THE EFFECT OF SELF-SELECTED MUSIC ON FRONTAL ALPHA ASYMMETRY AFTER EXPERIENCING A COGNITIVE STRESSOR

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
bfCPT	Bilateral Feet Cold Pressor Test
BIS/BAS	Behavioral Inhibition and Activation Scales
EEG	Electroencephalography
ERQ	Emotion Regulation Questionnaire
FAA	Frontal Alpha Asymmetry
FFT	Fast Fourier Transform
fNIRS	Functional Near-Infrared Spectroscopy
GMSI	Goldsmith’s Musical Sophistication Index
GSR	Galvanic Skin Response
HR	Heart rate
HRV	Heart rate variability
MMR	Music and Mood Regulation
PET	Positron Emission Tomography
PFC	Prefrontal Cortex
rCBF	Regional Cerebral Blood Flow

ABSTRACT

Music is an effective means for improving mood, decreasing negative affect and anxiety, and increasing creativity (Chin & Rickard, 2014; Lynar et al., 2017). Recent studies have demonstrated that frontal alpha asymmetry (FAA) may reflect emotion processing, with greater left FAA representing positive affect and greater right FAA demonstrating negative affect (Arjmand et al., 2017). The purpose of this study was to investigate if FAA shifts to the right (indicating decreased alpha power) after a cognitive stressor, then to the left (indicating less alpha power) after listening to self-selected music as a function of changes in state anxiety and mood. Exploratory correlations investigated relationships between the self-reported affect and anxiety and changes in FAA. Participants completed baseline EEG recordings and self-report scales. They then completed a cognitive stressor (Paced Auditory Serial Addition Task) and listened to a self-selected song that "invokes positive mood" while EEG and self-reported mood were monitored. The results indicated that positive affect increased and negative affect and anxiety decreased after music. FAA did not change over time; however, frontal alpha activity increased from baseline to stressor, and further while listening to music. Correlations were found between changes in affect and self-report scales, but not with EEG correlates. Results suggest that music is not relaxing in the traditional sense of the word, in spite of improving state affect and anxiety, but could be representative of an active state of attention in which creative ideation and intersensory processing may occur.

I. LITERATURE REVIEW

Throughout one’s lifetime, engaging in music can act as a useful resource for managing emotion and mood regulation, invoking positive emotions, and promoting a sense of well-being (Chin & Rickard, 2014; Lynar, Cvejica, Schubert, & Vollmer-Conna, 2017; Papinczak, Dingle, Stoyanov, Hides, & Zolenko, 2015). Although it is widely accepted that there is an emotional component involved in music listening, there is much to learn about the underlying neurological processes which bring these emotions to the surface and how these processes can be characterized using physiological measures. In recent years, most neuroimaging studies on music and emotion have implicated the prefrontal cortex (PFC) as a focal point of activity for emotional and musical processing (Daly et al., 2014; Koelsch, 2014; Tsang et al., 2001). These findings indicate that there is a relationship between music listening and emotional processing in the PFC, which may contribute to the emotional benefits of music and provide a mechanism through which music can be used to regulate emotions.

The aim of the current study is to expand on previous research by using electroencephalography (EEG) to investigate frontal activation, specifically frontal asymmetry (FA), after being exposed to a cognitive stressor and while listening to self-selected music chosen to induce positive emotions. The goal of the proposed research is to gain insight into how music plays a role in emotional processing after unpleasant experiences. In this literature review, the background research in music and emotion research will be reviewed, including behavioral and neuroimaging studies on the relationship of music and emotion regulation, and EEG studies on changes in FA in relation to listening to music, as well as the purpose and rationale for the present study.

Behavioral Studies on Music and Emotion Regulation

The relationship between musically-induced mood improvement and emotion regulation has been studied extensively over the years in a variety of ways. Thoma, Ryf, Mohiyeddini, Ehlert, and Nater (2012) investigated how people use music to induce certain emotional states in everyday situations as a means of emotion regulation. To study this effect, the researchers had participants listen to various musical pieces thought to invoke certain emotional states and report how likely they would be to listen to a particular piece during an everyday situation, such as “angry at the boss” or “romantic dinner”. They also used self-reports to measure the participant’s emotion regulation style. The results of the study showed that there was a tendency for the participants to choose musical pieces which were emotionally congruent with the emotion elicited by the everyday situation They also found that specific emotion regulation styles may influence the decision to pick musical pieces that were characterized by a specific emotion (Thoma et al., 2012). The results of this study are important as they indicate that music can evoke specific emotions and can be used as a means for emotion regulation by selecting a song that is emotionally congruent with the situation at hand. Also, this study suggests that the emotion regulation style of the individual may play a role in the kind of music that is chosen when faced with everyday events.

Lynar et al. (2017) conducted a study measuring both the behavioral and physiological effects of music listening. Participants listened to four musical pieces (two researcher-selected pieces- one jazz and one classical, one self-selected “uplifting” piece, and white noise) in randomized order while heart rate (HR), galvanic skin response (GSR), and respiration were measured. The participants also completed self-report subjective responses on Likert scales which measured their enjoyment of the pieces. The results of the self-report measures showed that the self-selected piece produced the most joy and the classical piece was found to be the most relaxing. The physiological results indicated that there was increased HR, respiration, and GSR during the self-selected music, indicating a positive stress response (eustress). The researchers propose that low-arousal classical pieces cause a state of relaxation to occur, as indexed by higher heart rate variability (HRV; Lynar et al., 2017). These results add to the existing research that there are positive physiological responses as well as emotional responses when listening to music.

Neuroimaging Studies

Just as there have been a multitude of studies on the behavioral and physiological effects of listening to music on emotion, there have also been neuroimaging studies to examine which areas of the brain are activated while listening to music. A common thread in this field of research is the observation that the prefrontal cortex (PFC) plays a key role in the emotional processing of musical stimuli. Blood and Zatorre (2001) used positron emission tomography (PET) in order to study the neural mechanisms underlying intensely pleasurable emotional experiences while listening to music. PET is a neuroimaging technique that involves measuring changes in regional cerebral blood flow (rCBF) by injecting radioactive substances into the bloodstream for tracking purposes. PET recordings were obtained while the participants listened to self-selected music that they found extremely pleasurable and had been known to "give them chills". As the participants reported their feeling of chills increasing from the music, rCBF changes occurred in brain areas known to be important in reward and emotion processing, including the ventral medial prefrontal cortex (vmPFC), ventral striatum, midbrain, amygdala, and the orbitofrontal cortex (Blood & Zatorre, 2001).

