on socio-demographics (age, gender, race, marital status, religion, socioeconomic status, household size) 2. STAI-T and STAI-S 3. PSS 4. Mini-IPIP 5. I-PANAS-SF 6. Experiment: Verbal memory word list 1
Measured throughout study	1. Heart rate 2. Skin conductance 3. Emotions/Facial Expressions
Post-study	1. Experiment: Verbal memory word list 2 2. Questionnaire on reported discomfort, exposure to Chinese music, music background, openness to trying Chinese music to relieve stress, importance of and competence in stress management to perform student role 3. STAI-S 4. PSS 5. PAS 6. I-PANAS-SF

Data Analysis

Statistical analysis was performed using SPSS version 28.0. Descriptive statistics were used to summarize participants' sociodemographic data. Distributions were assessed for normality prior to analysis. Parametric tests were conducted for variables with normal distributions while non-parametric tests were conducted for variables with skewed distributions. One-way analysis of variance (ANOVA) was conducted to determine the significance of changes across the three conditions (i.e., TENG music with binaural beats, TENG music only, audio book) for each outcome measure including perceived stress, situational anxiety, affective states, skin conductance and heart rate variability. Post-hoc analysis, Tukey's Honest Significant Difference (HSD) test, was conducted to identify the pairs of conditions that are significantly different. In addition, the General Linear Model (GLM) repeated measures were additionally conducted to examine whether there were any interaction effects among the predictor variables including the conditions and covariates outlined above (no significant interaction effects were observed in the current study). The level of significance was set at $p<0.05$ for all analyses and $p<.10$ were reported as marginal significance. In the following section, we report the significant findings from the current research.

Results

Sociodemographic Characteristics

This research recruited one hundred and fifty-one university students as research participants study and were randomly assigned to TENG music with binaural beats (n=52), TENG music without binaural beats (n=52) and audiobook condition (n=47). Of which, thirty-two participants underwent physiological measurement; listen to TENG music with binaural beats (n=10), TENG music without binaural beats (n=12), or audiobook (n=10). Table 4 shows the sociodemographic characteristics of the full sample.

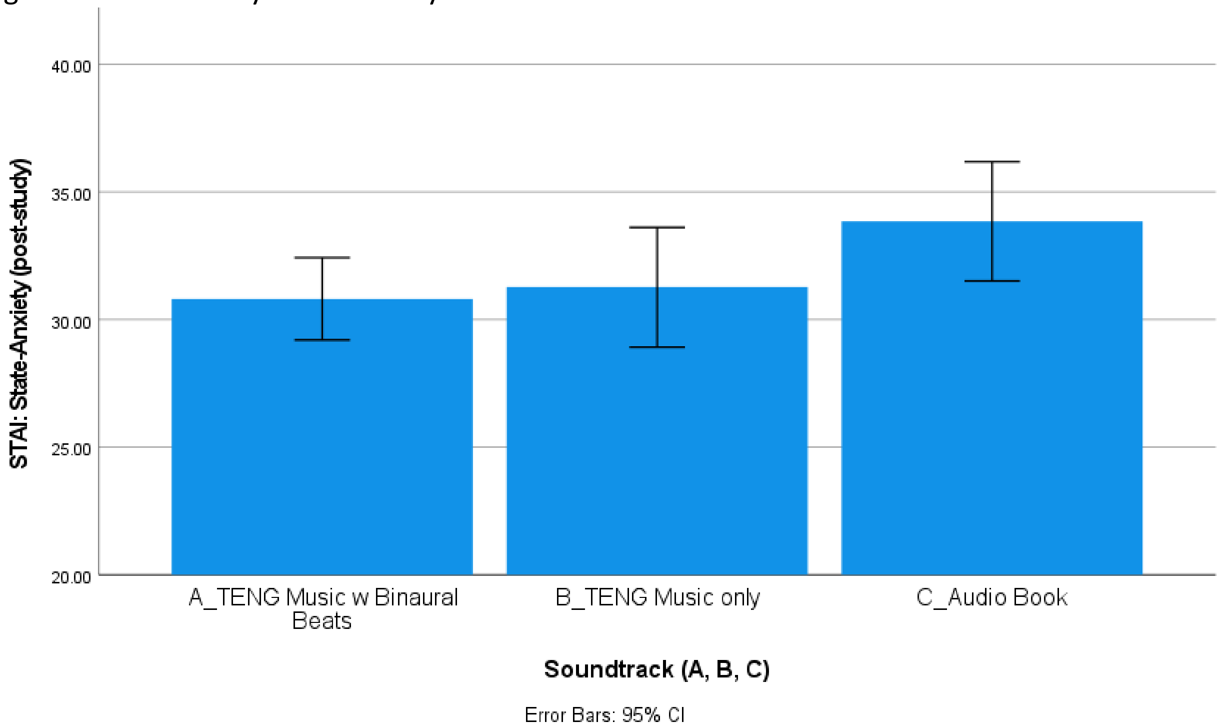
Table 4. Participant sociodemographic characteristics

