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The Effect of Binaural Beat Technology on the Cardiovascular Stress Response in Military Service Members With Postdeployment Stress

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Abstract

Purpose: To assess the efficacy of embedded theta brainwave frequency in music using binaural beat technology (BBT) compared to music alone on the cardiovascular stress response in military service members with postdeployment stress.

Design: A double-blinded, randomized, pre- and postintervention trial.

Methods: Seventy-four military services members with complaint of postdeployment stress were randomized to either music with BBT or music alone. Each group listened to their respective intervention for a minimum of 30 min at bedtime for three consecutive nights a week for a total of 4 weeks. A 20-min pre- and postintervention heart rate variability (HRV) stress test and daily perceived stress via diaries assessed intervention efficacy.

Findings: There was a statistical difference ($p = .01$) in low-frequency HRV between the music with BBT group compared to the music only group. The average low-frequency HRV decreased in the music with BBT group 2.5 ms^2/Hz, while in the music only group it increased 7.99 ms^2/Hz. There was also a significant difference ($p = .01$) in the high-frequency HRV measures, with the music with BBT group showing an increase in HRV by 2.5 ms^2/Hz compared to the music only group, which decreased by 7.64 ms^2/Hz. There were significant ($p = .01$) differences found in total power measures, with the music only group decreasing by 1,113.64 ms^2/Hz compared to 26.68 ms^2/Hz for the music with BBT group. Finally, daily diaries consistently showed that participants who used BBT reported less stress over the course of the 4 weeks.

Conclusions: When placed under an acute stressor, participants who used music with embedded BBT showed a decrease in sympathetic responses and an increase in parasympathetic responses, while participants who used music alone had the opposite effect.

Clinical Relevance: The use of BBT in the theta brainwave frequency embedded into music decreases physical and psychological indications of stress. BBT embedded with beta and delta frequencies may improve cognitive functioning and sleep quality, respectively.

Cardiovascular disease (CVD) is the leading cause of death in the United States (U.S. Department of Health and Human Services, Center for Disease Control, and Prevention, National Center for Health Statistics, 2015). Although young and held to a higher fitness standard than the general public, military personnel are at higher risk for CVD than the general population (Armed Forces Health Surveillance Center, 2011). Numerous studies have shown a link between combat exposure and increased risk for CVD in Vietnam veterans (Eisen et al., 2005; Gray, Reed, Kaiser, Smith, & Gastanaga, 2002; McCauley, Lasarev, Sticker, Rischitelli, & Spencer, 2002). Soldiers deployed in combat regions are 1.28 times more likely to develop hypertension than those who did not have combat exposure (Granado et al., 2009). Approximately 8% to 11% of veterans returning from deployment rate their health as "fair to poor," with an increase to 10% to 13% 6 months later (Armed Forces Health Surveillance Center, 2011). Returning veterans are at high risk for health concerns such as stress, anxiety disorders, poor sleep quality, and substance abuse, all of which have a negative effect on the cardiovascular (CV) system (Armed Forces Health Surveillance Center, 2011; Thomas et al., 2010).

The CV system is negatively impacted by anxiety and stress via neurological and endocrine pathways (Olafiranye, Jean-Louis, Zizi, Nunes, & Vincent, 2011). Overactivation of the stress response, or allostatic load, increases the risk for CVD (McEwen, 1998). Chronic stress produces an autonomic imbalance with a predominance of sympathetic activity that results in dysregulation of daily blood pressure patterns and heart rate variability (HRV). Typically, blood pressure decreases at night, surges upon awakening, and remains elevated throughout the day (Giles & Izzo, 2008; Kario et al., 2003). A dysregulated system secondary to chronic stress exposure will have a greater surge magnitude in the morning and a blood pressure (BP) that does not drop by at least 10% during sleep (Giles & Izzo, 2008; Grassi, 2009; Kario et al., 2003; Kikuya et al., 2000; Stolarz, Staessen, & O'Brien, 2002). As for HRV, a high HRV is associated with greater parasympathetic drive, which is cardioprotective, while low HRV associated with greater sympathetic drive increases CVD risk (Taylor, 2010).

Heart rate variability is mediated by the autonomic nervous system (ANS). The ANS comprises the parasympathetic nervous system (PSN) and the sympathetic nervous system (SNS; Larkin, 2005). The SNS, often known as the stress response, is characterized by pupil dilation, decreased saliva, increased heart rate, bronchial dilation, decreased gastrointestinal motility, glycogen glucose conversion, secretion of adrenaline and noradrenalin, and the inhibition of bladder contraction (Larkin, 2005). As for the PSN, the relaxation state, the opposite occurs. The pupils constrict, saliva increases, heart rate decreases, to name a few (Larkin, 2005). To measure HRV electrodes are often attached to display two commonly used measures, low frequency (LF) and high frequency (HF; Medicore, 1996; Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology, 1996). LF bands (.04–.15 Hz) measure both the PSN and SNS activity, while HF bands (.15–.4 Hz) measure PSN activity (Medicore, 1996). For example, during a stressor, LF increases while HF decreases, and when relaxed HF should increase while LF decreases.

