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The Effects of Ambient Music and Theta Frequency Binaural Beats on State Anxiety and Interoceptive Awareness

Jonathan Stockwell
Health and Wellness Promotion Department
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dr. Laura Jones

Abstract

The purpose of this study was to examine the effects of binaural beats, ambient music, and a combination of the two on psychological and physiological indices of stress. Music has long been recognized to have effects on human behavior. In the last two centuries, humans have invented and utilized electronic music synthesis. Electronic music synthesis has given humans the capability to produce pure sound waves (i.e., sine, triangle, square, and sawtooth waves), introducing new ways for sound to be experienced. Binaural beats involve two sine waves, less than 1500hz and less than 40hz apart played, played in opposite each using stereo headphones which creates beat that is the difference between the two frequencies being played into either ear. Studies prove this has an effect, but the degree to which it is effective for each individual has been debated. Music and Binaural beats have primarily been studied apart from one another. This research study combines a selection of ambient music composed by Brian Eno and theta frequency binaural beats together to examine if there can be a greater effect on self reported states of relaxation, anxiety, and interoception when the two are combined. The results found that no significant change in state anxiety across groups, significant changes in interoceptive subscale of noticing between groups and significant change in body listening across time and groups. All groups showed a significant increase in perceived relaxation but there was no significant difference between groups.

1. Body of Paper

1.1 Introduction

Many people in the western world experience high and prolonged periods of stress. Overwhelming amounts of stress can lead to physiological changes to our nervous system. In our fast paced society it is difficult to find the time to relax, and when we do find the time, it can be difficult to achieve a restful state. Autonomic nervous system dysregulation can be a risk factor for diseases, such as liver disease[1], metabolic syndrome[2], and diabetes[3]. Anxiety regulation is another important factor in dealing with stress and autonomic regulation. Anxiety may be mediated by a reciprocal "top down" and "bottom up" approach in the nervous system. Top down refers behavior and cognition and bottom up refers to physiological manifestations[4]. Music and binaural beats are two convenient ways in which people can regulate and relax.

Binaural beats are a type of auditory stimulation with reported psychological and physiological effects. Binaural beats consist of a steady rhythmic beat produced when a sine wave of a particular frequency is played in one ear while a sine wave of a different frequency is played in the opposite ear. This technique produces a third tone that is the difference between each frequency played into either ear, typically between 0hz and 40hz[5]. Binaural beats are unique in the way they are perceived by the brain. If one were to play a binaural beat through open air speakers they would hear the beat from the mixing of the two frequencies in the air before it reaches their ears. When binaural beats are

listened to through headphones the sound does not mix in the air, instead it is perceived in the brain. It is believed that the brain recognizes the binaural beats in the superior olivary nucleus of each brain hemisphere[6]. The brain exhibits a frequency following response to binaural beats. The frequency following response is described by Atwater as, "the result of a low-level coherent oscillation within the central nervous system and the brainstem in particular,[7]". This effect is also termed brainwave entrainment. The benefit of this type of auditory entrainment is that the difference in frequency is correlated with brainwave frequencies, many of which are below the hearing range of 20hz. Binaural beats are also non-invasive and carry very limited side effects making them a safer approach to psychological and physiological conditions than other traditional treatments.

The physiological effects of binaural beats is documented in the literature. A review of 20 studies was conducted to assess the psychological effects of brainwave entrainment. They cited one RCT that found an intervention of alpha/delta therapy to produce a significant reduction in anxiety from one session for day surgery patients. They also cited a crossover RCT that found theta stimulation in four healthy adults to be an effective intervention[8]. Theta frequency beats, between 4-8hz are believed to induce states of relaxation. A study from 2014 found that listening to theta frequency beats for 20-minutes after exercise increased high frequency power and decreased low frequency power and LF/HF ratio[9]. According to Wager et al. an increase in HF power in a known marker for parasympathetic activation. This activity is directed in regions of the anterior cingulate and medial prefrontal cortex[11]. This study utilized a 6hz binaural beat with hopes to promote a state of relaxation.

