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RESEARCH ARTICLE

# Binaural Beats and Music: A Preliminary Case Report

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## HIGHLIGHTS

Improved brain function, cardiovascular activity, and bioenergy effects can occur when binaural beats (a "pulsation" felt when two slightly different tones are played in each ear) are added to brown noise, or to music plus brown noise.

## ABSTRACT

We recruited subjects who reported feeling stressed and needing a break and were seeking an opportunity to experience relaxation. Inaudible binaural beats (BB) were used to measure the ability of BB to induce relaxation. Measurements included EEG, Menlascan (cardiovascular and ANS) (Menla Technologies, Independence, Missouri), and GDV (Gas Discharge Visualization/Kirlian Photography) (Korotkov et al., 2020). Further, a Big Five Character Assessment was administered, and individual Brief Mood Introspection Scales (BMIS) were collected for each condition. Subjects experienced an improvement in brain function, microcirculation or cardiovascular score, bioenergy, and a calmer brain after adding binaural beats to brown noise or to music plus brown noise, although the Menlascan scores and Big Five character assessment results were less conclusive. BB seems to have profound effects on the physiology of subjects, and since the beats were not audible, these effects could not be attributed to the placebo effect. These results are encouraging in terms of developing musical products incorporating BB to affect human neural rhythms and corollary states of consciousness and warrant further research with more subjects and different frequencies of BB and different music tracks.

## KEYWORDS

Audio beats, auditory illusion, binaural beats, bioenergy, frequency following, neural response, neural rhythms.

## INTRODUCTION

This preliminary case study aimed to assess the effects of adding binaural beats (BB) to music on the brain, bioenergy, and physiology of four study participants. Theories of bioenergy propose that electromagnetic fields are associated with basic life processes and that each human being radiates an electromagnetic field that can be described as an "aura" or field of bioenergy (Prakash et al., 2015). Peer-reviewed research on human bioenergy and aura includes topics such as stress levels (Abdullah et al., 2014) and the influence of bioenergy on the conformation of human DNA (Rein, 1995). Instruments currently used to detect bioenergy fields measure aspects of electromagnetic activity (Deshpande et al., 2016; Hansen & Lieberman, 2014; Prakash et al., 2015).

## METHOD

Study participants were randomly selected to participate twice on two consecutive days, with two male participants in the first week and two female participants in the second week, one week apart. A total of four auditory stimulations were administered during their two sessions, each session (Part 1 and Part 2) having two stimulations. The room was kept dark and quiet, and the participants were read a 1-minute relaxation script written by the Sponsor prior to each session. The same relaxation script was used for each session.

The four-day study began on October 31, 2021. All four subjects were tested at the same times on all four days to control for circadian rhythms, which may impact response to BB (Atwater, 2001; Rossi, 1986; Shannahoff-Khalsa, 1991; Webb & Dube, 1981).

The following was the schedule:

Week 1 Day 1: Subject 1 -9 am, Subject 2 – 1 pm
Day 2: Subject 2- 9 am, Subject 1 – 1 pm

Week 2 Day 3: Subject 3- 9 am, Subject 4 – 1 pm
Day 4: Subject 4- 9 am, Subject 3 – 1 pm

Each participant listened to the control track first and then the BB-enhanced track second so that we could clearly measure the difference between the Control Condition and the BB Condition. Subjects 1 and 3 began Day 1 at 9 am with Part 1 (Conditions 1 and 2), and subjects 2 and 4 began Day 1 at 1 pm with Part 2 (Conditions 3 and 4). This allowed everyone to listen to their four musical tracks at the same time of day. The two sequences were: Part 1: Condition 1 (brown noise only) and Condition 2 (brown noise plus binaural beats) and Part 2: Condition 3 (brown noise plus music) and Condition 4 (brown noise plus music plus binaural beats).

The study Sponsor provided the four auditory stimulation files, which were unidentified except for numbers 1 to 4, to provide a double-blind condition. The double-blind condition was met by keeping the track identities secret; neither the participants nor the lab assistant knew which track contained which condition. The tracks were presented to the lab only named 1- 4, so no one knew what those numbers represented. All audio tracks were 10 minutes long due to research showing a duration of at least 8 minutes is needed for the brain to resonate to the offered frequencies (Garcia-Argibay et al., 2019). The control condition was met by having each audio condition created both with and without the BB and presenting the non-BB condition first so that the difference could be tracked and measured. The study was conducted at PsyTek Labs, a licensed clinical and public health research lab, in collaboration with the California Institute for Human Science (CIHS), by principal investigator Gaétan Chevalier, PhD, who is the Research Director.