With the number of veterans returning with CV dysregulation indicated by increased anxiety, stress disorders, or elevated risk for CVD, there is a need for a low-cost, acceptable intervention designed to counteract this CV dysregulation. Since CV function can be conceptualized as primarily rhythmic processes, like many biological processes, interventions targeting physiological rhythms are appropriate (Glass, 2001). For instance, entrainment is a common phenomenon used by music therapists to influence behavioral, motor, or physiological responses of patients (Stegemoller, 2014). Entrainment principles have been useful in assisting stroke and Parkinson's disease patients improve gait, improve cardiac function, and decrease stress (Thaut, McIntosh, & Hoemberg, 2015).

Binaural beat technology (BBT) is a specific form of entrainment that was first discovered by a German researcher named Heinrich Wilhelm Dove in 1839 (Oster, 1973). This phenomenon occurs when one listens to two "mistuned" tones that in turn create a third tone known as the binaural beat. This third tone is not heard but is processed in the area of the brain where the contralateral integration of the auditory input (known as the superior olivary nucleus) resides (Moore, 2004; Swann, Bosanko, Cohen, Midgley & Seed, 1982). This in turn affects the reticular activating system, which alters the electrical potentials of the thalamus and cerebral cortex, changing the brainwave frequency. This concept is known as the frequency following response, in which the intervals of neural activity synchronize with the cycle of the stimulus (Smith, Marsh, Greenberg, & Brown, 1978). As a result, the entrainment or synchronization affects the listener's mental, physical, or emotional state (Monroe Products, 2016). If changing brainwaves can mediate psychological stress, this mediation may affect the CV stress response.

In a study published in 2014, 21 participants were randomized into two groups to assess the effect of BBT on HRV following 20 min of CV exercise at a 70% maximum oxygen uptake (VO_2 max; McConnell, Froeliger, Garland, Ives, & Sforzo, 2014). Using a double-blinded repeated measure approach, HRV was measured at three

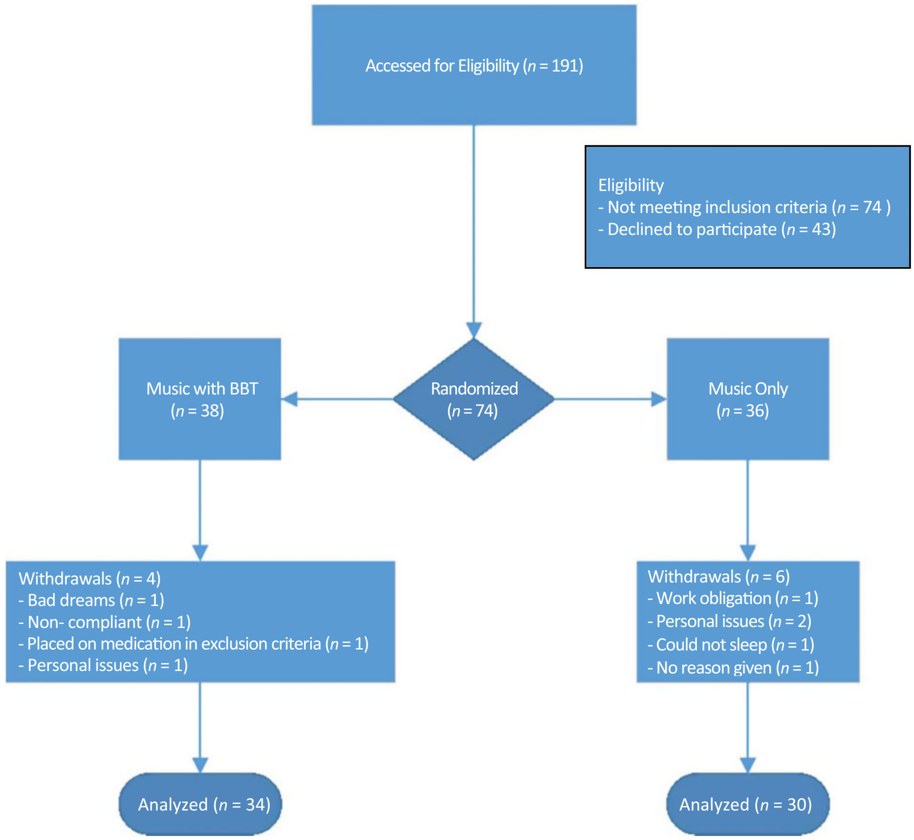

Figure 1. Participant flow diagram. BBT = binaural beat technology.

time points after the stressor. During the first 10 min of relaxation, there was a significant difference ($p = .003$) in LF, with the placebo group indicating a constantly higher LF compared to the BBT group (McConnell et al., 2014). Additionally, the BBT group had a consistently higher HF compared to the control group during the first 10 min, and this difference was statistically significant ($p = .03$; McConnell et al., 2014). Perceived stress measures were also taken. Participants in the BBT group reported more relaxation in comparison to the placebo group ($p = .04$; McConnell et al., 2014). While McConnell et al.'s study assessed the effect of BBT on HRV (while in use) and perceived relaxation after a "physical" stressor, the current study assessed the effect of BBT on HRV (after using it for 4 weeks) and perceived stress after a "psychological" stressor. This study is the first documented study using entrainment in a military population.