Demographics	TENG music with binaural beats (n=52)	TENG music only (n=52)	Audiobook (n=47)
Age (mean ± SD)	22.9 ± 2.98	22.9 ± 2.63	22.6 ± 2.67
Gender n (%)			
Male	13 (25.0)	14 (26.9)	8 (17.0)
Female	39 (75.0)	38 (73.1)	39 (83.0)
Ethnicity n (%)			
Chinese	49 (94.2)	44 (84.6)	43 (91.5)
Malay	2 (3.8)	2 (3.8)	2 (4.3)
Indian	0 (0)	3 (5.8)	1 (2.1)
Others	1 (1.9)	3 (5.8)	1 (2.1)
Religion n (%)			
Buddhist	12 (23.0)	14 (26.9)	13 (27.7)
Christian/ Catholic	22 (42.3)	18 (34.6)	13 (27.7)
Hindu	0 (0)	2 (3.8)	1 (2.1)
Islam	2 (3.8)	4 (7.7)	3 (6.4)
Free thinker	16 (30.7)	13 (25.05)	14 (29.7)
Others	0 (0.0)	1 (1.9)	3 (6.4)
Marital status n (%)			
Single	52 (100)	52 (100)	47 (100)
Married	0 (0)	0 (0)	0 (0)
Housing type n (%)			
HDB	41 (78.8)	38 (73.0)	40 (85.1)
Condominium	7 (13.5)	10 (19.2)	3 (6.4)
Bungalow/Semi-detached/Terrace	4 (7.7)	4 (7.7)	4 (8.5)
Gross household income per month n (%)			
≤ \$2,750	12 (23.1)	6 (11.5)	10 (21.3)
\$2,751 to \$4,000	7 (13.5)	7 (13.5)	5 (10.6)
\$4,001 to \$6,900	9 (17.3)	11 (21.2)	8 (17.0)
\$6,901 to \$9,000	7 (13.5)	11 (21.2)	8 (17.0)
Prefer not to say	17 (32.7)	17 (32.7)	16 (34.1)
Listen to Chinese instrumental music n (%)			
Yes	23 (44.2)	17 (32.7)	15 (31.9)
No	29 (55.8)	35 (67.3)	32 (68.1)
Music background n (%)			
Yes	31 (59.6)	32 (61.5)	25 (53.2)
No	21 (40.4)	20 (38.5)	22 (46.8)

Psychological Outcomes

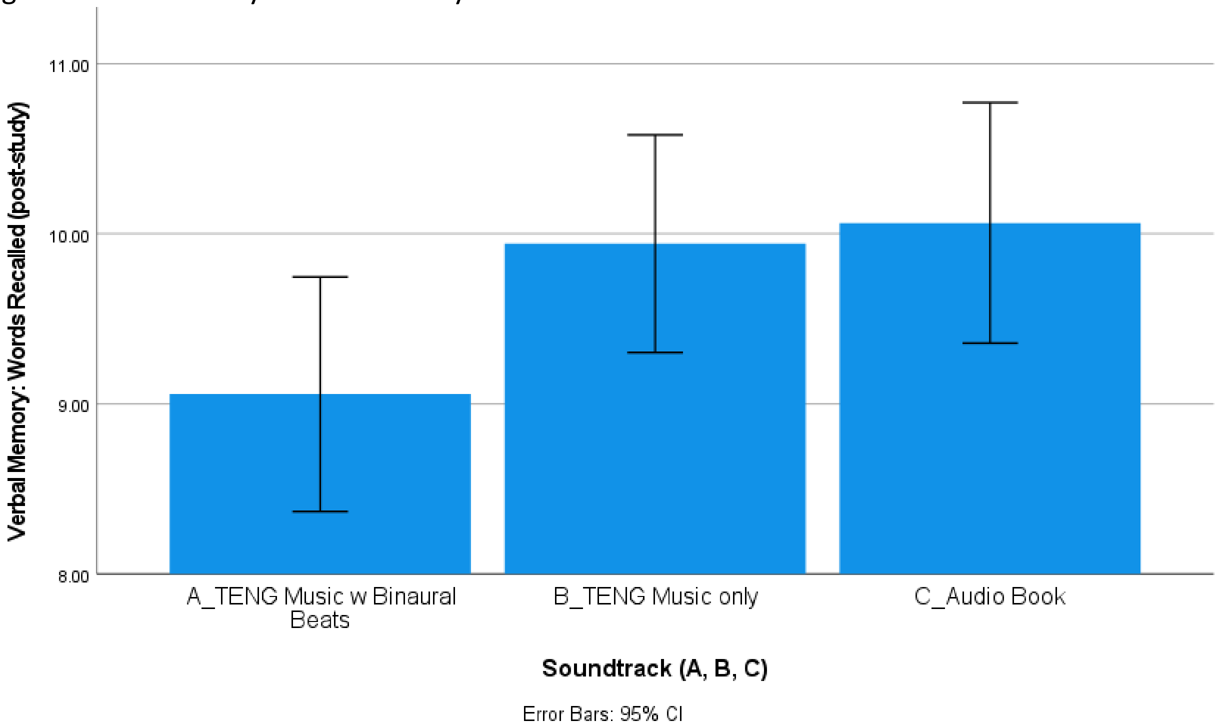
Participants who listened to TENG music with binaural beats reported a lower state-anxiety compared to those who listen to the audio book (see Figure 5.1). No statistical difference was found between those who listened to TENG music with binaural beats and TENG music only (see Appendix B1).