Using functional near-infrared spectroscopy (fNIRS), Bigliassi et al. (2015) investigated how differently valenced musical pieces influence changes in activation in the PFC. This neuroimaging technique, fNIRS, is a relatively new method which involves measuring relative hemodynamic variations in the brain to assess temporal changes in blood flow (Bigliassi et al., 2015). The participants were recorded using fNIRS while listening to motivational and relaxing musical pieces. They also completed self-report measures on arousal and valence and their HRV was recorded to measure emotional responses. The results of the study showed that listening to music, regardless of type, corresponded with significant overall alpha activity in the prefrontal cortex. The participants rated the motivational song with a more positive valence and arousal and had lower HR, but no effects on HRV, than they did with the calming song, indicating a positive emotional response. The HRV results do not coincide with the previously mentioned study which indicated low-arousal classical music as having a significant effect on HRV. However, the results of this study correspond with other neuroimaging studies observing PFC activation while listening to music, presumably reflecting emotional effects.

Using functional magnetic resonance imaging (fMRI), researchers investigated the neural mechanisms underlying a wide array of complex emotions (such as wonder, nostalgia, and sadness) provoked by listening to music (Trost, Ethofer, Zentner, & Vuilleumier, 2012). fMRI is a neuroimaging technique which records neuronal activity by measuring cerebral blood flow and is known for its high-degree of spatial resolution.

Participants were recorded while listening to musical excerpts which were meant to induce 9 different emotional states differing in valence and arousal. The results indicated that there was a significant increase in the fMRI signal (i.e., increases in the blood oxygen level dependent signal or BOLD response) in the orbitofrontal cortex during positively-valenced, low-arousal emotions (nostalgia, tenderness) and significant increase in the BOLD signal in the ventromedial prefrontal cortex (vmPFC) during low-arousal emotions regardless of valence (nostalgia, peacefulness, sadness (Trost et al., 2012). These results are important as they indicate that different emotional states produced by listening to music can activate different areas of the frontal region of the brain depending on the valence and arousal of the music. Studies such as this have led researchers to look deeper into which specific regions of the PFC activate in response to positively and negatively valenced musical pieces, as well as the laterality of these effects.

EEG and Frontal Asymmetry

The vast majority of research on the relationship between music and emotion regulation is conducted using electroencephalography (EEG), so it is important to explain EEG methodology and how it is used in studying the neural mechanisms that are involved in music and emotion processing, including FA. Electroencephalography is a physiological method in which cerebral electrical potentials are recorded by placing electrodes onto the scalp (Binnie & Prior, 1994). By measuring these electrical impulses, researchers can record oscillations in the electrical activity in the brain that can be characterized on the basis of their amplitudes and frequencies that indicate rhythmic changes in neuronal excitability in different areas of the brain (Maki & Ilmoniemi, 2010). Neural oscillations manifest as cyclical changes in the voltages measured on the cortical surface, and these fluctuations are evident using EEG because they are synchronized time and space across large groups of neurons (Mathalon & Sohan, 2015). In general, synchronized neural oscillations are understood to depend on inhibition that paces assemblies of excitatory neurons to produce alternating temporal windows of reduced and increased excitability (Mathalon & Sohan, 2015). Because synchronization occurs due to extensive networks of local and long-range bidirectional connections between neurons, oscillations are thought to be very important for neural communication (Mathalon & Sohan, 2015). The electrical activity that is recorded using EEG includes action potentials that are brief and produce specific electrical fields, and postsynaptic potentials which are slower and cover a more widespread area (Binnie & Prior, 1994). However, the predominant contribution is the synaptic potentials. EEG is popular among psychological researchers because it provides an affordable, ecologically valid and non-invasive recording situation (sitting quietly in a room), rather than lying inside of an fMRI machine (loud machine, tight space) or a PET scanner (injecting radioactive substances). Furthermore, EEG has superior temporal resolution, so researchers can study neuronal processes at different time scales. One way of representing these time scales is to deconstruct the complex EEG signal into frequency bands, which are thought to represent different mental functions and emotional states (Sammler, Grigutsch, Fritz, & Koelsch, 2007).

The human EEG power frequency spectrum is divided into 5 different frequency bands: delta, theta, alpha, beta, and gamma (Neidermeyer, 1999). In order to study the hemispheric lateralization which occurs while listening to music, researchers typically choose to study the alpha frequency band. The alpha frequency range describes oscillations between 8 to 12 Hz and is associated with perceptual processing, memory tasks, creative ideation, multisensory attention modulation, and emotional processing as well as conditions of physical relaxation, relative mental inactivity, and wakefulness (Benwell et al., 2019; Misselhorn, Friese, & Engel, 2019; Niedermeyer, 1999; Sammler, Grigutsch, Fritz, & Koelsch, 2007; Schwab et al., 2014). Alpha power is hypothesized to be inversely related to brain activity, therefore a decrease in alpha power may indicate an increase in brain activity (Benwell et al., 2019). However, alpha activity has also been implicated in states of active attention, such as inhibiting irrelevant information in order to focus on a cognitively demanding task (Frey, Ruhnau, & Weisz, 2015) as well as during creative ideation (Gültepe & Coskun, 2016; Ritter & Ferguson, 2017). When studying frontal asymmetry, researchers generally choose to observe the alpha frequency band because activity in alpha range may be inversely related to synchronization, since decreases in alpha tend to be observed when underlying cortical systems engage in activity (Coan & Allen, 2004). By studying the alpha frequency band and differences in this frequency across the hemispheres, researchers have gained insight into how FAA is involved in music and emotional processing.

Frontal asymmetry refers to the asymmetrical activation of the two hemispheres of the PFC during emotion processing, as indexed by the ratio of alpha power across the two hemispheres. According to Coan and Allen (2004), FA serves as an individual difference variable relating to emotional responding/emotional disorders and as a state-dependent concomitant of emotional processing, therefore acting as both a mediator and moderator of emotion- and motivation-based constructs. In order to measure FAA, electrodes are placed on midfrontal sites, such as F3/F4 and FC3/FC4, in accordance with past studies on positive and negative affect which focused on activity in the frontal cortex (Arjmand et al., 2017; Blood & Zatorre, 2001; Davidson et al., 1990; Dennis & Solomon, 2010). Generally, a baseline recording and a post-stimulus recording are taken, with the difference between the baseline and post-stimulus activity representing the inferred changes in activation in response to the stimulus (Coan & Allen, 2004).