Purpose

The aim of this study was to assess the efficacy of music embedded with BBT in the theta brainwave frequency (4–7 Hz) on the CV stress response in a group of military service members with a complaint of chronic stress following deployment compared to music alone.

Methods

Design

The research team used a prospective, double-blinded, randomized, pre- and postintervention design to conduct this study.

Participants

Since this study involved the comparison of two groups at a minimum of two intervals, a power analysis was conducted for the 2 × 2 mixed analysis of variance (ANOVA; between and within design). For a medium effect (.025) and a power of 0.95, a target sample of 54 was needed. To address the possibility of attrition over the 3 years of the study, the sample size was increased by 35%, which equaled an additional 19 participants for a sample size of 73. To make the groups equal, the total sample size was increased by one for a total 74 participants (**Figure 1**).

The participants consisted of military service members with a complaint of continued stress following a deployment. Participants were recruited from two military healthcare treatment facilities located in the eastern United States. To be included in the study, participants had to be 18 years of age or older, have a history of deployment within the last 10 years, be eligible to receive health care at the two military healthcare treatment facilities, and be able to commit to the 4-week study. Participants were excluded if they were taking any medication in the antihypertensive, antianxiety, or antiseizure categories, had been diagnosed with moderate to severe traumatic brain injury (TBI), or had a history of epilepsy, documented hearing deficit, utilization of a hearing aide, or ear trauma.

Measures

Heart rate variability. The Biocom Technologies© HRV Live 1.0 Heart Rate Variability Monitor and Software (Poulsbo, WA, USA) was used to capture HRV measures at baseline and again after using the intervention for 4 weeks. Using a dual chest electrode, continuous HR signals were captured, digitized, and analyzed on a computer via Bluetooth technology. Continuous HR measures were collected during five 5-min intervals: (a) baseline, (b) while being trained for the hand-eye coordination challenge, (c) during the challenge, (d) after the challenge, and (e) when verbally coached to relax.

Daily logs. Daily logs were completed upon awakening to document if they followed the protocol as instructed and to answer the questions "Were you tense (stressed) at work yesterday?", if applicable, and "Were you tense (stressed) at home yesterday?"

Intervention

The Monroe Institute's Hemi-Sync "Dreamland" audio files (embedded with BBT in the theta brainwave frequency, approximately 4–7 Hz) via a mini mp3 player and specialized headphones was used as the intervention. "Hemi-Sync is an audio-guidance process system that works through the generation of complex, multilayered audio signals, which act together to create a resonance that is reflected in unique brain wave forms characteristic of specific states of consciousness" (Monroe Products, 2016). The audio file contained a variety of separate tracks, each ranging from 5 to 10 min in length with an assortment of different music styles. All mp3 players started with the same track and after reaching the last track looped back to the beginning for continuous play throughout the night. Those in the music only group had the same identical tracks but without the technology. Each week the participants chose a minimum of at least three consecutive nights in which they were to use their respective intervention for a minimum of 30 min at bedtime. This process was repeated each week for the duration of the 4 weeks.

Procedure

The study was approved by the Walter Reed Army Medical Center's Institutional Review Board, and the data were collected between June 2012 and July 2015. As participants enrolled, they were assigned a unique study identification number and were asked to blindly pick from a box of preloaded mp3 players (half containing music with BBT and half containing music alone). To ensure that the investigator remained blinded throughout the duration of study, the mp3 players were shipped from the distributor already coded with unique identifiers, randomized, and packaged in groups of 10 to ensure that at any given time during the 3 years there would be equal distribution between both groups. The distributor maintained the key code until all participants completed the intervention.

Pre-intervention phase. After they consented, participants completed a participant information sheet that included age, race, ethnicity, gender, marital status, military branch of service, military status, rank, date returned from last deployment, location of deployment, and number of times deployed. Participants were instructed to abstain from caffeine products at least 6 hr before participating in the hand-eye coordination challenge to collect baseline HRV measures.

Hand-eye coordination challenge. To put the participants into a stressed state, participants were asked to play the Mattel game "Operation" for 5 min while connected to the HRV monitor. In this game, forceps are used to extract small pieces from an animated figure. If the forceps touch the sides of the figure, a loud sound occurs. To make the challenge more stressful, participants had to play the game via a mirror with only 10 s per piece. If the piece was not extracted within 10 s, a second buzzer was activated signaling the participant to move to the next piece.

At the conclusion of the HRV test, participants were given:

1. MP3 player preloaded with Hemi Sync's audio files (depending on group assignment).
2. SleepPhone stereo headphones to work in conjunction with the mp3 player.

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3. A set of daily diaries.
4. Participant instruction sheet.

Intervention phase (4 weeks). Participants were instructed to listen to their respective mp3 player for a minimum of 30 min at bedtime on three consecutive nights per week for 4 weeks. Upon awakening, participants were instructed to complete a short daily log. Each week the research coordinator contacted the participants for quality checks to ensure compliance.