Studies also have examined psychological and physiological responses to music in humans. Researchers have employed a range of methods to evoke a particular change in mood and bodily awareness. The literature on this topic provides evidence that music has an effect on psychological and physiological functioning[11]. A study of relaxing music on heart rate and heart rate variability during ECG GATED-myocardial perfusion scintigraphy in 100 patients found a significant reduction in heart rate in the group with music compared to the control group[11]. They did not give any information on what they used for 'relaxing' music. A review of music interventions for hospital patients found nine studies examined the effects of music on anxiety, using the Spielberger State Trait Anxiety Inventory to measure anxiety[12]. Six of these studies were included in the meta analysis because they were used in studies of hospital patients and were an effective intervention[12].

It must be noted, however, the pattern of results from music studies has been largely inconsistent[13]. Evans[12], Pelletier[14], and Nilsson[15] have published reviews that indicate that listening to music can be effective in relieving state anxiety. They also find that there exists large gaps of inconsistency in the studies that were reviewed. Evans[12] looked at music for relief from anxiety in hospital patients and found that music was an effective relief but, for procedures that were deemed to be unpleasant, there was no effect on self reported anxiety. Nilsson[15] reviewed 42 studies and found only 50% produced the desired psychological effect and only 27% produced the desired physiological effect. Changes in self reported states of mood, anxiety, and stress may not reflect the data collected by physiological recording devices.

Highlighting the different variables that may influence the outcome of music related studies is important to our research. Music studies employ different selection methods, for example researcher selection and participant selection. Music must be examined in order to select music for the purpose of the study. Researcher selection of music grants the research team an advantage by developing the selection with intention for the particular purpose of the study and standardized the music playlist for each individual. A potential disadvantage to researcher selection is that the music may not be preferred to the listener. Advantages to participant selection are that this method allows each study subject to bring in music they may find relaxing and that fits their taste[13]. The disadvantage to this method is that studies cannot be controlled for parameters of relaxing music. Each comes with its own set of advantages and disadvantages.

Interoceptive awareness assessments are not often utilized in these studies. Interoceptive awareness, refers to "the conscious perception of sensations from inside the body that create the sense of the physiological condition of the body, such as heartbeat, respiration, satiety, and the autonomic nervous system sensations related to emotions" [16]. An assessment of interoceptive awareness may provide key insights into the literature of music and binaural beats studies. One's awareness of body sensations, and their reactions to them, may influence the outcome of these interventions. Gaining information on each participant's interoceptive awareness may be important to these studies. High sensitivity to interoceptive awareness can be adaptive or maladaptive[17]. Awareness of body signals can help one adapt to new body sensations but some people can also become hyper aware of uncomfortable or painful body sensations [18, 19].

This study expands the existing research by incorporating binaural beats, with known physiological and psychological effects, with researcher selected music. To our knowledge no other study has examined both of these simultaneously. The research aims to assess if adding binaural beats to ambient music will have a greater effect on perceived relaxation, state anxiety or interoception markers than just binaural beats or just music alone. Incorporating the Multidimensional Assessment of Interoceptive Awareness adds to the scope of inquiry for music and binaural beats studies. The three primary research questions for this study are the following: 1) How do music, binaural beats,

and the combination of the two impact levels of state anxiety? 2) How do music, binaural beats, and the combination of the two impact levels of interoceptive awareness?, and 3) How do music, binaural beats, and the combination of the two impact levels of relaxation?

2. Method

2.1 Method

Snowball and convenience sampling was used in this study. Participant selection took place via email and physical flyer throughout the UNCA campus. Potential participants were asked to submit their interest through Google Forms. From there, they were contacted to schedule their study date. Participants were instructed to arrive at the UNCA Biofeedback lab between 8:00am and 10:00am, having not eaten breakfast and having consumed no caffeine no less than three hours earlier. Scheduled arrival at the same time of day aimed to reduce confounding variables associated with diurnal cycle of daily cortisol release. These cycles can lead to variation in autonomic nervous system response that may impact anxiety, perceptions of relaxation, or one's awareness of their bodily states. Time for digestion and metabolism will also provide consistency given that digestion relies on parasympathetic nervous system activation. At this point participants read and signed the informed consent prior to beginning procedures.