In order to determine which hemispheric effects are responsible for certain asymmetries, an asymmetry index is computed and analyzed, typically as a difference score, rather than analyzing asymmetry as a two-level factor (Coan & Allen, 2004). The most common FAA index involves subtracting the natural log of the left hemisphere alpha power from the natural log of the right hemisphere alpha power (ln[right alpha] – ln[left alpha]). This asymmetry index results in a unidimensional scale representing the relative activity of both hemispheres, with the midpoint of the scale being zero and representing symmetry (Coan & Allen, 2004). Positive scores (greater than zero) represent relatively greater left frontal alpha activity and negative scores (less than zero) represent relatively greater right frontal alpha activity, keeping in mind that higher scores result from greater right frontal alpha power (the inverse of activity; Coan & Allen, 2004). A limitation of this particular index is that it is that is provides no information on the extent to which each hemisphere is contributing to the observed difference score (Coan & Allen, 2004). Nevertheless, there are many advantages to using asymmetry indices, including their ability for controlling individual differences in skull thickness that may produce artifactual individual differences in recorded power values. Also, asymmetry indexes make statistical tests more sensitive by reducing the number of contrasts in a model and increasing statistical power (Coan & Allen, 2004).

It is important to discuss the implications of frontal asymmetry research and the different theories on why FAA occurs in response to positive and negative stimuli. The first theory of FAA is that it occurs because of a trait-based tendency to use certain approach or withdrawal behaviors. According to Davidson’s (1992) valence theory of emotional reactivity and FA, the left and right cerebral hemispheres are associated with approach and withdrawal behaviors. Those with greater trait left FAA have tendencies for approach-related positive affect and those with greater trait right FAA show more withdrawal-related negative affect (Davidson, 1992. The most common form of measurement for this theory is the Behavioral Inhibition/Behavioral Activation Scale (BIS/BAS; Carver & White, 1994) and is based on Gray’s (1970) behavioral inhibition and activation systems. By using the BIS/BAS scales, we can determine that an individual who scores higher on the BAS should theoretically have greater left frontal activity and those who score higher on the BIS should have greater right frontal activity when recording EEG baselines.

Another interpretation of FAA is state-based in nature and was based on Harmon-Jones and Gable’s (2017) proposal that FA is associated with motivation, separating motivational direction from emotional valence when considering frontal activity. Motivational direction refers to the behaviors associated with responding to an emotional stimulus where emotional valence refers to the mood state which arises from emotional stimuli. This theory was expanded from Davidson’s (1992) theory to purport that greater left frontal activity is associated with approach-related behaviors and greater right frontal activity is associated with avoidance-related stimuli (Harmon-Jones & Gable, 2017). Greater left frontal activity is also known to be associated with a more intense response to positive stimuli and greater right frontal activity is associated with a more intense reaction to negative stimuli (Schmidt & Hanslmayr, 2009). This pattern of frontal asymmetrical activation in the alpha band has been found over the years in numerous studies, from showing individuals pleasant and unpleasant pictures to presenting infants with sweet and tart flavors (Budimir, Meštrović, & Palmović, 2017; Fox & Davidson, 1986). Studies on stress and FAA have also indicated that greater right frontal activation occurs when a participant is presented with stressful stimuli during both natural and unnatural stressors (Lewis, Weekes, & Wang, 2007; Zhang et al., 2018).

The present study assumes that state is the main factor, and so the Harmon-Jones theory will be used for reference. If FAA is reactive to the study's manipulation, it can be determined that FAA is based on state-based factors. If there is no reaction of FAA to the study's manipulation, then it can be assumed that FAA is based more on the affective style or temperament of the individual. Because of this, the BIS/BAS will be used used to investigate if there is a relationship between changes in FAA and the individual's tendency towards approach or withdrawal behaviors.

Frontal Asymmetry and Music

It is important to focus on the effects that music has on FAA, as it may lead to a better understanding of the emotional benefits that individuals experience while listening to music. Several studies have been conducted in which FAA was measured in relation to different kinds of music, including music of different valence, intensity, and genre. In this section, these studies will be covered in detail to form a foundation of how music effects FAA and therefore emotion regulation.

When recording EEG while participants listened to musical excerpts of varying valence and intensity, greater left FAA was found to occur when participants listened to self-selected music of positive valence and greater right frontal activation was found when listening to self-selected music of negative valence (Arjmand et al., 2017). This corresponds to the FAA reaction to the intensity of the researcher-selected music that is being listened to, with there being greater left FAA during positive, high-intensity music (joy) than positive, low-intensity music (happy). There was also greater right FAA with more intense negative pieces (fear) than with less intense negative pieces (sadness; Schmidt & Trainor, 2001). These findings tie into the FAA theory which states that hemispheric activity is involved in emotional valence.

Genre has also been implicated in playing a role in FA while listening to different musical pieces. Altenmüller et al. (2002) used EEG to study the neural mechanisms underlying emotional valence perceptions while listening to different kinds of music. Participants listened to several clips from a variety of auditory stimuli, including jazz music, rock-pop music, classical music, and environmental sounds and reported their emotional valence after presentation of the stimuli. The EEG recordings that took place while the participants listened to the stimuli showed significant bilateral frontotemporal activation throughout the presentation of the stimuli, which corresponds to previous findings in emotion and music research (Arjmand et al., 2017; Schmidt & Trainor, 2001) in that greater left FAA occurred during reports of positive emotional valence and there was greater right frontal activation during reports of negative emotional valence (Altenmüller et al., 2002). Participants who listened to researcher-selected musical excerpts from a variety of musical genres (jazz, classical, and rock-pop) were shown to have greater left frontal activation when listening to pieces of music that they rated as being more enjoyable to them and had greater right frontal activation when they listened to pieces of music that they rated as being less enjoyable These findings correspond to the Harmon-Jones (2017) theory of FAA in response to positively and negatively-valenced stimuli, in that the greater right FAA during negatively valenced pieces and greater left FAA during positively valenced pieces seemed to be due to a state-based response to the stimuli.