Headphones are required for using binaural beats. The study Sponsor supplied the headphones. All participants used the same brand and serial number of headphones (Blue Lola Sealed Over-Ear) and the same auditory volume (40 dB) for all audio conditions. The musical track was composed in the ambient relaxation genre using piano music and synthesizer pads at a tempo of 60 bpm. Binaural beats were added in Protools, a professional audio production software. The musical track was titled Relax 1. The BB added were Theta at 4 Hz (4 cycles per second) and Alpha at 8 Hz (8 cycles per second).

These frequencies were chosen for their correlation to deep, inward, yet awake meditative states (Shapero & Prager, 2020). The carrier frequency selected was 440 Hz. The exact formula was 438 Hz in the left ear, 442 Hz in the right ear for Theta, 436 Hz in the left ear, and 444 Hz in the right ear for Alpha. The carrier frequency of 440 Hz was selected due to the research that frequencies in this range are the most effective due to the size of the human skull (Atwater, 2001; Oster, 1973). The Sponsor chooses to disclose all formulas for the enrichment of the research community as a whole and invites all researchers to do the same. The Sponsor has previously made all BB dissertation research available as open source to this community.

A combination Alpha-Theta frequency was chosen due to the findings of Garcia-Argibay et al. (2019), which showed that mixed frequencies were more effective. This was also the conclusion of pioneer researcher Atwater (2001). The Sponsor chose to make the BB (and brown noise) inaudible after reading research showing that BB still produces effects even when one of the carrier frequencies is below hearing (Oster, 1973). The added benefit of inaudible BB was the removal of the placebo effect, given that the BB was inaudible and no one knew when they were present. All tracks were the same length of 10 minutes due to the research showing that a minimum of 8 minutes is needed for the brain to resonate to the offered frequencies (Garcia-Argibay et al., 2019). Brown noise contains all frequencies, like white noise, but emphasizes the lower frequencies and de-emphasizes the higher frequencies (Blum & Jamet, 2022). Research shows that pink noise is an effective binaural beats carrier (Garcia-Argibay et al., 2019). The sponsor selected brown noise instead due to personal preference; it is much easier and more pleasant to listen to 10 minutes of brown noise than pink noise, and brown noise is a comparable full-spectrum sound. The Sponsor hypothesized that adding an

unchanging brown noise carrier tone under the musical track, which has variations, would more effectively carry the BB. The numerical data extracted from the EEG analysis supported this outcome. Due to time limitations, the condition of the music and BB, without the brown noise, was not tested. Further research, including this condition, is recommended.

## Measures

**EPI/GDV (Electro-Photonic Imaging/Gas Discharge Visualization).** We measured the bioenergy of the subjects using the Gas Discharge Visualization (GDV). Electro-Photonic Imaging (EPI), also known as Gas Discharge Visualization (GDV), is an advanced form of Kirlian photography developed by Korotkov et al. (2010). This technology produces an electric impulse, which generates a response of the subject in the form of electron and photon emission. The glow of the photon radiation owing to the gas discharge generated from the electromagnetic field is captured by a digital camera and processed by sophisticated software where a report can be generated.

**WAVi P300.** The instrument used to measure the functioning of the brain was the brain scan platform WAVi P300 Brain Mapping System. WAVi is a non-invasive, HIPAA-compliant brain measurement platform that provides data about brain function using EEG technology to measure brain activity in response to a stimulus (Grover et al., 2017; Joffe et al., 2021; Oakley et al., 2021; Tarrant et al., 2019). WAVi can be considered as research-friendly since EEG with audio P300 has been used in health screening exams for research conducted by hospitals and clinics for clinical evaluations (Joffe et al., 2021). The P300 wave is an electrical response of the brain that shows the brain's response to stimuli as well as how quickly or easily the response occurs (Tarrant et al., 2019). P300 is considered to be an endogenous potential, as its occurrence links not to the physical attributes of a stimulus but to a person's reaction to it. More specifically, the P300 is thought to reflect processes involved in stimulus evaluation or categorization. The EEG signals are processed, and the P300 is extracted by the WAVi software.

**Menlascan.** Menlascan (Menla Technologies, Independence, Missouri) provided measurements on the cardiovascular system in response to the auditory stimulus, which refers to the heart (cardio) and blood vessels (vascular). This system distributes blood to all parts of the body and is governed by the autonomic nervous system (ANS). The ANS is a component of the peripheral nervous system that regulates involuntary physiologic processes, including heart rate, blood pressure, respiration, digestion, and sexual arousal (Waxenbaum et al., 2022). Microcirculation is blood flow through the smallest vessels of the cardiovascular system. The most important results here are the improvement of cardiovascular and microcirculation scores as the ANS is prone to rapid changes with emotions.