Participants were randomly assigned to experimental and control groups based on when they enrolled in the study. The first control group was given a theta frequency binaural beat track. This track features a 6hz beat. The second control group featured only music. For music selection, we decided to use the researcher selected method. We believed that this would reduce confounding variables created by participant selected music. We also chose to use electronically based ambient music for our study. All tracks in the selection are composed by the artist Brian Eno[20]. The tracks are played continuously taking roughly 19 minutes to complete. The experimental group features a track that contains the above music selection as well as a theta frequency binaural beat track. The binaural beat track in this selection follows the tonic of each track but keeps a steady 6hz beat throughout the entire session. We chose to do this to reduce any dissonance between the binaural beat track and music track.

2.2 Materials

The study used three pre and three post paper based surveys. We created a survey to gain demographic information, one's history of contemplative practice, one's use of binaural beats, one's musical knowledge, and one's use of music for relaxation. The post survey consisted of qualitative questions asking about noticing physical changes in one's body, changes in mood or feelings after the session, or if anything was discomforting about the experience. A likert scale graded 1-7 with 1 being not at all and 7 being very much so, was used to assess current level of relaxation, enjoyment of the audio track, attentiveness to the audio track, and the likelihood that they would continue to use music or binaural beats for relaxation. The Multidimensional Assessment of Interoceptive Awareness, MAIA was included to gain insight of each person's interoceptive awareness.. This assessment uses eight subscales to measure degrees of interoceptive awareness. Those subscales are, "(1) Noticing: the awareness of uncomfortable, comfortable, and neutral body sensations; (2) Not-Distracting: the tendency to ignore or distract oneself from sensations of pain or discomfort; (3) Not-Worrying: emotional distress or worry with sensations of pain or discomfort; (4) Attention Regulation: the ability to sustain and control attention to body sensation; (5) Emotional Awareness: the awareness of the connection between body sensations and emotional states; (6) Self-Regulation: the ability to regulate psychological distress by attention to body sensations; (7) Body Listening: actively listening to the body for insight and (8) Trusting: experiencing one's body as safe and trustworthy," [19]. MAIA has been shown to have acceptable rates of reliability using internal consistency reliability (Chronbach's alphas for the eight scales: 0.69; 0.66; 0.67; 0.87; 0.82; 0.83; 0.82; 0.79)[13]. Lastly, the Spielburger's State Trait Anxiety Inventory[21], STAI, which attempts to measure one's general trait anxiety level and their current state anxiety level. Reliability generalization of scores for the STAI was conducted citing 52 studies. They found mean internal consistency for state anxiety to be .91 with minimum ranges between .65 - .96 for state and mean internal consistency for trait anxiety to be .89 with a range of .72 - .96[3]. Participants also took at follow up MAIA and STAI questionnaire.

The music was selected from the artist *Brian Eno*. Many studies do not include the titles of music they play, which makes critiquing their method more difficult. The track list is as follows (Table 1).

Table 1. Track List

Title	**Album**
An Ending (Ascent)	Apollo
Against the Sky	The Pearl
Drift	Apollo
Signals	Apollo
Deep Blue Day	Apollo

2.3 Procedure

Following informed consent, participants completed a series of paper-based pre-assessments including Spielberger's State-Trait Anxiety Inventory, the Multidimensional Assessment of Interoceptive Awareness, and demographics form requesting information on age, ethnicity, gender identity, status at the university, department/major, binaural beats (used before or never used), and experience with contemplative practices. Each participant sat in a comfortable chair with legs reclined. Participants were randomly assigned to one of the two control groups or the experimental group based on the order of their session.

After the pre-assessments, participants were told to sit reclined in a comfortable chair and listen to the audio track, theta binaural beats, music, or both. Following the control or experimental condition, each participant completed a final set of self-report assessments analogous to those used at the start of the study. One additional survey was given to gain insight of the participant's familiarity, emotional response to the music, level of relaxation and comfort. Following the session, an oral debriefing was conducted to inform the participants about the reasons for the study, let them know in which condition they were placed, and allow control participants an opportunity to listen to the music and/or binaural beats. Participants were informed that they may contact the researchers using the contact information on the Informed Consent Document following the conclusion of the study to ascertain the overall results of the study once it has been completed in December 2019.