Postintervention phases. After using the intervention for 4 weeks, each participant returned (within 1 week of last use of the technology) for one post-intervention HRV test, conducted in the same manner as the pre-intervention HVR test conducted 4 weeks earlier, in order to compare pre- and postmeasures.

Data Analysis

SPSS v. 22 statistical software (SPSS, Inc., Chicago, IL, USA) was used to assist in analyzing the data. Descriptive statistics were used to compile the demographic data. A mixed ANOVA was conducted to determine to what extent the two groups differed on LF, HF, and total power HRV measures across the two waves of data collection based on the following 2 × 2 (Group × Time) comparisons. For the daily diary questions that contained dichotomous answers, output for the means (which is the proportion that endorsed the "yes" option), a Microsoft Excel line chart was used. All assumptions were examined (e.g., homogeneity of variance-covariance matrices, sphericity if $t > 2$, etc.) as well as any data anomalies (e.g., outliers). The level of significance was set at α of .05 for all analyses.

Table 1. Demographics

Demographics		Music with BBT *n* = 37 (51%)[a]	Music only *n* = 36 (49%)	*p* value
Years of age, mean (*SD*)		38.3 (±8.29)	37.9 (±10.16)	.873
Race	American Indian or Alaskan Native	1 (3%)	0 (0)	.423
	Asian	3 (8%)	4 (11%)	
	African American	11 (30%)	5 (14%)	
	Caucasian	21 (57%)	24 (69%)	
	Other	1 (3%)	2 (6%)	
Ethnicity	Non-Hispanic	11 (65%)	12 (8%)	.52
	Hispanic	6 (35%)	4 (25%)	
Gender	Female	7 (18%)	14 (39%)	.051
	Male	31 (82%)	22 (61%)	
Marital status	Single	8 (22%)	9 (25%)	.727
	Separated	2 (5%)	4 (11%)	
	Divorced	5 (14%)	3 (8%)	
	Married	22 (60%)	20 (56%)	
Branch	Army	26 (70%)	25 (69%)	.811
	Navy	6 (16%)	8 (22%)	
	Air Force	4 (11%)	2 (6%)	
	Marines	1 (3%)	1 (3%)	
Military status	Active Duty	32 (84%)	32 (89%)	.893
	Reserve	2 (5%)	2 (5%)	
	National Guard	2 (5%)	1 (3%)	
	Retired	2 (5%)	1 (3%)	
Months deployed, mean (*SD*)		9.84 (5.29)	9.67 (3.68)	.87
Times deployed, mean (*SD*)		2.32 (1.42)	2.89 (3.79)	.387

Note. BBT = binaural beat technology.
[a]Sample sizes may differ given missing data.

Results

Participant demographics are presented in **Table 1**. The average length of deployment for the entire sample was 9.76 (SD = 4.5) months, the average number of deployments was 2.59 (SD = 2.8), and 54.1% were deployed in Afghanistan.

There was a statistically significant ($p < .01$) difference in the LF HRV measures in which the BBT group showed a decrease (–2.5 ms^2/Hz), while the control group showed an increase (+7.99 ms^2/Hz; **Figure 2**). A statistically significant ($p < .01$) difference was also found in the HF HRV measures, with the BBT group showing an increase (+2.5 ms^2/Hz), while the control group showed a decrease (–7.64 ms^2/Hz) in HRV (**Figure 3**). Finally, the control group showed a statistically significant ($p < .05$) decrease in total power HRV (–1,113.64 ms^2/Hz) compared to the decrease in total power HRV for the BBT group (–26.68 ms^2/Hz; **Figure 4**). When participants were asked if they were stressed at work or at home, the BBT group consistently scored lower across all time points (Figures 5 and 6).

Discussion

Although there are only a handful of studies using HRV as a measure to assess the technology's efficacy, findings were consistent (McConnell et al., 2014; Roy et al., 2012). This study's results suggest that music embedded with BBT in the theta brainwave frequency had a positive