**Big Five Inventory.** The theory of five basic personality traits (Big Five) was developed by D. W. Fiske (1949). The five basic personality traits described by the theory include extraversion/extroversion, agreeableness, openness, conscientiousness, and neuroticism. Evidence of this theory has been reported by researchers including Kachur et al. (2020), and in meta-analyses by Buecker et al. (2020), Mammadov (2022), and Plessen et al. (2020).

**BMIS Assessments.** The Brief Mood Introspection Scale (BMIS) is an open-source mood scale based on 16 mood adjectives such as "Are you 'happy'? (Mayer & Gaschke, 1988). The scale yields measures of moods including pleasant-unpleasant mood, arousal-calm mood, as well as scores for positive-tired and negative-calm mood (Mayer & Gaschke, 1988). The scale has been validated in numerous studies, including Aldrich et al. (2021), Flexer et al. (2021), and Nugraha et al. (2020). In order to evaluate any possible correlation between subjective assessment and quantitatively gathered data, participants filled out a BMIS form after each condition. Seven of the eight forms were completed. In addition to present-time mood assessments, an overall mood assessment on a scale of 1 to 10 was requested.

## Participants

The experimental group consisted of four healthy adults. Random sampling recruitment started on October 14, 2021, by posting flyers, electronic marketing, and by snowball sampling. The pilot study flyer was advertised for individuals who were looking to take a break from their stress and experience profound relaxation. All participants read and signed a standard Informed Consent form prior to participation in the study. Written informed consent was obtained from the individuals for the publication of any potentially identifiable images or data. Exclusionary criteria included having a serious illness or inability to abstain from medication or stimulants on the days of the study. The four participants were all in good health according to the demographic data they provided; any minor health conditions and medications are noted below. See supplemental files for further information.

SUBJECT 1 is a 52-year-old male (DOB 7/31/1969) dealing with high blood pressure and a stress level of 5 on a scale of 1 to 10. Subject 1 experiences stress due to money and career ambition, which affects his emotion-

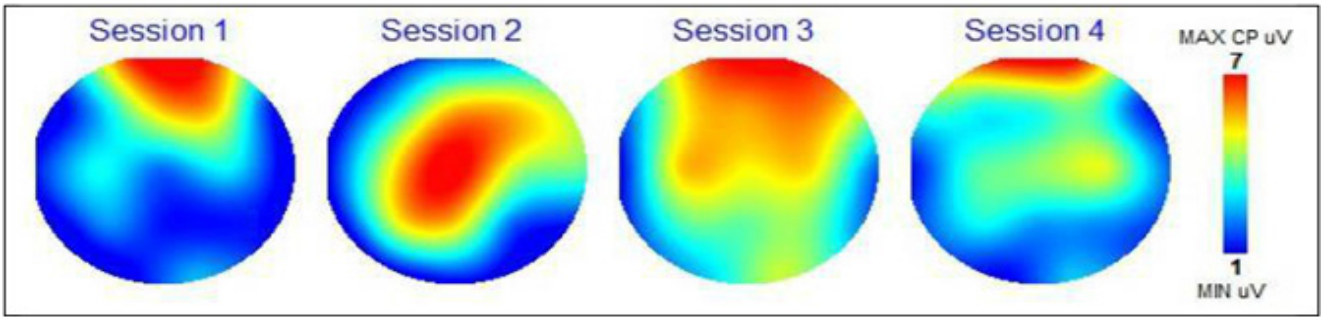


**Figure 1**. Scalp Topography of Brain Response: Subject 1.

al health, and he is looking for help regulating sleep and lowering his stress levels. Exercise and meditation work for this individual.

SUBJECT 2 is a 46-year-old male (DOB 9/9/72) experiencing little stress in his life, a three on a scale of 1-10, and reports no other physical, mental, or sleep issues, just managing high blood pressure with the medication Norvasc. He is looking to enjoy the retirement phase of his life. He is just beginning his journey into self-care.

SUBJECT 3 is a 33-year-old female (DOB 02/04/1988) who has a stress level of 5 on a scale of 1 to 10. Subject 3 experiences stress due to work and relationships, which affects her emotional and physical health. She would like to achieve more relaxation, lower her stress, and sleep better. Her self-care program involves relaxation music which helps her to fall asleep at night immediately. She reports no significant physical or mental issues and is taking no medications.

SUBJECT 4 is a 52-year-old female (DOB 3/22/1969) who has predominantly anxiety at a level of 3 on a scale of 1 to 10. Subject 4 experiences menopausal symptoms such as anxiety and poor sleep, for which she takes Bijuva. Her anxiety is amplified by work and poor organization/planning ahead skills, and she would like to use BB to experience greater relaxation. She has tried over-the-counter sleep aids.