Levene's test of equality of variance was used to assess normality of data. No corrections were made. Three way repeated measures ANOVA was used to assess differences in post intervention outcomes and Bonferonni's post hoc analyses was used to assess for significant effects between groups.

3. Results

3.1 Demographics

A total of 18 participants (n=18) were enrolled from UNCA's campus via email flyer and physical flyer. We collected basic demographic information on age, biological sex, gender, race, student year and major, and faculty department. A total of 13 participants identified as biologically female, while 5 participants identified as biologically male. We found that 83% of participants were caucasian, 11% were black/African American, and 6% were more than one race. Of the total 18 participants, 16 were students representing six academic disciplines, one participant was faculty and one participant was staff. We asked about frequency of contemplative practices such as mindfulness, meditation, or prayer and found that 11% of participants never engage in contemplative practice, 11% engage 1-4 times per month, 28% engage 1-2 times per week, 17% engage 3-4 times per week, and 33% engage in these practices 5-7 times per week. We also asked about the participant's use of music for relaxation for which 6% answered 1-4 times per month, 11% answered 1-2 times per week, 17% answered 3-4 times per week, and 67% answered 5-7 times per week. We also wanted to gauge participants use of binaural beats in the past. We used the same likert scale with 67% of

participants having never use binaural beats, 22% having used binaural beats 1-4 times per month, 6% used binaural beats 3-4 times per week, and 6% used binaural beats 5-7 times per week. Participants were selected randomly for experimental group based on the order they came in for their session. The study did not control for past experience of contemplative practice, use of music for relaxation, or use of binaural beats.

3.2 Statistical Assumptions

Assumptions for skewness and kurtosis were met across all variables with the exception of prestests for MAIA Noticing and MAIA Emotional Awareness. These two variables were platykurtic in nature, with kurtosis values of 4.270 and 4.649 respectively. Levene's test was used to test equality of error variance in all pre tests. No significant differences were found in the STAI pre assessment scores, $F(2,15)=.236$, $p=.793$. All but one of the eight subscales of the MAIA, similarly showed an equality of error variance of the pretest scores (see Table 2). MAIA Not Worrying is the only pretest that demonstrated an inequality of error variances. The demographics survey asked about level of relaxation and found significant error variance for the pre variable, $F(2, 15)=4.091$, $p=.038$). Out of the entire data set, only two items were not answered. We calculated the averages among those items to insert into the data set. Our rationale for using averages is because data set is very small and excluding data would further take away from the data.

Table 2. Eight subscales of the MAIA, similarly showed an equality of error variance of the pretest scores

MAIA Subscale	Levene's Test of Equality of Error Variances
Noticing	$F(2, 15)=.078$, $p=.925$
Not Distracting	$F(2, 15)=.503$, $p=.615$
Not Worrying	$F(2, 15)=16.180$, $p=.000$
Attention Regulation	$F(2, 15)=2.334$, $p=.131$
Emotional Awareness	$F(2, 15)=1.727$, $p=.211$
Self Regulation	$F(2, 15)=.763$, $p=.484$
Body Listening	$F(2, 15)=.157$, $p=.856$
Trusting	$F(2, 15)=.384$, $p=.687$

3.3 Data Analysis

Scores of the STAI found that state anxiety went down for the binaural beats and music groups but went up for experimental group. The MAIA utilized a likert scale from 0-5 with 0 being never applies to your normal life and 5 being always applies to your normal life. Means have been calculated for pre and post intervention scores in each of the subscales. The MAIA showed the same general pattern except for conflicting findings with regard to Not Distracting and Not Worrying subscales. Not Distracting showed a decrease in not distracting in the music group, but an increase in the both group. Not Worrying showed a similar trend with a decrease in not worrying in the binaural beat group but increases in music and both groups. In addition we also calculated scores for pre and post level of relaxation from our demographics survey.