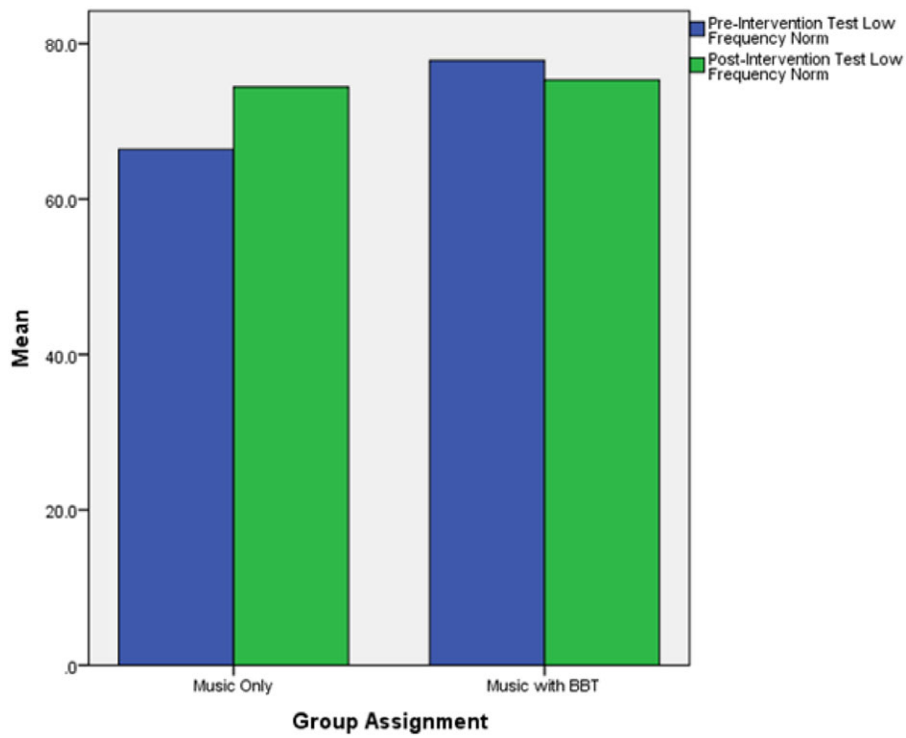

Figure 2. Low frequency heart rate variable while under an acute stressor. BBT = binaural beat technology.

effect on the CV stress response in military service members. Just as in the McConnell et al. (2014) study, which used BBT in the same brainwave frequency (theta) but on a physical stressor, there was a higher incidence of self-reported relaxation with increased parasympathetic activation and decrease sympathetic response after using the technology. This important finding suggests that military service members may be able to more effectively manage stress using music embedded with BBT. Music tends to be a great method for reducing stress in many people; however, the use of the embedded BBT music has the potential to make even greater positive impact on stress. It has become common knowledge that the accumulation of stress over time can lead to multiple behavioral health problems such as posttraumatic stress disorder, anxiety, insomnia, substance abuse, eating disorders, etc. If stress can be managed early and in a noninvasive way, these subsequent issues may diminish.

Interestingly, this study's control group not only had a significant difference when compared to the BBT group, but had the total opposite effect (e.g., decreased parasympathetic activation and increased sympathetic activation). This opposite effect is troubling, because this effect indicates that stress without an intervention poses a significant threat to the health of today's military service members. With the criteria being complaints of continued stress within 10 years of deployment, this may be a cumulative effect of stress that is being demonstrated.

To support the evidence that the control group fared worse, HRV total power was also assessed. Total power reflects overall autonomic activity where sympathetic activity is a primary contributor (Medicore, 1996). In healthy adults, total power should be at least 1,000 ms^2/Hz (Medicore, 1996). In the case of chronic stress, total power decreases due to the weakened regulating function (Medicore, 1996). In this study, the total power in the BBT group remained consistently around 1,200 ms^2/Hz, whereas the control group significantly dropped 1,113.64 ms^2/Hz to a measure of 985.26 ms^2/Hz. This suggests that the control group exhibited more signs of chronic stress, although they were placed under a situation created by an acute stressor in this study.

Several questions still remain. First, does BBT have a dose effect? In other words, would someone who used the technology for 1 week have the same effect as someone who used it for 2 weeks. Since this study was neither stratified nor set up to measure postintervention HRV measures at different intervals, this was difficult to assess. Second, is there a latency period after using the technology? In other words, how long will the participant feel the effect of BBT after it is turned off or does it only work when it is in use? The McConnell et al. (2014) study