Figure 5.1. Post-study state-anxiety across conditions.



No difference was observed for verbal memory before listening to the soundtracks. However, after listening to TENG music with binaural beats, the participants recalled fewer items compared to those who listened to the audio book (see Figure 5.2). No statistical difference was found between those who listened to TENG music with binaural beats and TENG music only (see Appendix B2).

Figure 5.2. Post-study verbal memory task recall across conditions.



The following analyses examines subsamples based on state anxiety and positive affect at the beginning of the session. These subsamples were examined in response to the significant findings for the physiological outcomes within these subsamples.

Among participants who reported highest state anxiety (based on tertile split) at the beginning of the session, TENG music with binaural beats led to lower state-anxiety at the end of the session compared to participants who listened to TENG music only (see Figure 5.3 and Appendix B3) and lower recall of words compared to the audiobook condition (see Figure 5.4 and Appendix B3).

Figure 5.3. Post-study state-anxiety across conditions among participants who reported greatest state anxiety at the beginning of the session.

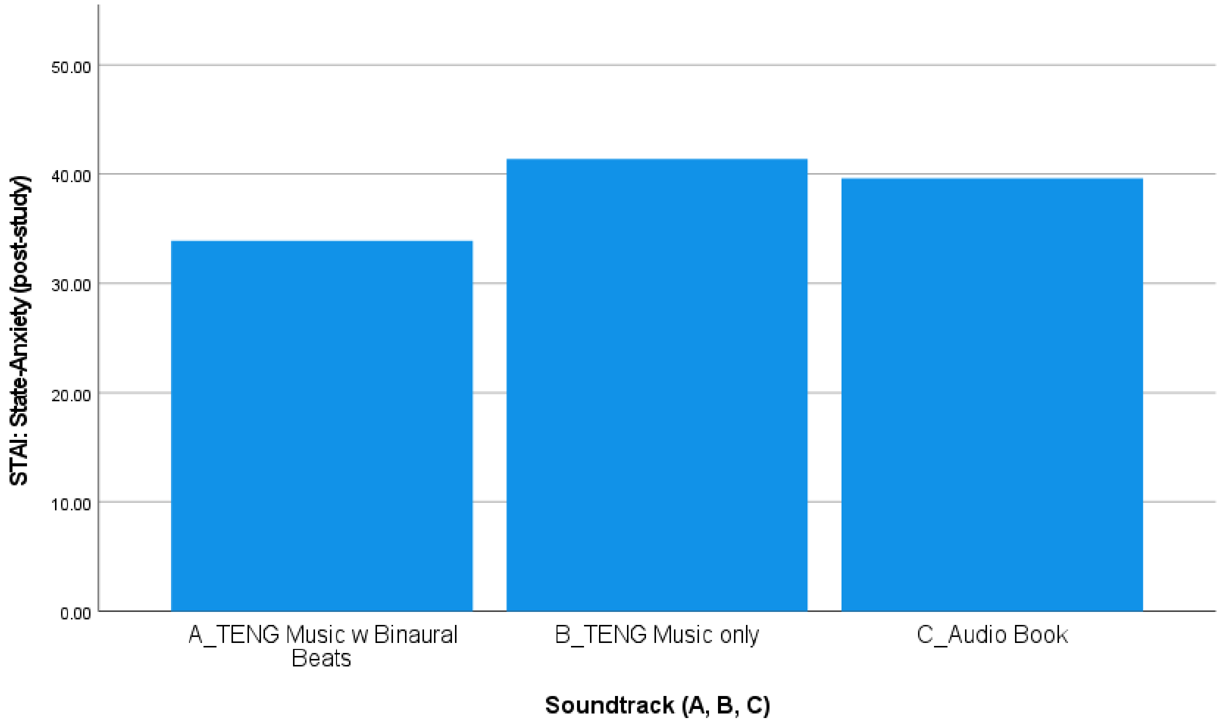
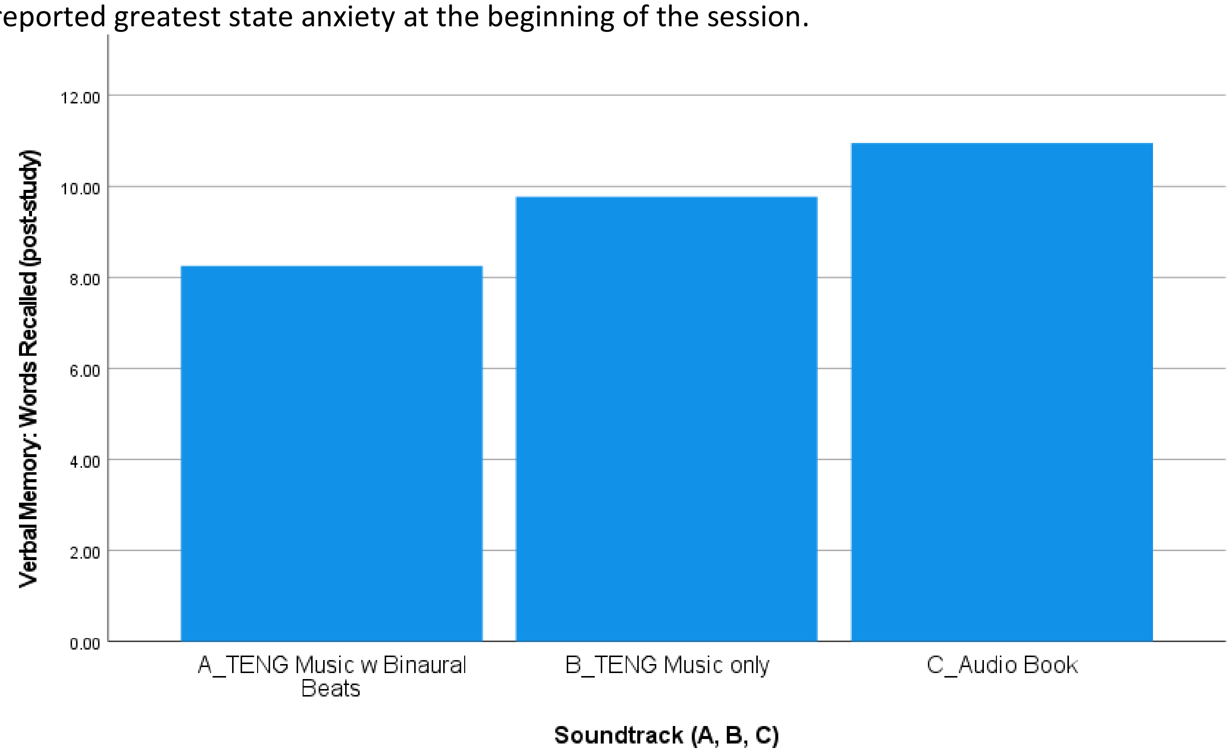
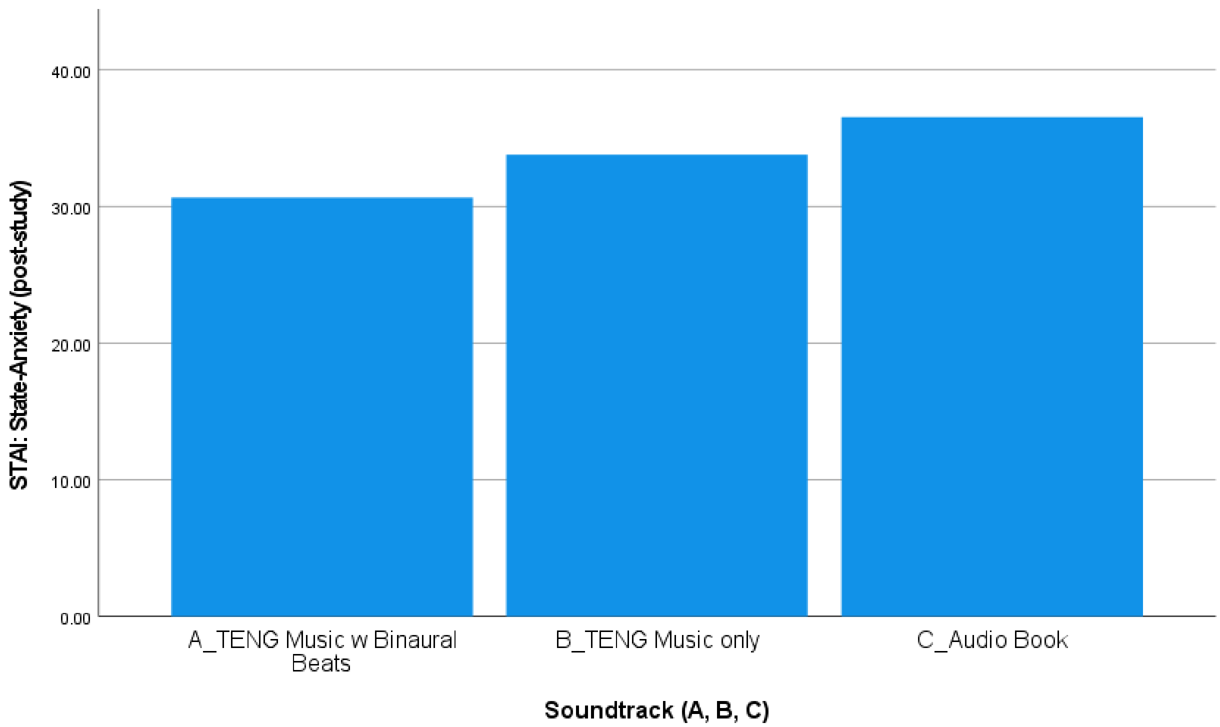


Figure 5.4. Post-study verbal memory task recall across conditions among participants who reported greatest state anxiety at the beginning of the session.