Table 3. Pre and post Intervention means of STAI and MAIA subgroups

Group	Test	N	Pre Mean	Pre SD	Post Mean	Post SD
Binaural Beat	STAI	6	48.667	3.777	46.833	5.193
Music	STAI	6	46.167	4.792	45.333	6.121
Both	STAI	6	47.667	4.633	49.500	4.593
Binaural Beat	MAIA Noticing	6	4.375	.440	4.458	.5342
Music	MAIA Noticing	6	3.500	.447	3.625	.666
Both	MAIA Noticing	6	3.958	.621	4.083	.516
Binaural Beat	MAIA Not Distracting	6	2.611	1.182	2.611	.976
Music	MAIA Not Distracting	6	2.278	.878	1.778	.981
Both	MAIA Not Distracting	6	2.722	1.124	2.833	1.243
Binaural Beat	MAIA Not Worrying	6	3.167	.753	3.111	.689
Music	MAIA Not Worrying	6	2.389	.2501	2.889	.834
Both	MAIA Not Worrying	6	2.667	1.116	2.722	1.182
Binaural Beat	MAIA Attention Regulation	6	3.857	.478	4.071	.812
Music	MAIA Attention Regulation	6	2.833	.825	3.095	1.413
Both	MAIA Attention Regulation	6	3.310	.702	3.429	.823
Binaural Beat	MAIA Emotional Awareness	6	4.533	.372	4.58	.458
Music	MAIA Emotional Awareness	6	3.667	.891	3.800	.829
Both	MAIA Emotional Awareness	6	4.300	.486	4.300	.576
Binaural Beat	MAIA Self Regulation	6	3.875	.628	3.611	.828
Music	MAIA Self Regulation	6	3.333	.861	2.056	1.389
Both	MAIA Self Regulation	6	3.792	.914	3.500	.889
Binaural Beat	MAIA Body Listening	6	3.611	.828	4.278	1.084
Music	MAIA Body Listening	6	2.056	1.389	3.389	1.182
Both	MAIA Body Listening	6	3.500	.888	3.833	.587
Binaural Beat	MAIA Trusting	6	4.444	.886	4.500	.837
Music	MAIA Trusting	6	4.278	.772	4.556	.807

Both	MAIA Trusting	6	4.111	.701	4.000	.667

Table 4. Current level of relaxation for each group

Group	Test	N	Pre Mean	Pre SD	Post Mean	Post SD
Binaural Beat	Current Level of Relaxation	6	5.500	1.049	6.500	.837
Music	Current Level of Relaxation	6	4.167	.983	6.000	1.265
Both	Current Level of Relaxation	6	4.500	2.258	6.667	.516

3.4 Statistical Tests

Statistical analysis found no significant differences within groups or between groups for the STAI assessments. No significant differences were found within groups for the MAIA subscale Noticing, but a significant difference was found between groups, F(1, 15) =1258.643, p=.025. Post Hoc Bonferroni's test revealed a significant difference between Binaural Beat and Music groups. Significant differences were found for time in the Body Listening subscale, F(1, 15)=30.625, p=.000. Significant differences were also found for within group effects of time by group, F(2,15)=4.375, p=.032. No significances were found within groups or between groups for MAIA subscales Not Distracting, Not Worrying, Attention Regulation, Emotional Awareness, Self Regulation, or Trusting. Although these were not significant, nonsignificant trends were found in some of the analyses. Significant differences were also found in the pre and post level of relaxation self report F(1,15)=25.281, p=.000, although there is no significant differences across groups.