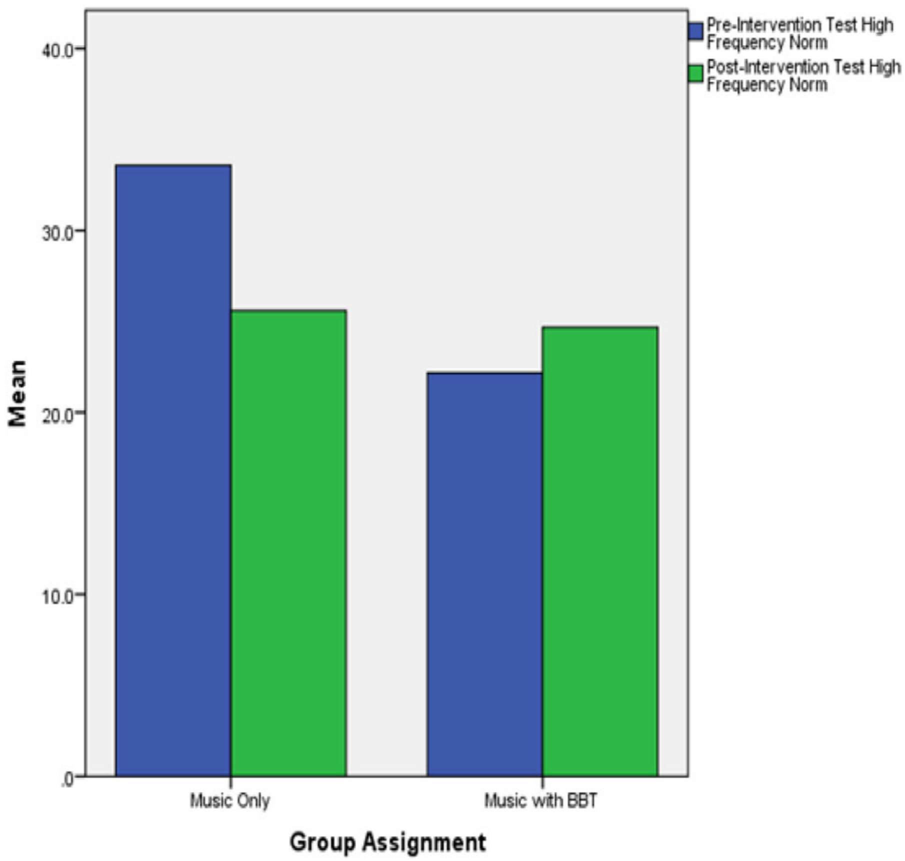

Figure 3. High-frequency heart rate variability while under an acute stressor. BBT = binaural beat technology.

showed that when using BBT for 20 min, there was a significant difference between the BBT and control group in the first 10 min. However, at the 20-min mark both groups had a similar effect. Using a randomized stratified group exposed to the technology for varying times and stopping at different time points could answer these questions.

Limitations

This study had several limitations. First, the two groups were not divided equally (e.g., 37 vs. 37). When the distributor was asked to make the groups equally distributed, they inadvertently sent two equal groups instead (36 vs. 38). Since the study was double blinded, the investigator was not aware of this until the end. Although not divided equally, this did not make a significant impact on the results. Second, although randomized, more females were in the control group than the intervention group (39% vs. 18%). Lastly, other than verbal confirmation from the participants and notes in the daily diary, there was no way to objectively capture the total number of minutes that the intervention was used.

Implications for Nursing Practice and Future Research

BBT does not require a physician's order nor does it need to be administered by an advanced practice provider. It can be an independent nurse-initiated action in an outpatient setting, inpatient setting, or even on military deployments. The vast majority of the participants felt that the SleepPhones and mp3 players were easy to extremely easy to use, had very good quality sound, and were really comfortable to wear. Buy-in from patients is imperative when implementing new innovative treatment modalities. It has been shown that patients who are engaged in their care are more likely to adhere to treatments recommended. For military populations, the capability of an effective intervention that can be used in an austere environment is paramount to keeping service members healthy. Given the stigma often associated with postdeployment stress and the seeking of treatment, the use of BBT is unassuming as it appears as though the service member is simply listening to music.

This technology also has the capacity to be altered to help other common deployment health concerns such as

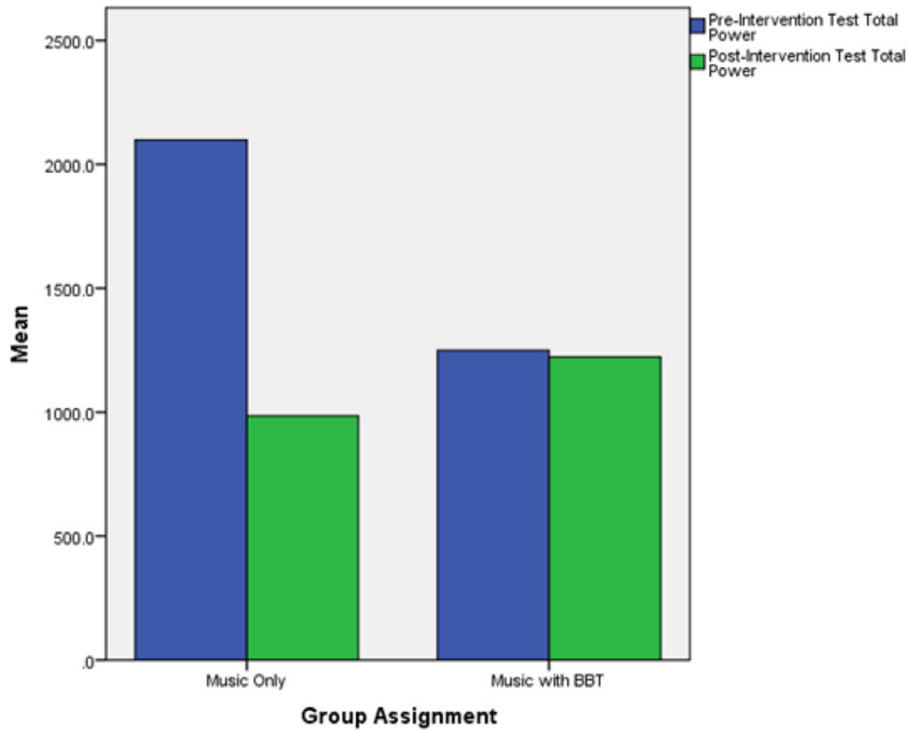

Figure 4. Total power heart rate variability while under an acute stressor. BBT = binaural beat technology.