While these studies show that there is a neurological basis behind the emotional valence that humans feel while listening to music, it is important to note that the musical pieces that the participants listen to are selected by the researcher to induce specific emotions. Because musical preference is very individualized and subjective to the listener's past experiences and emotional associations, researchers have recently been studying the effects of listening to self-selected music on patterns of FAA. Arjmand et al. (2017) recorded EEG while participants listened to four musical stimuli (pleasant, unpleasant, neutral music, and no music), with both the pleasant and unpleasant musical pieces being self-selected. The participants were asked to bring in a musical selection that they enjoy, and which would "give them chills" for the pleasant music condition, while the unpleasant music condition was a dissonant version of the song of their choice. The researchers found the greatest increase in left frontal activation when the participants listened to pleasurable music than the other musical pieces. They also found peak FAA responses during periods of musical change, such as a change in instruments or a change in acoustical dynamics (Arjmand et al., 2017). This study is particularly interesting in that the self-selected musical pieces produced the greatest left frontal activation. However, since there was not a manipulation in affect, the understanding of music's ability to regulate mood is limited. By adding in a cognitive stressor and therefore, induce negative mood, it should be more apparent as to how music positively changes mood, which the present study hopes to investigate.

Frontal Asymmetry and Stress

The relationship between FAA and stress should be mentioned as the present study aimed to incorporate a cognitive stressor to induce negative mood, and therefore demonstrate a switch in FA. Prior studies have demonstrated that stressful experiences can be related to greater frontal right alpha activity (Pérez-Edgar, Kujawa, Nelson, Cole, & Zapp, 2013; Zhang et al., 2018; Lewis, Weekes, & Wang, 2007). These studies will be discussed in further detail below.

Pérez-Edgar et al. (2013) investigated FAy6A in the alpha frequency band in relation to stress caused by social interactions. To do so, they measured the participants frontal alpha activity using EEG at baseline, which were later be compared with post-stressor recordings. The stressor was an emotion-face dot-probe attention task, in which the participants were presented with pairs of faces depicting angry, happy, and neutral emotions. Each emotional face was paired with a neutral face. An up or down arrow would then appear beneath one of the faces and the participant was directed to indicate which direction the arrow was pointing in. Participants were told that they would have to give a speech on one of their most embarrassing moments. They were recorded using EEG during the 3 minutes that they had to prepare for the speech. The results of the study indicated that there was an increase in right FAA from baseline to the speech condition that was associated with vigilance to angry faces and avoidance of happy faces, which may indicate that there are individual trait-based differences in the patterns of emotional response with the introduction of a stressor. This study relates more to Davidson's (1992) theory in that the FAA response may seem to be based on a trait-based proclivity to react in a certain way to the emotional stimuli.

Zhang et al. (2018) investigated how physiological stress is involved in FA in the alpha frequency band by having participants complete an automatized bilateral feet cold pressor test (bfCPT) and a warm water control procedure in counterbalanced order on two separate days, one week apart. The bfCPT involves having the participant submerge their feet in cold water for three minutes, inducing a negative physiological stress response. The participants' EEG, HR, and BP were recorded before, during, and after the bfCPT. Salivary cortisol and subjective ratings of anxiety were also measured before and after the bfCPT. The results of the study revealed that there was a stronger relative right frontal activation during the bfCPT compared to the control condition at electrodes F7 and F8, indicating a negatively valenced response to the physiological stressor. This study relates to the Harmon-Jones (2017) theory that the FAA response seemed to be state-based in nature, as can also be seen in the results of the salivary cortisol, HR, and BP measures.

Finally, Lewis, Weekes, and Wang (2007) investigated the effect of a naturalistic stressor, examination stress, on EEG FAA, psychological stress, hormonal stress, and negative health. Participants completed high- and low-stress examinations as EEG was being recorded. Salivary cortisol and subjective ratings of state anxiety were also measured. The results of the study revealed that there was a relative shift in FAA from greater left frontal alpha activity during the low-stress examination to greater right frontal alpha activity during the high-stress examination. These results coincided with the results of the subjective ratings of state anxiety which indicated heightened anxiety during the high-stress examination. Like the previous study, this study supports the Harmon-Jones (2017) theory of FAA, in which hemispheric lateralization occurs as a state-based reaction to the stressor.

The studies mentioned in this section highlight that there is a measurable relationship between stress, both naturalistic and non-naturalistic, and FAA. As can be seen by these studies, the results can be related to both the Harmon-Jones (2017) and Davidson (1992) theories of FAA, demonstrating that the hemispheric lateralization that occurs in response to stressful stimuli seems that it could be based on both a state-based reaction and a trait-based tendency to respond to stressful and emotional stimuli in a particular way. However, there seems to be a stronger argument for the Harmon-Jones (2017) theory of FAA, as reactions to stressful stimuli can be seen not only using EEG, but also in the measures of salivary cortisol, HR, and BP as well.

The Present Study

Given what is known about the relationship between the PFC and emotional processing, EEG was used as a measure for evaluating the changes in electrical brain activity that occur when someone is presented with musical stimuli after enduring a stressor, as music has been shown to be powerful at producing emotional responses. It is proposed that by administering both a cognitive stressor and a self-selected piece of music to the participant, we can produce a change in FAA from greater right activity from baseline to stressor (due to the negatively-valenced experience of the stressor) and greater left activation from stressor to music (due to the positively-valenced experience of listening to music).

The current study expanded Arjmand et al.’s (2017) study by adding in the component of the cognitive stressor, in which participants perform mathematical problems at increasing speeds. By adding in a stressful experience, it was hypothesized that FA would shift from greater right frontal activation during the stressor relative to baseline, then to greater left frontal activation when the participant listened to self-selected music chosen to induce relaxation. Baseline positive and negative mood and state- anxiety were measured first, prior to exposing participants to a cognitive stressor (PASAT; Gronwall, 1977; see Appendix G). The PASAT is a measure of cognitive function that assesses auditory information processing speed and flexibility and calculation ability in patients who have suffered from head traumas, that can also be used as a cognitive stressor. It was expected that there would be greater right FAA during and shortly after the stressor, as previous research has demonstrated that right FAA occurs during negatively valanced and stressful experiences (Lewis, Weekes, & Wang, 2007; Pérez-Edgar et al., 2013; Zhang et al., 2018) . After this, participants were asked to listen to the pleasurable song of their choice. It was expected that there would be a change in FAA where there would be greater left frontal activity as the participant is experiencing the song (Arjmand et al., 2017). The expectation was for a lasting increase in left frontal activation after listening to the song and the intention was to investigate how long this effect will last after the song finishes. Other self-report measures, such as the BIS/BAS, the Music in Mood Regulation Scale, and the Emotion Regulation Questionnaire were administered to investigate any potential correlations between the scales themselves and between the scales and changes in FAA, positive and negative affect, and state anxiety.