Among participants who reported lowest positive affect (based on tertile split) at the beginning of the session, TENG music with binaural beats led to lower state-anxiety at the end of the session compared to the audiobook condition (see Figure 5.5 and Appendix B4).

Figure 5.5. Post-study state-anxiety across conditions among participants who reported lowest positive affect at the beginning of the session.

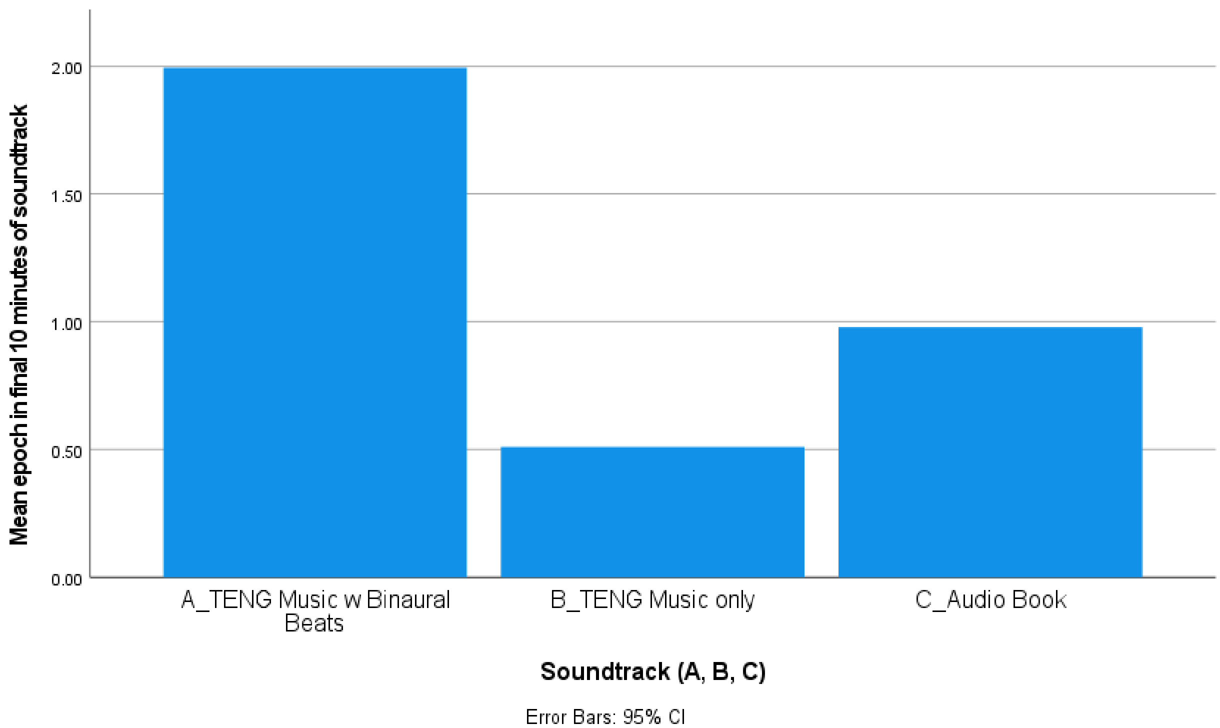


In general, the psychological set of findings suggest that while TENG music with binaural beats appear to reduce state-anxiety and led to lower recall of words compared to the audiobook condition. Further analyses based on part of sample revealed that these observations may be specific to participants who reported the highest state anxiety at the beginning of the session. A lower state-anxiety after listening to TENG music with binaural beats was also observed specifically among participants who reported the lowest positive affect before listening to the soundtracks.