## RESULTS

The combined results for each study participant were as follows. The combined three WAVi P300 measurements for each study participant are presented first with the bioenergy results. The Menlascan results are summarized at the end. See supplementary summary charts for CZ Theta Beta Assessment Scores, F3/F4 Alpha Assessment Scores, and Menlascan Scores. There is also a sample bioenergy reading.

### Subject 1

**State CZ Theta Beta Assessment Scores.** Subject one began with a control score of 2.1, which lowered dramatically to .8 when BB was introduced to the brown noise. In the second session, the number lowered dramatically again from 2.7 to 1.1 when BB was introduced to the music.

**State F3/F4 Alpha Assessment Score.** Subject 1 experienced the opposite of the expected outcome, instead showing a lowering of numbers from .7 to .2 when BB was added to the brown noise, indicating a more negative processing mode rather than a more positive mode. However, it correlated with his personal assessment, in which Subject 1 reported the brown noise as intolerable, saying: "Felt a "white noise" calm almost "ocean" but over time it became less calming and almost causing mild discomfort like if I was trapped in a loud "machine" room. When the headset was removed, it was a relief." By contrast, when BB was added to the music in session 2, the expected positive increase from .7 to 1.5 was achieved.

**Scalp Topography.** Figure 1 shows the scalp topography of the brain response for each session for Subject 1. In Session 1, we see that his otherwise calm brain became more attentive in the frontal area after brown noise, indicating thinking, but adding the BB in Session 2 moved the activity to the middle of the brain (location of the CZ point), indicating psychomotor or sensory processing. Condition 3 of music only created a very active brain, especially in the frontal areas. Condition 4 with the BB calmed down all but the frontal brain, a possible indication of the positive effects of BB.

**Bioenergy.** Subject 1's bioenergy rose after listening to brown noise plus BB from 22011 area and 94% symmetry to 23325 area and 94% symmetry. Listening to music plus brown noise plus BB caused an increase to 25205 area and 94% symmetry.

### Subject 2

**State CZ Theta Beta Assessment Scores.** Subject 2 began with a control score of 2.3, which lowered dramatically to 1.5 when BB was introduced to the brown noise. In the second session, the number lowered again from 2.6 to 2.5 when BB was introduced to the music.

**State F3/F4 Alpha Assessment Score.** Subject 2 be-

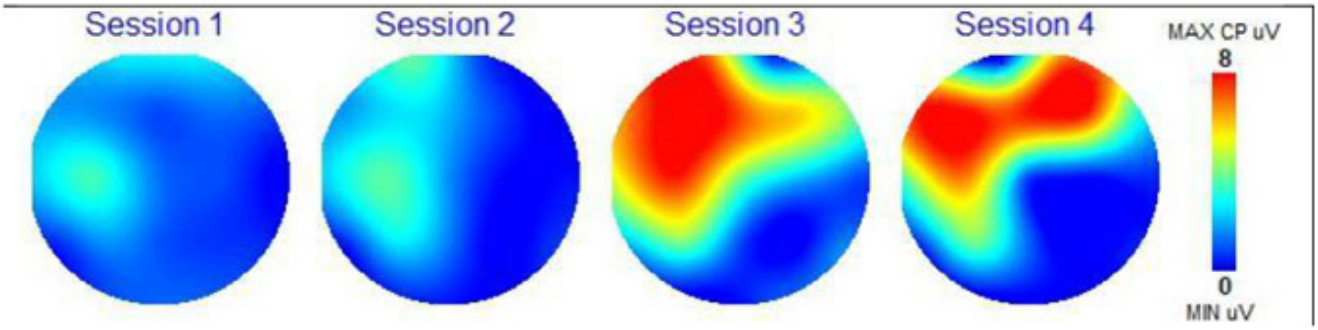


**Figure 2**. Scalp Topography of Brain Response: Subject 2.

gan with a control score of 0.5, which expectedly rose to 0.9 when BB was added to the brown noise. When BB was added to the music in session 2, again, the expected positive increase from 1.0 to 1.1 was achieved.

**Scalp Topography.** Figure 2 shows scalp topography for each session for Subject 2. The brain of Subject 2 became slightly more attentive after adding BB in Session 2 in the area of sensorimotor integration. There was not much overall activity in response to the first two brown noise Conditions. The music in Sessions 3 and 4 seems to have had a profound effect on the brain of this subject in the left and temporal areas. These brain regions correspond to attention, motor planning, working and verbal memory, and sensorimotor integration. Adding the BB increased attention in the right frontal lobe area, which is related to motor planning and emotional expression.

**Bioenergy.** Subject 2's bioenergy rose after listening to brown noise and BB from the 20741 area and 94% symmetry to the 20741 area and 93% symmetry. Listening to music plus brown noise plus BB caused an increase to 20283 area and a slight decrease in symmetry to 92%.