II. METHOD

Participants

The total number of participants run was 39; however, 11 participants were removed during data cleaning for having fewer than 90 s of artifact-free EEG recording per condition and three were removed for having both mastoid electrodes working incorrectly. The final sample consisted of 25 individuals (18 female, 5 male, 2 unspecified) who were recruited from the student population at Texas State University in San Marcos, Texas. Participants ages ranged from 18 years to 24 years (*M* = 19.04, *SD* = 1.744). Participants' races were representative of the Texas State University student population with 44% Hispanic, 28% Caucasian, 18% African American, 4% Native American/Pacific Islander, and 8% identifying as other. Recruitment occurred via class announcements in undergraduate Psychology courses. Individuals were excluded from the study if they were not within the ages of 18 to 35 years, had any hearing impairments (uncorrected or corrected) that may prevent listening to music with headphones, were taking any medications which may have affected their mood or concentration, or had a medical history of brain injury, concussion, or seizure disorders within the last six months.

Individuals interested in volunteering for this study signed up by using an online link and choosing an available appointment time. Upon entering the lab, they were asked questions about their medical history, hearing ability, and current medications. Those who met the criteria for inclusion continued on to read and sign the informed consent and complete the study. Participants were compensated with extra credit in their designated Psychology course. Materials and procedures used in this study were approved by the

Texas State University Institutional Review Board.

Materials

Self-Report Measures

Upon arrival in the lab, prospective participants were screened and those who met the criteria for the study then read and signed the informed consent.

After, participants completed numerous self-report measures while they were being prepped for EEG recordings. The measures included the Positive and Negative Affect Scale (PANAS), the State-Trait Anxiety Scale (STAIS/STAIT), the Music and Mood Regulation Scale (MMR), the Emotion Regulation Questionnaire (ERQ), the Goldsmiths Music Sophistication Index v1.0 (GMSI), and the Behavioral Inhibition Scale/Behavioral Activation Scale (BIS/BAS). Each is discussed in further detail below.

The BIS/BAS (Carver & White, 2004; see Appendix A) is a 24-item questionnaire which measures the respondent's sensitivity to either the behavioral inhibition system or the behavioral approach system. There are three subscales for the BAS measurements: Drive, Fun-Seeking, and Reward Responsiveness. The respondent is given statements such as "I go out of my way to get things I want" and "I feel pretty worried or upset if I think or know that someone is angry with me" and are asked to indicate how much they agree with the statement on a 4-point Likert scale (1 – *very true for me;* 4 – *very false for me*). The BIS/BAS is a widely used questionnaire and is considered valid in measuring sensitivity to the behavioral inhibition and behavioral activation systems (Campbell-Sills, Liverant, & Brown, 2004; Poythress et al., 2009).

The ERQ (Gross & John, 2003; see Appendix B) is a 10-item questionnaire which measures the respondent's tendency to regulate their emotions in one of two ways: Cognitive Reappraisal and Expressive Suppression. They are given statements such as

"When I want to feel less negative emotion (like sadness or anger), I change what I am thinking about" and "I control my emotions by not expressing them", and are asked to indicate how much they agree with the statements on a 7-point Likert scale (1 – *strongly disagree;* 7 – *strongly agree).* The ERQ is a widely used in emotion research and is found to be a valid and reliable measurement of an individual's emotion regulation style (Brady, Kneebone, & Bailey, 2019; Preece, Becerra, Robinson, & Gross, 2019).

The GMSI (Müllensiefen, Gingras, Musil, & Stewart, 2014; see Appendix C) is a 39-item questionnaire which assesses self-reported musical skills and behaviors on multiple dimensions. There are five subscales which measure varying musical behaviors and training: active engagement, perceptual abilities, musical training, singing abilities, and emotion. There is also an overall scale of general musical sophistication. Participants are asked a series of questions such as, "I find it difficult to spot mistakes in a performance of a song even if I know the tune" and "I am able to talk about the emotions that a piece of music evokes for me", and are asked to indicate how much they agree with the statements on a 7-point Likert scale (1 – *completely disagree,* 7 – *completely agree).*

The MMR (Saarikallio, 2008; See Appendix D) is a 40-item questionnaire which measures how an individual uses music for emotion regulation in their everyday lives. There are 7 subscales: Entertainment, Revival, Strong Sensation, Diversion, Discharge, Mental Work, and Solace. The participant is given different statements, such as "I listen to music to make cleaning and doing other housework more pleasant" and "When I'm tired, I rest by listening to music", and are asked to indicate how much they agree with the statements on a 5-point Likert scale (1 – *strongly disagree;* 5 – *strongly agree).* The subscales of the MMR have been found to be reliable, with *Entertainment* as r = .96, *Revival* as r = .86, *Strong Sensation* as r = .86, *Diversion* as r = .77, *Discharge* as r = .92, *Mental Work* as r = .85, and *Solac*e as r = .91 (Saarkallio, 2008).

The PANAS (Watson, Clark, & Tellegan, 1988; See Appendix E) is a 20-item measure that is used to determine the current mood state of the participant. The items they are presented with are 20 words that describe different emotions and feelings, such as “Interested” and “Distressed”. They are asked to indicate on a 5-point Likert scale (1 – *very slightly or not at all;* 5 *extremely)* to what extent they are feeling that particular emotion in the present moment. The PANAS is a widely used scale and has been shown to be a valid and reliable measurement of affect (Watson, Clark, & Tellegan, 1988).

The STAIS and STAIT (Speilberger, 1983; See Appendix F) are each 20-item measures which determine how anxious an individual is in the present moment and in general. The items in the STAIS describe specific feelings, such as “I feel secure” and “I am tense”, and the participants are asked to identify how much they agree with the statement in the present moment on a 4-point Likert scale (1 – *Not at all;* 4 – *Very much so).* The STAIT also gives statements such as “I feel nervous and restless” and “I make decisions easily” and the participant is asked to describe how much they agree with the statement in general on a 4-point Likert scale (1 – *Not at all;* 4 – *Very much so).* The STAI is a popular measurement of state and trait anxiety and has been shown to be a reliable assessment (Barnes, Harp, & Jung, 2002; Spielberger, 1983).