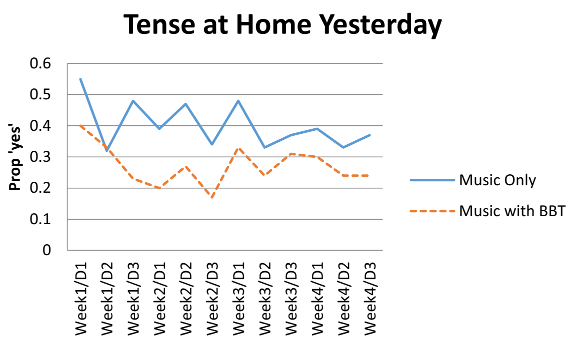

Figure 5. Sleep diary entries: "Were you tensed (stressed) at home yesterday?" BBT = binaural beat technology.

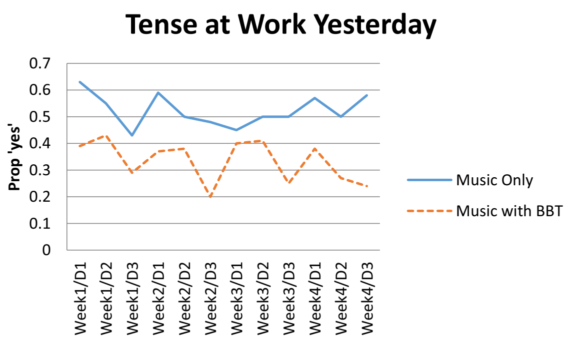

Figure 6. Sleep diary entries: "Were you tensed (stressed) at work yesterday?" BBT = binaural beat technology.

the beta frequency range to improve focus when tired and the delta frequency range to improve sleep quality when hours are limited. One study examined nurse burnout among a group of Army nurses and found high levels of emotional exhaustion secondary to working extended hours and providing care for combat casualties (Lang, Patrician, & Steele, 2012). This treatment modality may prove very beneficial to a group of military nurses that provide care of combat casualties on a daily basis. It is common for many to overlook the stress placed on caregivers. Military nurses are in a very unique situation, whereby they provide care for U.S. military personnel, as well as enemy military and civilian personnel. These particular situations have the potential to put military nurses in ethical dilemmas in which care must be provided to the enemy that targeted friends, colleagues, and fellow service members. Since the technology affects the brainwaves with no required action of the user, it could help minimize some of the negative outcomes associated with these types of psychological stressors.

In future BBT studies, investigators should consider much larger sample sizes that have enough participants to stratify for various outcome measure time points such as dose effect and duration of effect after intervention has ceased. Using mp3 players that can automatically track minutes of use will help provide more objective data. For investigators who plan to conduct BBT studies in the postdeployed population, they need to be cautious given that many in this population may have sustained mild to moderate TBI. The sound technology may in fact worsen the ringing in the ears, which is one of the most common clinical presentations, and it is unclear if the manipulation of brainwave activity may worsen the clinical presentations of a TBI. Finally, adding a functional magnetic resonance imaging of the head before, during, and after using BBT would also provide great objective measures. The fact that BBT can be replicated by anyone with the proper equipment and distributed freely to the public through methods such as YouTube, Apple App store, and Apple iTunes warrants further scrutiny for quality control measures and regulatory oversight. Unfortunately, consumers currently have no way to validate if the correct brainwave frequency is embedded or if the technology is included at all for that manner.

Conclusions

Music embedded with BBT, in the theta brainwave frequency, was found to be beneficial in decreasing the effects of chronic stress exposure. Using HF and LF HRV measures, those who used BBT reported greater relaxation with increased parasympathetic activation and decrease sympathetic response when placed under an acute stressor. The technology's portability, low cost, and ease of use make it a great alternative to other methods often used to decrease stress.

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Clinical Resources

- AcousticSheep LLC. SleepPhones: http://www.sleepphones.com
- Medicore: Heart rate variability analysis system. http://medi-core.com/download/HRV_clinical_manual_ver3.0.pdf
- Monroe Products: Introduction to Hemi-Sync technology video: http://www.hemi-sync.com

References

Armed Forces Health Surveillance Center. (2011). *Deployment health assessments: U.S. Armed Forces*. Retrieved from https://health.mil/Search-Results?query=deployment%20health%202011

Atwater, F. H. (1997). Accessing anomalous states of consciousness with a binaural beat technology. *Journal of Scientific Exploration*, *11*(3), 263–274.

Blake, G. J., Rifai, N., Buring, J. E., & Ridker, P. M. (2003). Blood pressure, C-reactive protein, and risk of future cardiovascular events. *Circulation*, *108*(24), 2993–2999.

Eisen, S. A., Kang, H. K., Murphy, F. M., Blanchard, M. S., Reda, D. J., & Henderson, W. G. (2005). Gulf War veterans' health: Medical evaluation of a U.S. cohort. *Annals of Internal Medicine*, *142*(11), 881–890.

Giles, T., & Izzo, J. (2008). *The hemodynamics of hypertension—The importance of pathophysiology and pharmacology*. Retrieved from http://cme.medscape.com/viewarticle/574350

Glass, L. (2001). Synchronization and rhythmic processes in physiology. *Nature*, *410*(6825), 277–284.

Granado, N. S., Smith, T. C., Swanson, G. M., Harris, R. B., Shahar, E., Smith, B., . . . Gulf War Study Participating Investigators. (2009). Newly reported hypertension after military combat deployment in a large population-based study. *Hypertension*, *54*(5), 966–973.