## Subject 3

**State CZ Theta Beta Assessment Scores**. Subject 3 began with a control score of 1.8, which lowered dramatically to 1.0 when BB was introduced to the brown noise. In the second session, the number lowered again from 1.4 to 1.3 when BB was introduced to the music.

**State F3/F4 Alpha Assessment Score.** Subject three began with a control score of 1.2 which rose to 1.4 when BB were added to the brown noise. When BB were added to the music in session 2, the expected positive increase from 0.4 to 0.9 was achieved.

**Scalp Topography.** Figure 3 shows the scalp topography of the brain response for each session for Subject 3. It can be noted that after listening to Condition 1, her brain was aroused almost all over, indicating some level of agitation. After listening to Condition 2, the brown noise plus BB, her brain calmed down. After listening to Condition 3, the music track with brown noise, her brain became somewhat active, but not excessively, indicating that some memories were slightly activated (the top central yellow region) and that there was some cognitive processing (as shown by the bottom yellow region). After listening to Condition 4, the music track with brown noise and BB, her brain calmed down.

**Bioenergy.** Subject 3's bioenergy rose after listening to brown noise and BB from 18909 area and 87% symmetry to 22289 area and 93% symmetry. Listening to music plus brown noise plus BB caused an increase to 20932 area and symmetry to 93%.

## Subject 4

**State CZ Theta Beta Assessment Scores.** Subject 4 began with a control score of 1.0, which lowered to 0.9 when BB were introduced to the brown noise. In the second session, the number did not decrease, but rose

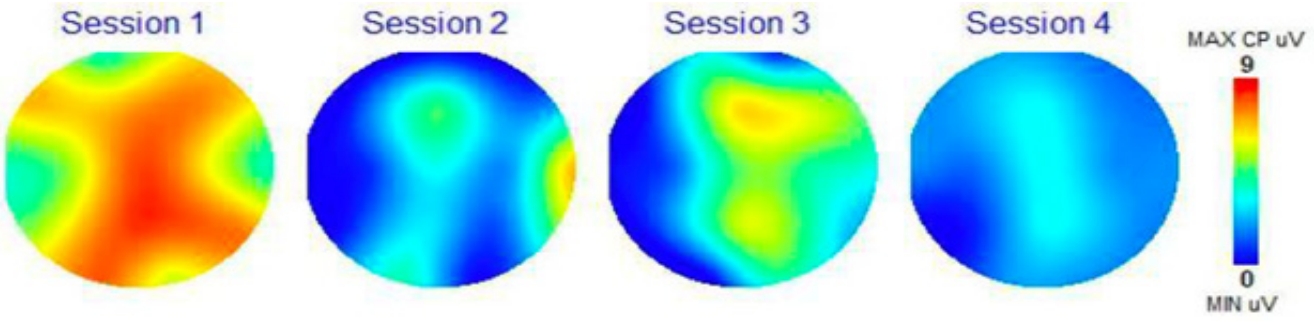


**Figure 3**. Scalp Topography of Brain Response: Subject 3.

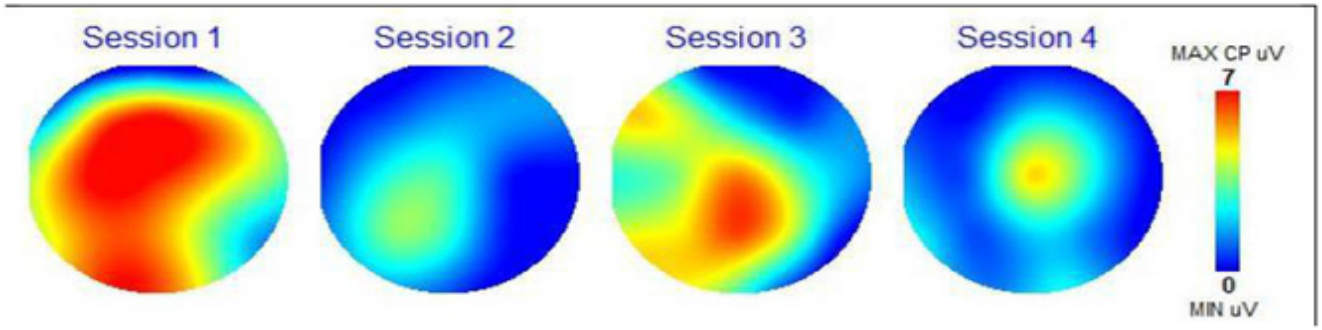


**Figure 4**. Scalp Topography of Brain Response: Subject 4.

from 0.9 to 1.5 when BB were introduced to the music. The unexpected increase may be attributed to processing of memories. Adding BB increased her bioenergy significantly.

**State F3/F4 Alpha Assessment Score.** Subject 4 began with a control score of 1.1, which rose to 1.4 when BB was added to the brown noise. When BB was added to the music in session 2, again, the expected positive increase from 1.1 to 1.8 was achieved.