Cognitive Stressor

The cognitive stressor task used in this experiment was the Paced Auditory Serial Addition Task (PASAT; Gronwall, 1977; see Appendix G). The PASAT is primarily a measure of cognitive function that assesses auditory information processing speed and flexibility and calculation ability in patients who have suffered from head traumas, but it is also known to be useful as a cognitive stressor in EEG experiments (e.g., Ceballos, Giuliano, Wicha & Graham, 2012). The PASAT was presented using the VLC media player (VideoLAN, Paris, France) running a CD copy of the PASAT to control the rate of stimulus presentation. For this experiment, the PASAT was ran three times, once with numbers presented at 3 second intervals, then at 2 second intervals, and then at one second intervals. For all rates, the participant was presented with single digits at specified intervals and were asked to add each new digit to the one presented immediately prior to it and give the sums aloud. If the participant answered incorrectly or became overwhelmed, they were instructed to "jump back in" as quickly as possible. Social support was not otherwise provided.

Musical Stimuli

Participants self-selected the musical pieces in this study, as previous research has indicated that self-selected rather than researcher-selected music is more likely to promote greater positive emotions (Arjmand et al., 2017; Blood & Zatorre, 2001). Participants were asked to select a musical piece that "evokes positive emotions in themselves, such as joy, happiness, or excitement" before coming to their scheduled lab appointment. Chosen songs were required to have a duration of 3 to 6 minutes.

Acoustic stimuli (PASAT and music) were presented via ER-1 pneumatic insert headphones (Etymotic Research, Elk Grove Village, IL), which are designed to imitate the normal resonance of the open ear and do not contribute electrical noise to the EEG recordings. The ER-1 headphones have a flat frequency response referenced to the sound field. There is 70+ dB isolation between the ears, which reduces the need for masking, and 30+ dB external noise exclusion. Participants were allowed to adjust the volume to suit their own personal comfort.

Electrophysiological Recording

EEG data was recorded continuously from 64 channels using a sintered silver-silver chloride (Ag/AgCl) QuikCaps electrode cap, the SynAmps2 system and Acquire version 4.5 (Neuroscan, Compumedics, USA). The electrode locations in the cap were in accordance with the international 10-10 system; however, data quantification and analyses were focused primarily on EEG recorded from frontal sites (F3/F4), as hemispheric asymmetry associated with positive and negative affect has been focused primarily on the frontal cortex (Arjmand et al., 2017; Blood & Zatorre, 2001; Davidson et al., 1990; Dennis & Solomon, 2010). Data were filtered online with a bandwidth of 0.01 Hz to 35 Hz and referenced to digitally-linked mastoid electrodes (M1-M2). If one of the mastoid electrodes was malfunctioning, data were referenced to the remaining good electrode (M1 or M2). Data in which both mastoid electrodes were malfunctioning were not used (*n* = 3). The ground electrode was situated between FPZ and FZ and impedances were maintained at or below 5 kOhms.

EEG Data Analysis

EEG data was visually inspected for eye and muscle movements using Neuroscan (Neuroscan Edit, 5.1, Compumedics, NC), and artifacts were removed manually prior to data analysis. Participants with fewer than 90 s of artifact-free EEG recording per condition were discarded (*n* = 11). In the case of faulty electrodes at the F3 and F4 sites, alpha power was interpolated from the surrounding electrode sites. If the F3 site was faulty, alpha power was interpolated from the AF3, F1, F5, FC1, FC3, and FC5 electrode sites. If the F4 site was faulty, alpha power was interpolated from the AF4, F2, F6, FC2, FC4, and FC6 electrode sites. EEG was recorded with a sampling rate of 1000 Hz. Eye movements were manually removed with automatic artifact rejection of > 100 μV in reference to VEO.

Data preprocessing followed methods outlined in Arjmand et al. (2017): data for analysis was extracted in epochs of 1024 ms length using a Cosine window with 50% overlap. An average of 8 trials were retained for each participant after artifact removal. A Fast Fourier Transform (FFT) was applied to each epoch of EEG data, permitting the computation of the amount of power at different frequencies. Power values of specific frequency bands from epochs within each experimental phase were averaged (Dumermuth & Molinari, 1987). The dependent measure that was extracted from the raw EEG data was the power density ($\mu V^2/Hz$) in the alpha band (8-12 Hz) frequency at frontal sites (F3 and F4). The data was log transformed to normalize their distributions because power values are positively skewed (Davidson, 1988). Alpha band power is inversely related to activation (Lindsley & Wicke, 1974) and is most often looked at in studies pertained to frontal asymmetry. Therefore, estimates of cortical asymmetry [ln(right) – ln(left)] were computed for the alpha band from frontal sites.

The frontal asymmetry (FA) score represents the amount of activity of the left and right hemispheres over a given pair of electrodes (e.g., F3 and F4 electrode sites). Scores of zero indicate that there is no frontal asymmetry. Scores greater than zero indicate that there is greater frontal activity in the left hemisphere than in the right hemisphere, suggestive of a positive affective response. Scores less than zero indicate greater frontal activity in the right hemisphere than the left hemisphere, indicating a negative affective response.

Procedure

Participants were recruited via class announcements in designated undergraduate psychology courses. The flyers detailed what the study entailed and inclusionary criteria. Individuals who qualified for the study scheduled a time and day to come to the EEG lab (UAC 261) for one, approximately 2-hour, experimental session using an online link. Participants were asked to continue their regular tobacco and/or caffeine intake prior to coming in for the study. These guidelines were to help reduce any possible withdrawal effects. Participants were asked to have chosen a song of their choice “that evokes positive emotions in themselves” prior to their lab visit. A record was kept of the song and artist that each participant brought. Upon arrival to the lab and prior to participation, the procedures of the study were reiterated, and the participant had the opportunity to ask any questions regarding the study. Informed consent was then obtained, and the signed consent forms were kept in a locked file. A copy of the consent form was offered to the participant for their records.

The session consisted of three basic stages: capping the participant, questionnaires, and EEG recording, during which the individual will complete the cognitive stressor task and listen to music. While the participants were being fitted and capped, they completed the PANAS, STAIS/STAIT, MMR, ERQ, GMSI, and BIS/BAS questionnaires on an iPad. Participants were then seated in an armchair, housed in a soundproof, radio frequency-shielded chamber.