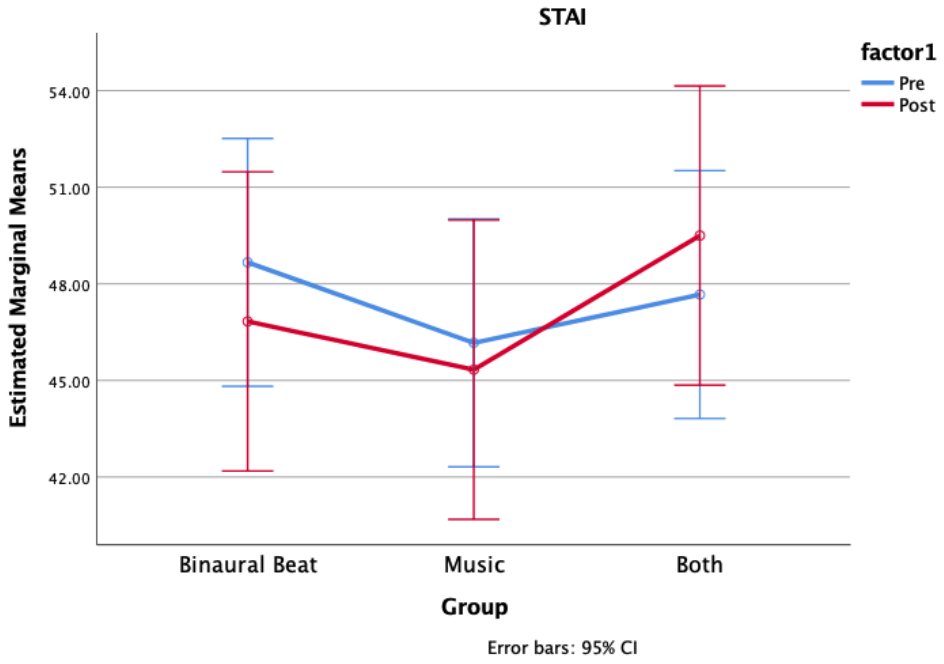

Figure 1. STAI pre and post scores

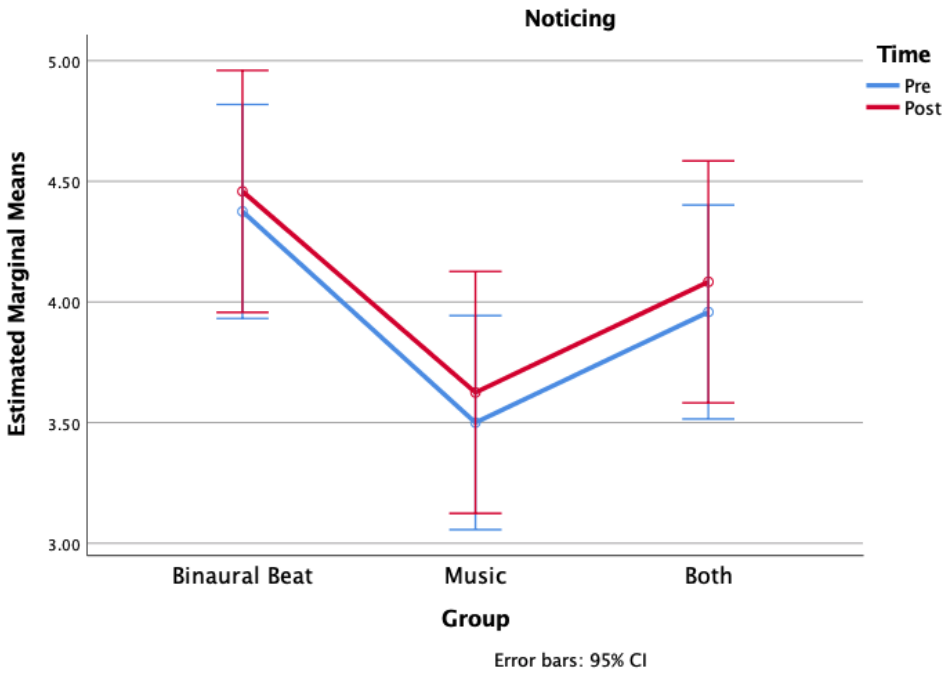

Figure 2. MAIA Noticing pre and post scores

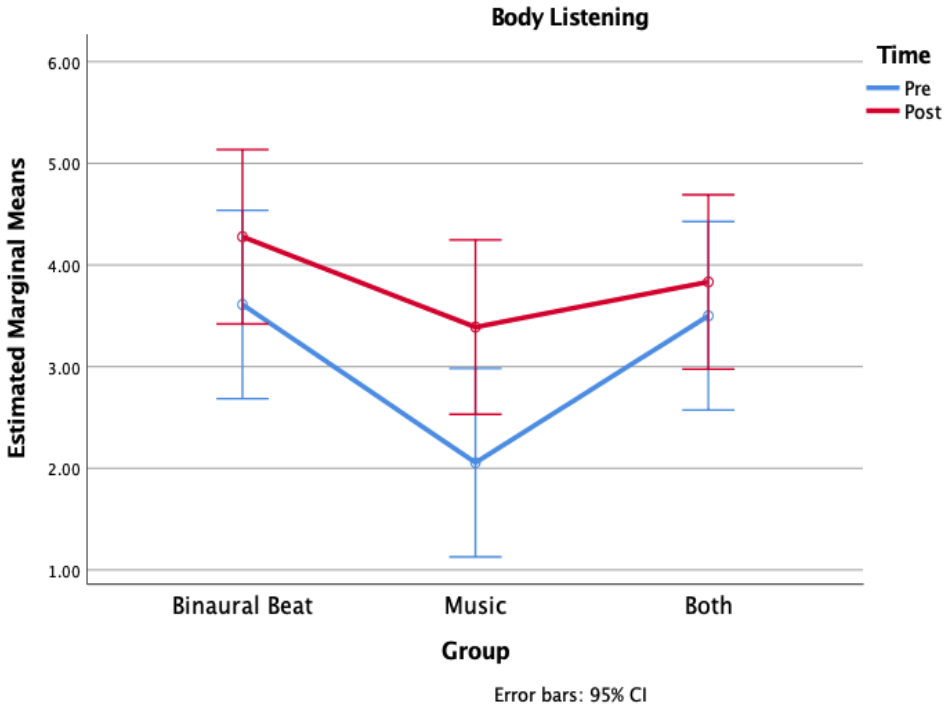

Figure 3. MAIA Body Listening pre and post scores

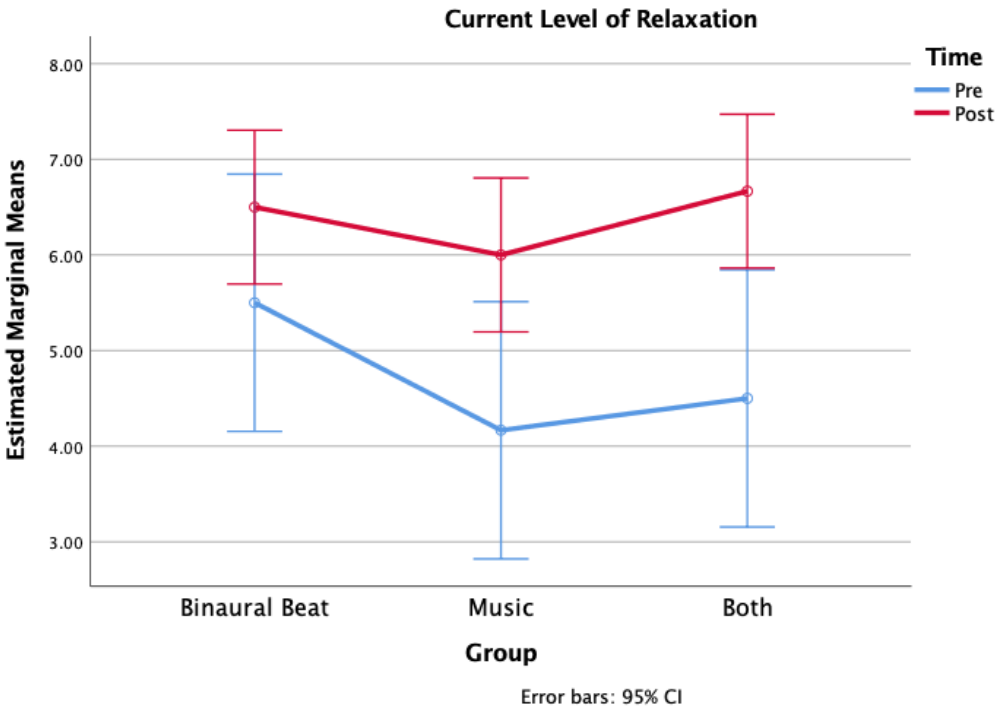

Figure 4. Current level of relaxation pre and post scores

4. Discussion

This study examined the relationship of binaural beats and ambient music with perceived state of relaxation, interoception, and state anxiety. The low number of participant data points presents challenges to normality and assumptions and renders the majority of data difficult to interpret, however we can discuss interesting points and potential trends.