**Scalp Topography.** Figure 4 shows the scalp topography of Subject 4 for each session. It can be noted that after listening to Condition 1, brown noise, her brain was aroused almost all over, indicating some level of agitation. After listening to Condition 2, the brown noise plus BB, her brain relaxed quite a bit. After listening to Condition 3, the music track with brown noise, her brain became active in the central lower central region of the brain, a region performing cognitive processing. After listening to Condition 4, the music track with brown noise and BB, her brain calmed down further, with the middle of the brain slightly active, a region performing sensorimotor integration.

**Bioenergy.** Subject 4's bioenergy rose after listening to brown noise and BB from 13521 area and 65% symmetry to 18728 area and 915% symmetry. Listening to music plus brown noise plus BB caused an increase to 19927 area and symmetry to 94%.

### Menlascan

The Menlascan results provided measurements of the cardiovascular system and microcirculation. The most important results here are the improvement of cardiovascular and microcirculation scores as the ANS is prone to rapid changes with emotions. Subject 1 had the highest microcirculation score with Condition 2, brown noise and BB, and an increased cardiovascular score from Condition 4, music and BB (although just the control musical track increased cardiovascular as well). For subject 2, there was no improvement with Condition 2, brown noise, and BB. Condition 4, music, and BB increase both the cardiovascular and microcirculation score.

For subject 3, our introverted subject, we see the least effect, with both Condition 1, brown noise and Condition 2, brown noise and BB, increasing only cardiovascular score, and Condition 4, music and BB providing only a mild cardiovascular improvement. In subject 4, there is a mild improvement only in cardiovascular after Condition 2, brown noise and BB, Condition 3 and Condition 4.

## DISCUSSION

In conclusion, Subject 1 became more attentive after Session 2 and Session 4, a possible indication of the positive effects of BB. Additionally, the brain of this subject became calmer after Session 4, a possible additional benefit of combining BB with music. Subject 1 had the highest microcirculation score with Session 2, brown noise and BB, and an increased cardiovascular score from Session 4, music and BB (although just the control musical track increased cardiovascular as well). These results agree with a personality that is conscientious and open.

Subject 2 became more attentive after Session 2 and had a more positive mood. Adding BB to brown noise and to music with brown noise seems to have helped this subject to be more present and have a more positive mode of processing information. The cardiovascular and microcirculation results were unremarkable. Overall, this subject has an excellent cardiovascular system. These results are consistent with the personality of this subject, which is very stable emotionally, with tendencies toward agreeableness and openness. After listening to the music track with brown noise, Subject 3's brain became somewhat active but not excessively, indicating that some memories were slightly activated.

After listening to the music track with brown noise and BB, her brain calmed down. A notable change that occurred when comparing before and after listening to Condition 2, brown noise and BB, is a decrease in microcirculation score that is unexpected. Also, unexpectedly, after listening to brown noise with BB, the cardiovascular score dropped as well. However, when Subject 3 came

to the lab the next day (day 2), her microcirculation and cardiovascular scores had improved, possibly from the effects of the BB. After listening to Condition 3, music with brown noise, the only change is a decrease in microcirculation score. Maybe she did not like the music? This subject is more of an introvert than an extrovert. Perhaps here we see the interaction of this quality, and the above results are related to this feature of her personality?

After listening to Condition 2, the brown noise and BB, Subject 4's brain relaxed quite a bit. The same happened when listening to Condition 4, music plus brown noise and BB. She has a positive processing brain (F3/F4 scores), which has become even more so after adding BB. Subject 4's Menlascan scores did not change much after listening to brown noise, with the exception of the cardiovascular score going down. However, this score improved after listening to Condition 2, brown noise with BB. After listening to Condition 4, music plus brown noise with BB, both her microcirculation and cardiovascular scores improved. BB seems to be enhancing whatever this subject hears. Subject 4 has strong tendencies toward Agreeableness and Conscientiousness. Maybe she did not like brown noise alone, but she liked the music, which mitigated the effect of the brown noise. Adding BB seems to have the effect of increasing this subject's scores.