Grassi, G. (2009). Assessment of sympathetic cardiovascular drive in human hypertension: Achievements and perspectives. *Hypertension*, *54*(4), 690–697.

Gray, G. C., Reed, R. J., Kaiser, K. S., Smith, T. C., & Gastanaga, V. M. (2002). Self-reported symptoms and medical conditions among 11,868 Gulf War-era veterans: The Seabee Health Study. *American Journal of Epidemiology*, *155*(11), 1033–1044.

Kario, K., Pickering, T. G., Umeda, Y., Hoshide, S., Hoshide, Y., Morinari, M., & Shimada, K. (2003). Morning surge in blood pressure as a predictor of silent and clinical cerebrovascular disease in elderly hypertensives—A prospective study. *Circulation*, *107*(10), 1401–1406.

Kikuya, M., Hozawa, A., Ohokubo, T., Tsuji, I., Michimata, M., Matsubara, M., & Imai, Y. (2000). Prognostic significance of blood pressure and heart rate variabilities: The Ohasama study. *Hypertension*, *36*(5), 901–906.

Lang, G. M., Patrician, P. A., & Steele, N. (2012). Comparison of nurse burnout across Army hospital practice environments. *Journal of Nursing Scholarship*, *44*(3), 274–283.

Larkin, K. T. (2005). *Stress and hypertension: Examining the relation between psychological stress and high blood pressure*. New Haven, CT: Yale University Press.

McCauley, L. A., Lasarev, M., Sticker, D., Rischitelli, D. G., & Spencer, P. S. (2002). Illness experience of Gulf War veterans possibly exposed to chemical warfare agents. *American Journal of Preventive Medicine*, *23*(3), 200–206.

McConnell, P. A., Froeliger B., Garland, E. L., Ives, J. C., & Sforzo, G. A. (2014). Auditory driving of the autonomic nervous system: Listening to theta-frequency binaural beats post-exercise increases parasympathetic activation and sympathetic withdrawal. *Frontiers in Psychology*, *14*(5), 1248.

McEwen, B. S. (1998). Protective and damaging effects of stress mediators. *New England Journal of Medicine*, *338*(3), 171–179.

Medicore. (1996). *Heart rate variability analysis systems: SA-3000P clinical manual version 3.0*. Retrieved from http://medi-core.com/download/HRV_clinical_manual_ver3.0.pdf

Monroe Products. (2016). *Hemi-Sync: How Hemi-Sync works*. Retrieved from http://www.hemi-sync.com/hemi-sync-technology/how-hemi-sync-works

Moore, B. (2004). *An introduction to the psychology of hearing*. San Diego, CA: Elsevier Academic Press.

Olafiranye, O., Jean-Louis, G., Zizi, F., Nunes, J., & Vincent, M. (2011). Anxiety and cardiovascular risk: Review of epidemiological and clinical evidence. *Mind & Brain*, *2*(1), 32–37.

Oster, G. (1973). Auditory beats in the brain. *Scientific American*, *229*, 94–102.

Roy, B., Choudhuri, R., Pandey, A., Bandopadhyay, S., Sarangi, S. & Ghatak, S. (2012). Effect of rotating acoustic stimulus on heart rate variability in healthy adults. *Open Neurology Journal*, *6*, 71–77.

Smith, J. C., Marsh, J. T., Greenberg, S., & Brown, W. S. (1978). Human auditory frequency-following responses to a missing fundamental. *Science*, *201*, 639–641.

Stolarz, K., Staessen, J. A., & O'Brien, E. T. (2002). Night-time blood pressure: Dipping into the future? *Journal of Hypertension*, *20*(11), 2131–2133.

Stegemoller, E. L. (2014). Exploring a neuroplasticity model of music therapy. *Journal of Music Therapy*, *51*(3), 211–227.

Swann, R., Bosanko, S., Cohen, R., Midgley, R., & Seed, K. (1982). *The brain: A user's manual*. New York, NY: G. P. Putman's Sons.

Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology. (1996). *Heart rate variability: Standards of measurement, physiological interpretation, and clinical use*. Retrieved from http://circ.ahajournals.org/content/93/5/1043.full.print

Taylor, C. B. (2010). Depression, heart rate related variables and cardiovascular disease. *International Journal of Psychophysiology*, *78*(1), 80–88.

Thaut, M. H., McIntosh, G. C., & Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: Rhythmic entrainment and the motor system. *Frontiers in Psychology*, *18*(5), Article 1185. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4344110

Thomas, J. L., Wilk, J. E., Riviere, L. A., McGurk, D., Castro, C. A., & Hoge, C. W. (2010). Prevalence of mental health problems and functional impairment among active component and national guard soldiers 3 and 12 months following combat in Iraq. *Archives of General Psychiatry*, *67*(6), 614–623.

U.S. Department of Health and Human Services, Center for Disease Control, and Prevention, National Center for Health Statistics. (2015). *Health, United States 2015: With special feature on racial and ethnic health disparities*. Retrieved from https://www.cdc.gov/nchs/data/hus/hus15.pdf#019