Physiological Outcomes

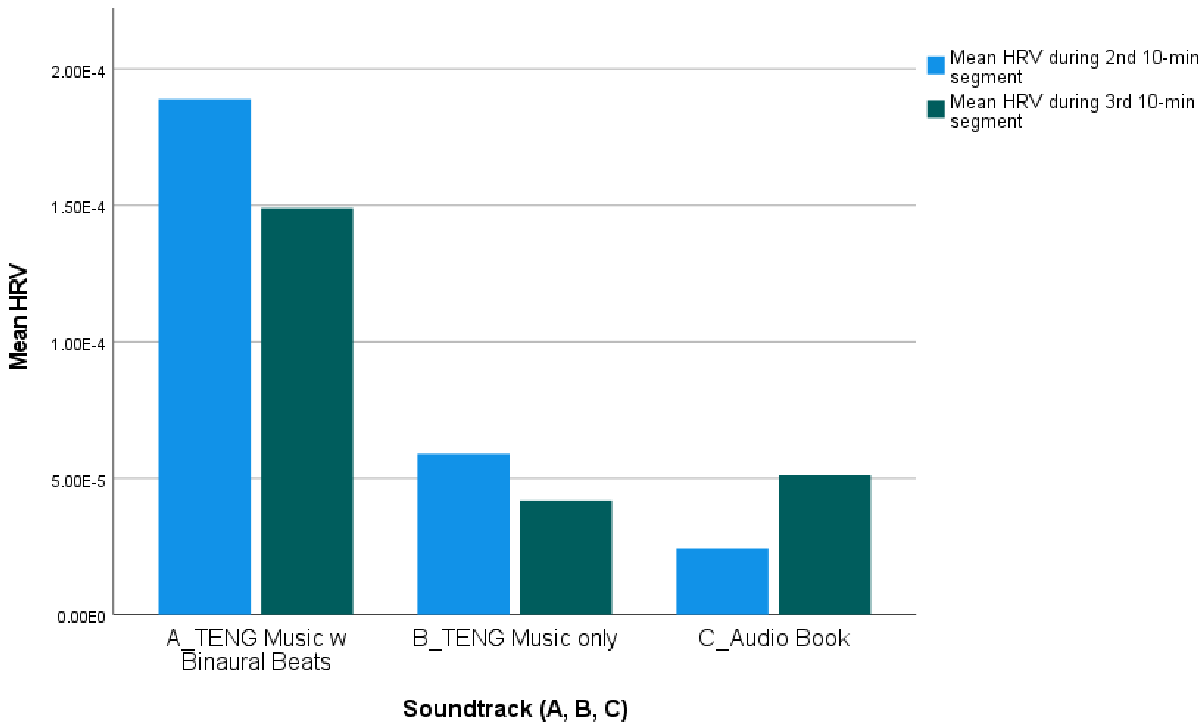
No significant main effects related to the hypotheses were observed for the physiological outcomes across participants in the TENG music with binaural beats, TENG music only, and audio book conditions. However, among those who reported highest state anxiety (based on tertile split) at the beginning of the session, TENG music with binaural beats led to greater arousal compared to TENG music only (see Figure 6.1; note small sample size, n=9) in the final 10 minutes of the soundtrack. No statistical difference was found between those who listened to TENG music with binaural beats and audio book (see Appendix A1).

Figure 6.1. Mean epoch (arousal spikes) in the final 10 minutes across conditions among participants who reported highest state anxiety at the beginning of the session.



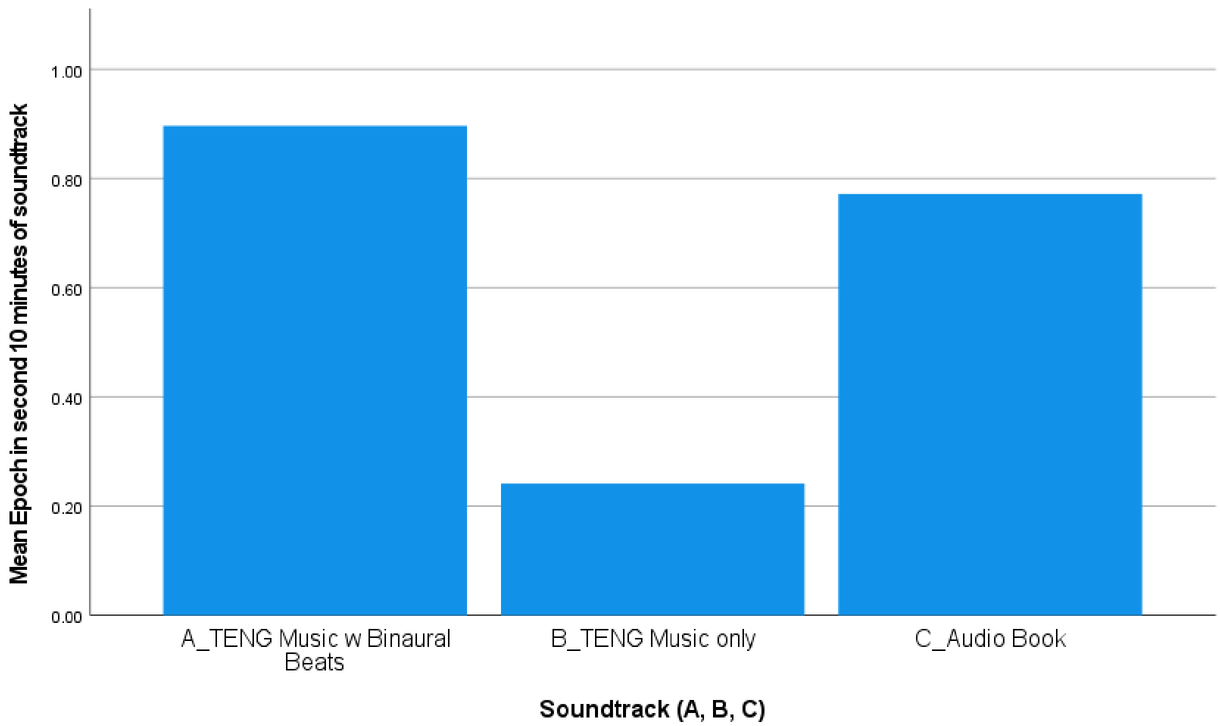
Among those who reported greatest state anxiety (based on tertile split) at the beginning of the session, TENG music with binaural beats led to greater Heart Rate Variability (HRV) compared to audio book in the second 10-minute segment of the soundtrack; and compared to TENG music only in the last 10-minute segment of the soundtrack (see Figure 6.2; note small sample size, n=9 and low HRV). No statistical difference was found between those who listened to TENG music with binaural beats and audio book and TENG music only in the last 10-minute and second 10-minute segment respectively (see Appendix A2).