Based on these results, all four recipients responded positively to therapeutic relaxation from listening to BB. For the most part, they left the lab feeling better and more relaxed than when they arrived, per our data and their own BMIS self-assessment—especially after BB was added to relaxation music. Given their individual preferences and needs, the Sponsor would recommend Alpha-Theta relaxation BB music as a form of meditation for Subjects 1, 3, and 4. It is best to listen to music for 10 minutes a day, and headphones must be worn. The best times are during morning or evening meditation practice times or in the afternoon for rest and recharge or integration of a busy day. Subjects 1, 3, and 4 would benefit from Delta BB sleep tracks, which are best listened to before sleep. And subject two would benefit from an active meditation, such as an Alpha-Theta BB walking tracks. Subject 2 would also benefit from Alpha-Theta BB tracks for creativity as he plans the second chapter of his life in retirement. Subject 3 would also find support for their menopausal lack of focus and disorganization with Beta BB focusing tracks. These recommendations essentially lay the framework for future studies with large sample sets of individuals, consistently using the BB tracks 10 minutes a day, Monday through Friday, for a period of six weeks. A home measurement device to measure the brain would need to be employed, as well as self-assessment questionnaires. There is particularly the question of how menopausal women would respond to BB, given the hormonal component of the response to BB (Tobias, 1965).

The Sponsor chose a within-subject design to specifically test all independent control variables (noise, noise and BB, music, music, and BB) on all subjects, wanting to know if adding the BB into the exact same condition would provide any differences at all. As it happens, it did. In order to make sure that each condition was cleanly measured, we gave enough time for participants to return to baseline conditions, in addition to having part one and part two on two different days, but it is important to remember that the brain always changes and a new baseline had to be established for each experiment. Either way, four subjects are not enough to conduct statistical analysis or to do between-subject comparisons. What this study hopes to illustrate is that it is important to begin to develop protocols for studying BB so that larger studies can be conducted and their results can be compared.

The scalp topography maps illustrate the impact of the four auditory conditions on the electrical activity of the brain, changing its activity in response to the control state. In most instances, we are seeing a calmer brain when BB is added to the auditory condition. The CZ Theta Beta scores and F3/F4 Alpha scores presented a clear path toward observing the impact of the BB conditions on the specific frequency bands in the brain. Here, we are able to trace the changes in the brainwaves as they respond to different conditions. Although the sample set is small, 14 out of 16 measurements were as expected. This is a clear indication that this biometric is a strong choice for further studies with larger sample sets.

Overall, there is a mild increase in relaxation metrics such as cardiovascular and microcirculation scores, and there is not enough data to be conclusive. Bioenergy also improved for each subject. The Sponsor hopes to model an excellent method for studying the effects of BB on the cardiovascular system, but a larger sample size is needed for any true narrative to be discovered.

As regards the circadian rhythms component of the experiment, there was no way to discern a difference between the morning and afternoon data because they were experiencing different conditions. In fact, the design of the experience was such that everyone did the same thing at the same time for the express purpose that there be no difference in the data. Accounting for circadian rhythm is an important and suggested protocol for testing stimulation therapies, including BB (Atwater, 2001; Rossi, 1986; Shannahoff-Khalsa, 1991; Webb & Dube, 1981).

Given the research, we would expect to see that the introverted subject is less affected than the extroverted subjects (Chaieb et al., 2015; Stelmack et al., 1993), and

we have hypothesized a potential difference, but again, there is not enough data to come to a full conclusion. Either way, the Sponsor wants to model that this data should be included in every BB study, given the research that introversion and extroversion are pertinent factors (Chaieb et al., 2015). There is a growing field of personality assessment and music preferences, indicating that these factors are of importance (Anderson et al., 2021; Rentfrow et al., 2011). A similar study with a greater number of participants is suggested.

## IMPLICATIONS AND APPLICATIONS

The results of the present case study are encouraging. Further study into brainwave response to BB can contribute to potential therapeutic applications. It is recommended that further research be performed using different ranges of BB, varying amounts of exposure time, and a combination of multiple frequencies of BB to identify the most effective applications.

## CONCLUSION

The aim of this case study is to assess the effects of adding BB to music and to brown noise on the brain, bioenergy, and physiology of four study participants who were seeking relief from stress and/or relaxation. As seen in the scalp topography maps and the cardiovascular data in particular, each participant had very different responses to the four auditory conditions, yet data from the brain activity of all four participants showed in visual and numerical representation that the effects of BB were deeply embedded within the mind. All four study participants experienced an improvement in brain function and had a calmer brain after adding BB to brown noise or to music plus brown noise. Most also showed an improvement in microcirculation or cardiovascular score after listening to music, plus brown noise and BB. Since the BB was not audible, these effects could not be attributed to the placebo effect.