Next, baseline EEG recordings were obtained, in which the participant sat still with their eyes open for approximately three minutes and with their eyes closed for three minutes. The entire baseline recording took approximately 6 minutes total. EEG continued to be recorded while participants completed the PASAT which took about 7 minutes, including the practice trials. EEG was recorded again for three minutes eyes open and three minutes eyes closed post-PASAT in order to record their initial reactions to the cognitive stressor. After this recording, the participants completed the PANAS and STAIS questionnaires again. Music for the participant was presented by loading their song on YouTube. After the post-PASAT recording, the participants listened to the song of their choice, which took approximately 3 to 6 minutes. EEG was recorded throughout the music listening. After finishing the song, the participant was recorded while sitting still with their eyes open for approximately three minutes and with their eyes closed for three minutes. This recording was necessary to measure their post-music reaction, and to determine if there was a lingering FAA reaction after listening to music. This was the final EEG recording. Finally, participants were asked to complete the PANAS and STAIS a final time. Once they completed the questionnaires, they were debriefed, compensated, and thanked for their time (see *Figure 1*)

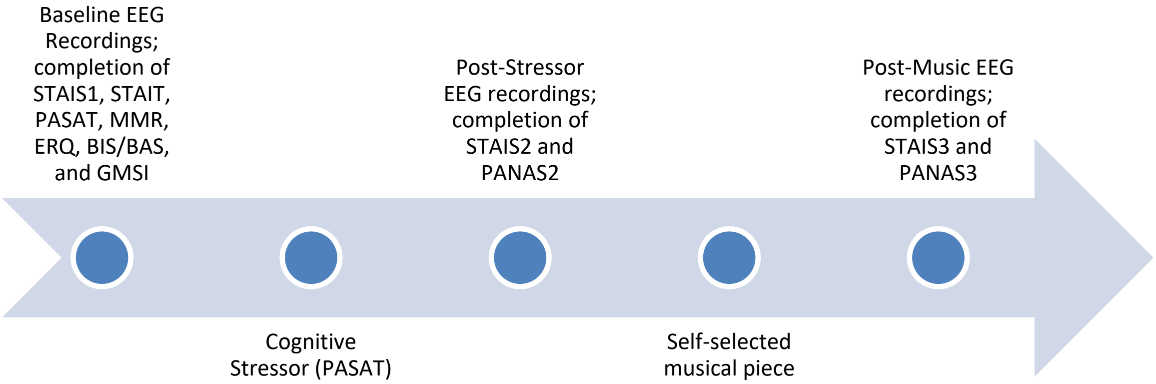

Figure 1. Timetable of study’s events.

Analytic Strategy

Data analysis consisted of three stages. First a manipulation check was conducted on STAIS scores (pre- vs. post-stressor) to confirm the efficacy of the PASAT as an acute stressor. This was followed by the main analyses, consisting of four repeated measures ANOVAs, to examine changes in anxiety, positive and negative mood, and frontal EEG asymmetry over time (baseline, post-stressor, during music, post-music). The final set of analyses was exploratory in nature, examining changes in anxiety, mood, and frontal asymmetry and their relationship with self-reported MMR, ERQ, GMSI, and BIS/BAS scores.

Manipulation check

First, a manipulation check for the effectiveness of the acute stressor was conducted. To this end, STAIS scores (pre- vs post-PASAT) were compared via a paired-samples *t*-test, in order to confirm that the PASAT did influence the participant's state anxiety.

Hypothesis tests

Four repeated measures ANOVAs were conducted on the STAIS scores, the positive PANAS scores, the negative PANAS scores, and FAA estimates with time as the within-subject factor. For the ANOVAs on the self-reported measures, time had three levels: baseline, post-PASAT, and post-music. For the ANOVA on FAA, time had four levels: baseline, post-stressor, during music, and after music. There was also an additional factor of location of frontal electrode sites (F3 and F4). It was predicted that there would be a significant increase in positive affect and a significant decrease in negative affect and state anxiety over time. It was also predicted that there would be greater right frontal activation at Time 2 and greater left activation at Time 3 and Time 4. If significant main effects or interactions are found in any of the ANOVAs, Bonferroni-corrected *t*-tests were conducted to interpret the results. Where violations of sphericity were noted, Greenhouse-Geisser corrections were implemented and degrees of freedom were adjusted accordingly.

Exploratory correlations

For the exploratory analyses, correlations were conducted with condensed time change scores from the PANAS, STAIS, and FAA data and the scores from the ERQ, BIS/BAS, GMSI, and MMR scales. As was previously stated, condensed time change variables were used to measure the change in positive affect, negative affect, state anxiety, and FAA from Time 2 (post-stressor) to Time 3 (post-music). Analyses focused on these two time points and condensed the original data to change scores because of the specific focus on changes in mood, anxiety, and asymmetry due to listening to music.

Correlations were conducted between changes in positive affect from Time 2 (post-PASAT) to Time 3 (music) and the ERQ, BIS/BAS, and MMR scores. Correlations between changes in negative affect from Time 2 (post-PASAT) to Time 3 (music) and the ERQ, BIS/BAS, and MMR scores were also conducted. Correlations between changes in FA from Time 2 (post-PASAT) to Time 3 (music) and the ERQ, BIS/BAS, and MMR scores were run. Finally, correlations were also run between the ERQ, BIS/BAS, GMSI, and MMR scales to determine any possible relationships between the subscales. Due to multiple comparisons, only correlations with *p*-values $< .01$ were considered noteworthy.

III. RESULTS

Data was extracted in epochs using a Cosine window with 50% overlap and a FFT was applied to each epoch. The power density (density (μV^2/Hz) in the alpha band (8-12 Hz) frequency at frontal sites (F3 and F4) was extracted from the raw EEG data and the data was then log transformed to normalize their distributions. Data derived from Scan 5.1 were exported as ascii files, the mean window for alpha from the F3 and F4 electrodes were exported to Microsoft Excel, and were entered into IBM SPSS Statistics 25 for analyses.

Manipulation Check

First, a manipulation check was conducted to check for the effectiveness of the acute stressor, the PASAT. A paired samples *t*-test was conducted which compared the STAIS scores pre- vs post-PASAT. The t-test showed that there was not a significant difference between STAIS scores pre-stressor (*M* = 1.871, *SD* = .388) and post-stressor (M = 1.960, SD = .396), *t* = -1.301, *p* = .206. The results indicate that although state anxiety increased from baseline, this change was not statistically significant.

Subjective Ratings of State Anxiety and Emotion

A repeated measures ANOVA was conducted to measure if there was change in self-reported state anxiety over time. Sphericity was met for changes in state anxiety. The repeated measures ANOVA determined that there was a statistically significant change in state anxiety over the three time points (*F*(2, 48) = 4.635, *p* = .014; see *Figure 2*).