Figure 6.2. Mean Heart Rate Variability (HRV; cardiovascular function) in the second and last 10 minutes across conditions among participants who reported highest state anxiety at the beginning of the session.



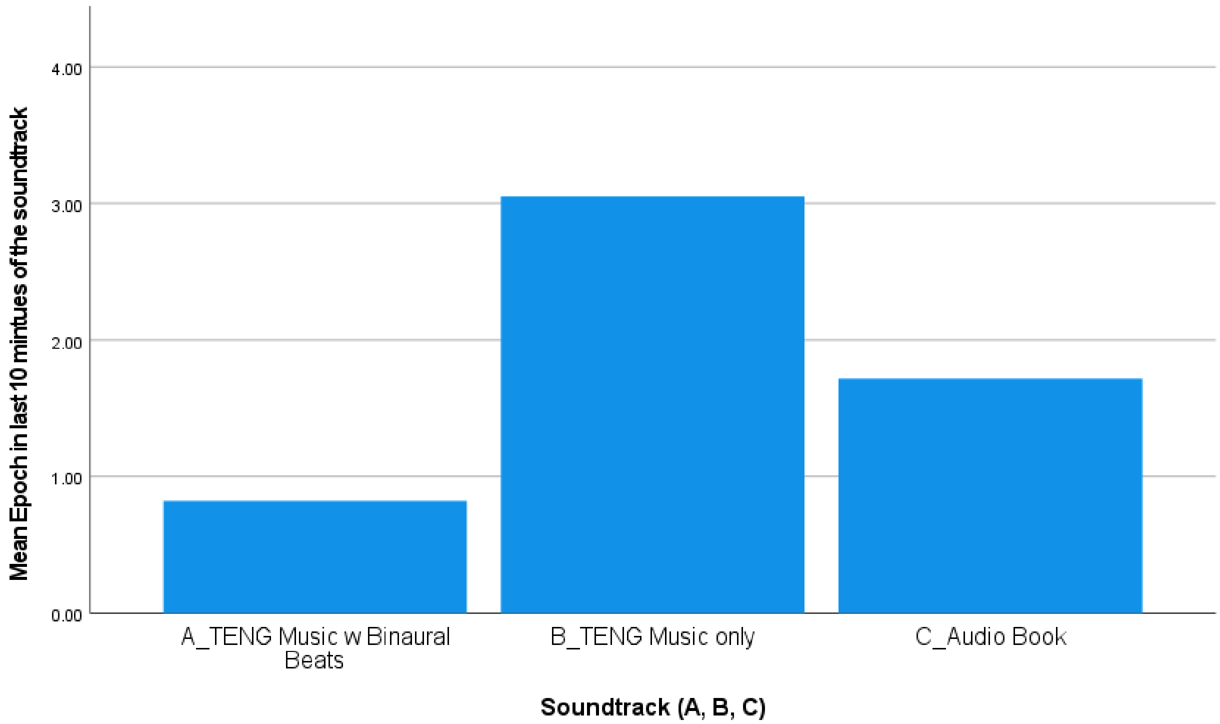
Among those who reported lowest positive affect (based on tertile split) at the beginning of the session, TENG music with binaural beats led to greater arousal compared to TENG music only in the second 10-minute segment of the soundtrack (see Figure 6.3; note small sample size, n=11). No statistical difference was found between those who listened to TENG music with binaural beats and audio book (see Appendix A3).

Figure 6.3. Mean epoch (arousal spikes) in the second 10 minutes across conditions among participants who reported lowest positive affect.