Listening to BB has been shown to induce synchronization of the brain hemispheres (Solca et al., 2016), and BB helps us to study or to affect cognitive brain function (Becher et al., 2015; Beauchene et al., 2016; Garcia-Argibay et al., 2019). When BB is used in a well-researched, conscious, evidence-based manner, there is a large amount of evidence showing that BB can be helpful in the categories of sleep (Bang et al., 2019; Gantt et al., 2017; Jirakittayakorn & Wongsawat, 2018; Lovati et al., 2019), anxiety (Garcia-Argibay et al., 2019; Isik et al., 2017), stress (Gantt et al., 2017), brain function (Gao et al., 2014; Reedijk et al., 2015), attention/cognition (Axelsen et al., 2020; Colzato, Barrone et al., 2017; Garcia-Argibay et al., 2019; Lim et al., 2018), memory (Colzato, Steenbergen, & Sellaro, 2017; Gálvez et al., 2018; Lim et al., 2018); nervous system (Da Silva Júnior et al., 2020), trance/meditation (Jirakittayakorn & Wongsawat, 2018; Perales et al., 2019), and as an analgesic (Garcia-Argibay et al., 2019; Gkolias et al., 2020; Perales et al., 2019). Gao et al. (2014) specifically suggested that treatments to improve clarity, focus, and sleep, deepen meditation relaxation, increase working memory and episodic memory, and support ADHD may be the proper application of this tool. In addition, they discussed Theta as a possible antidote for the Beta overwhelm that frequently occurs in patients with schizophrenia and depression (Krasnoff, 2021).

There are still many BB studies that show inconclusive or no effects (López-Caballero & Escera, 2017; Lovati et al., 2019; Munro & Searchfield, 2019; Perez et al., 2020; Solcá et al., 2016). This relatively new research field is still determining its parameters. Inconclusive studies could possibly be the result of selecting the wrong brainwave for the wrong task. Theta brainwaves are expected to induce relaxation but not increase focus, and we see Pluck and López-Águila (2019) conducted a controlled, double-blind experiment to explore the effect of Theta (6 Hz) BB on cognitive fluency and fear. Beta brainwaves would have been a more expected choice for this study. In other studies, such as López-Caballero and Escera (2017), we see a usage time of 3 minutes for the BB when research tells us that we need a minimum of 8 minutes (Garcia-Argibay et al., 2019). Inconclusive and negative result studies are essential for determining the parameters of this technology. What was once the main theory that BB operates through the process of entrainment is now a discussion about stochastic resonance, brain regulation, the RAS, and neurotransmitters (Krasnoff, 2021). These are key research directions that will benefit the field of BB.

Lastly, it should be remembered that each auditory brain is different, representing the sum total of an individual's life experiences (Kraus, 2021). The auditory brain is a living system that teaches itself how to interpret sound and how to hear that sound with each afferent/efferent loop in the auditory pathway we call hearing (Kraus, 2021). Therefore, no two brains will respond the same to any auditory condition. What this means is that each individual must be individually diagnosed, assessed, and treated when it comes to sound. A relaxation track for one individual might be a lullaby, and for another individual, a heavy metal group like Metallica. In this pilot study, we can see that brain activity responds differently to all auditory conditions, which underlines that individual responses must be taken into account. Large sample sets help to offset these individual differences. The results of the study are encouraging in terms of developing

musical products incorporating BB to affect human neural rhythms and corollary states of consciousness. This research represents a bridge between sound technology and neuroscience.

***Strengths.*** The strengths of this case study include the consistency of the time spent on data gathering. All testing was done at the same time of day so that all participants could account for circadian rhythm. The BB were inaudible, which eliminated the placebo effect, and sequenced into the experiment such that we could immediately see whether there was a change or not. The study was double-blinded and was conducted with two control conditions.

***Limitations.*** Limitations of this case study included the small number of participants – four. A small sample size may make it difficult to determine if a particular outcome can be generalized to a larger population. There was a geographic limitation of the sample since all participants were from the same area near the research laboratory site. Since study participants were not confined to the laboratory during the duration of the study, external conditions could have influenced their response to the auditory stimulation.

These results are encouraging and warrant further research with more participants and different frequencies of BB and different musical tracks. Further study into the use of binaural beats for augmenting brainwaves can help diversify the knowledge about potential therapeutic uses. Investigations using large sample sets, different ranges of binaural beats, varying amounts of exposure time, a combination of multiple frequencies of beats, different carrier frequencies, and more sophisticated statistical analysis (Atwater, 2001; Chaieb et al., 2015; da Silva Júnior et al., 2020; Gkolias et al., 2020; Huang et al., 2008; Solcá et al., 2016) are recommended to identify the most effective use of such strategies.

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## AUTHOR CONTRIBUTIONS

**Elizabeth Krasnoff, Ph.D.:** Sponsor - Writing – Editing – Supervision – Auditory software – Method - Conceptualization.
**Gaétan Chevalier**: Principal Investigator**,** Research Director

**Conflict of Interest**

Elizabeth Krasnoff, Ph.D discloses a conflict of interest. She uses binaural beats in her sound medicine practice. She also makes and sells binaural beats products.

**Data Availability**

Data Files available on Figshare: https://figshare.com/s/cfc3ca4e38bc88008ad4 (General link to use prior to publication)

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