The demographic survey provided information on identity and experience with music and contemplative practices. No basic identifying information on race, biological sex, gender, or age would seem to have significant influence on the data. The population did have an overwhelming majority of participants (78%) who reported using a contemplative practice, prayer, meditation, or mindfulness at least once per week. This could have influenced some of the high scores on the MAIA subscales. The connections from interoceptive awareness and health studies parallel with studies on contemplative practice and health. Contemplative practices, broadly mind-body meditations, may increase awareness and attenuate interoceptive signal processing[19]. The majority of participants (67%) had never used binaural beats before the session. Having never used binaural beats for the majority of participants makes the study more blind with regard to the participants not knowing which track they would be listening too, except for binaural beat group. For those that had used binaural beats before, they may have tried to hear them in the music track, even if they were not present. All participants likely had an expectation of what they would hear.

Although results were not significant, the STAI showed a decrease in state anxiety for the binaural beats and music groups. However, there was an increase in the binaural beats and music group (Figure 1). This conflicted with our hypothesis that state anxiety would decrease more with the combined binaural beats and music track. This conflict could be a consequence of keeping the groups blind to the audio track they would be listening to until it was played. We hypothesize that participants may have worried about which track they received. There was a significant difference between the binaural beats and music group for the MAIA Noticing subscale but no significant difference within those groups (Figure 2). The Noticing subscale was intended to measure the awareness of uncomfortable, comfortable, and neutral body sensations. The body listening subscale showed significant differences within groups and between groups with the music group having the largest increase in body listening (Figure 3). Body Listening subscale was intended to measure one's active listening of their body for insight. We asked about current level of relaxation on the pre and post demographics survey. The Both group scored highest overall on self reported relaxation (Figure 4). Although

there was no significant change across groups for the intervention, the results show a positive trend. On average, participants self reported being more relaxed after the intervention than before, which follows background data suggestion that binaural beats and music can be an effective intervention.

The minimal sample size (6 participants per group) had a considerable impact on statistical tests and significances. More data needs to be collected in order to better meet the statistical assumptions for using such statistical tests and see clearer results and more accurately determine significance among the relationships. Current levels of relaxation in the pre demographics survey were already high on average. Future studies wishing to implement the intervention for a specific population, i.e. stressed university student, staff, and faculty, may want to artificially create some stress before the session to see if any of the interventions have the desired effect on acute anxiety or stress. We may have created some unintentional anxiety with our method. We chose not to inform the participants of which audio track they received until after the session. This may have not been necessary as the person who may benefit from one of these three interventions in regular life would already know what they are about to listen to. Modifications can also be made to the music selection method in future studies, and different methods ought to be employed. We chose a researcher selection method to reduce confounding variables of differences in participant music selection. Part of the intention behind this playlist was to give a contour to shape the experience to lift one's mind up, settle it into a deeply relaxing place, and then to return it back to a wakeful state, temporarily allowing it to leave the stressful or anxiety provoking situation that it is in. We saw no studies that used electronically composed ambient music as the music intervention. We realize that intentions cannot be standardized, but we hope that more research studies will publish the track list that they have used and, if there was an intention behind that selection, to also publish those. We understand that this may always have it's limitations. Preferred music may overpower any intention to create a relaxing playlist. If the listener actively does not like the music then the intervention likely will not be as effective. Additional studies will provide more clarity on these subjects.

5. Conclusion

Significant differences were found with regard to changes in self reported relaxation after the interventions of all groups, binaural beats, music, and both. There were insignificant differences in state anxiety after the intervention and trends suggest a conflict with a reversal of outcome for the experimental group with music and binaural beats. Based on self reported perceived relaxation, each group saw significant changes in relaxation and every participant scored higher on post intervention scale of perceived relaxation. In conclusion, none of the interventions proved to be more effective in a clear way given the present data. Additional data needs to be collected to see if more clear trends will arise.

There were no conflicts of interest with this study.

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