Among participants who reported the lowest intellect/imagination trait (based on tertile split) at the beginning of the session, TENG music only led to greater arousal compared to TENG music with binaural beats only in the last 10-minute segment of the soundtrack (see Figure 6.4; note small sample size, n=10). No statistical difference was found between those who listened to TENG music with binaural beats and audio book (see Appendix A4).

Figure 6.4. Mean epoch (arousal spikes) in the last 10 minutes across conditions among participants who reported lowest intellect/imagination trait.



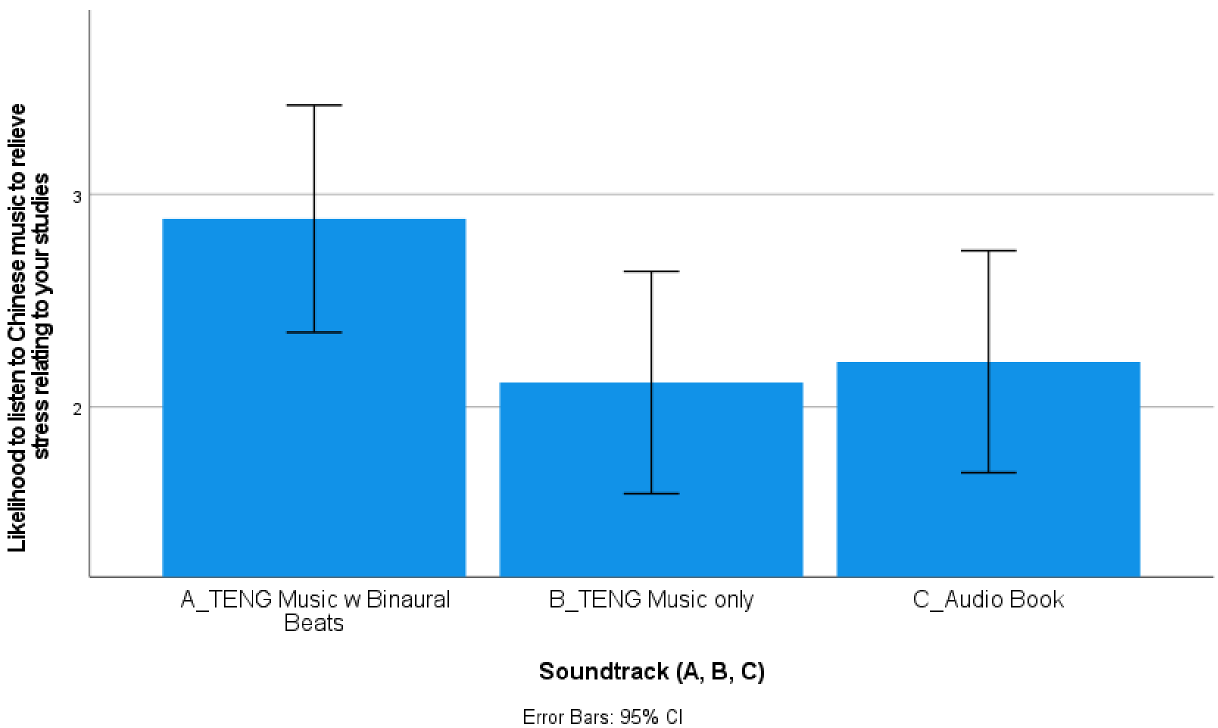
In general, the physiological set of findings suggest that participants who were in less favorable psychological states in terms of reported high anxiety and low positive affect tend to experience greater arousal after listening to TENG music with binaural beats. In addition, personality trait appears to influence physiological outcomes from listening to the soundtracks. In particular, participants who reported the lowest intellect/imagination trait experienced greater arousal after listening to TENG music only (compared to TENG music with binaural beat).

Incidental findings

In this section, we report other findings that were not part of the initial research conceptualization and hypotheses.

The participants indicated whether they were likely to listen to Chinese music to relieve stress relating to their studies after listening to the soundtracks (see Figure 7). Participants who listened to TENG music with binaural beats reported that they were more likely compared to those who listened to TENG music only (see Appendix B3).

Figure 7. Likelihood of listening to Chinese music to relieve stress relating to studies.



After listening to the soundtracks, the participants were asked whether they experienced any discomfort during the research. They were requested to share their experience if they indicated that they experienced discomfort. Seven out of the 151 participants indicated that they experienced discomfort and provided the following verbatim responses.

- Numbness from minimal movement of upper limb that has the device attached on.
- I think the headphone abit heavy, the pressure on my head was a little uncomfortable.
- Headphones were a little uncomfortable, slight thick, and a little warm compression on the head, therefore was uncomfortable.
- I was very thirsty which made me feel a bit more restless.

- Itchy ears (internal) (not due to the headphones).
- Felt discomfort when the transition music was suddenly very fast paced compared to the soothing pieces of music played during the explanation of the instrument's history. [audiobook condition]
- A bit of a headache probably due to the headphones which was a bit tight at the side of the head.

Discussion

☙ To be revealed in June 2022… ❧

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