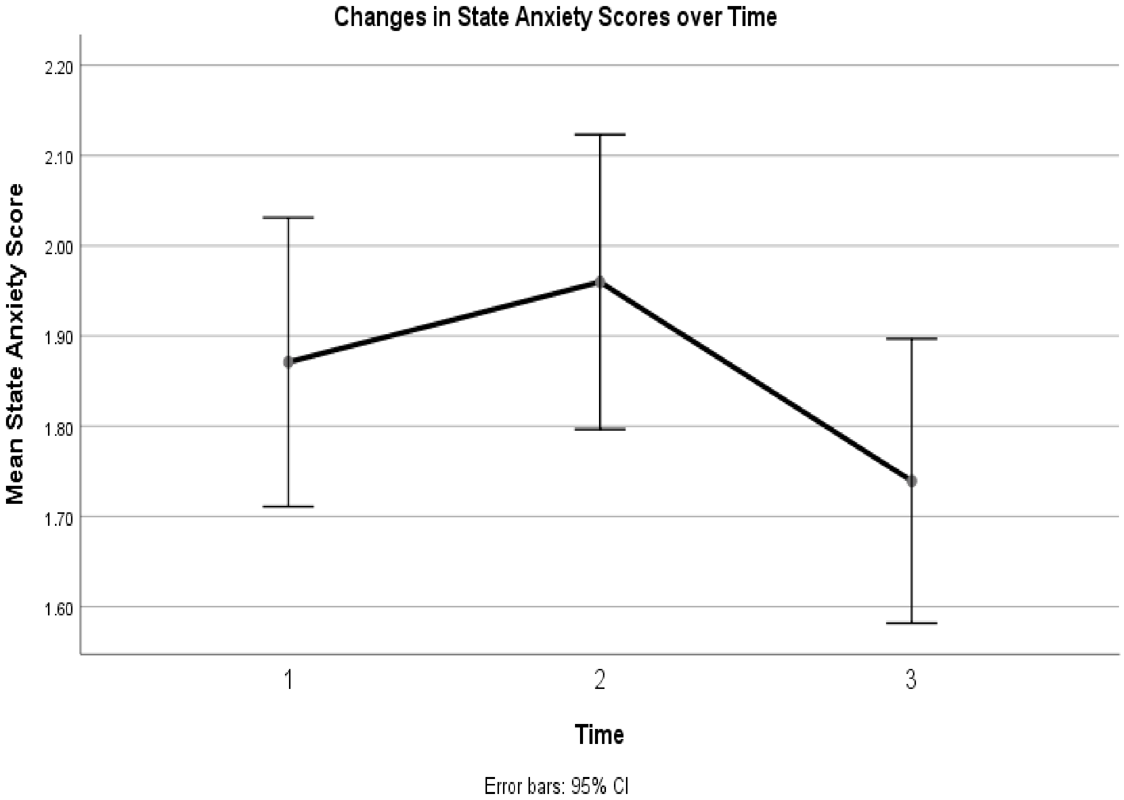

Figure 2. Changes in self-reported state anxiety scores over time.

Repeated measures ANOVAs were conducted to determine if there was a change in self-reported emotional valence over time. Sphericity was met for changes in emotional valence for both positive and negative ratings. The repeated measures ANOVA determined that mean PANAS scores for positive affect changed significantly over the three time points (eyes-open baseline, eyes-open post-stressor, and eyes-open post-music) (*F*(2, 48) = 7.469, *p* = .001; see *Figure 3*). Post-hoc comparisons using Bonferroni corrections showed that there was a significant decrease in positive affect scores from baseline to post-stressor timepoints (3.354 vs 2.921, *p* = .007). There was a slight increase in positive affect scores from post-stressor to post-music timepoints (2.921 vs 3.072, respectively), but it did not reach statistical significance (*p* = .546).

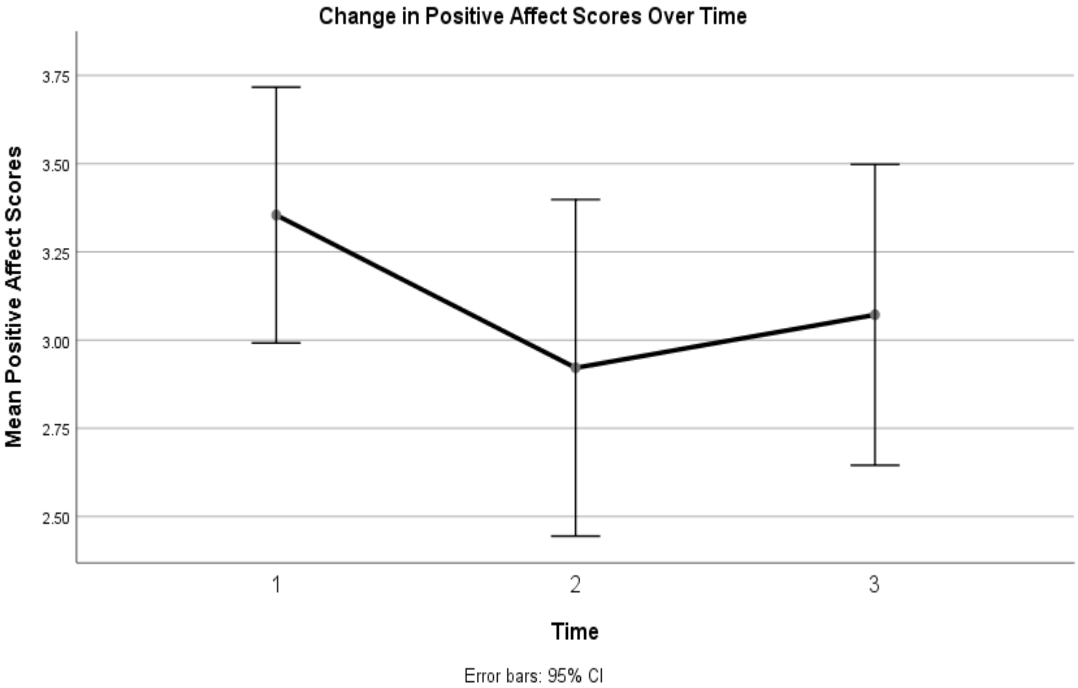

Figure 3. Changes in self-reported positive affect scores over time.

A repeated measures ANOVA determined that mean PANAS scores for negative affect changed significantly over the three time points (*F*(2, 48) = 6.599, *p* = .003; see *Figure 4*). Post-hoc comparisons using Bonferroni corrections showed that there was an increase in negative affect scores from baseline to post-stressor (1.449 vs 1.458, respectively), but this was not statistically significant (*p* = 1.000). However, there was a significant decrease in negative affect scores from post-stressor to post-music (1.458 vs 1.252, *p* = .011).

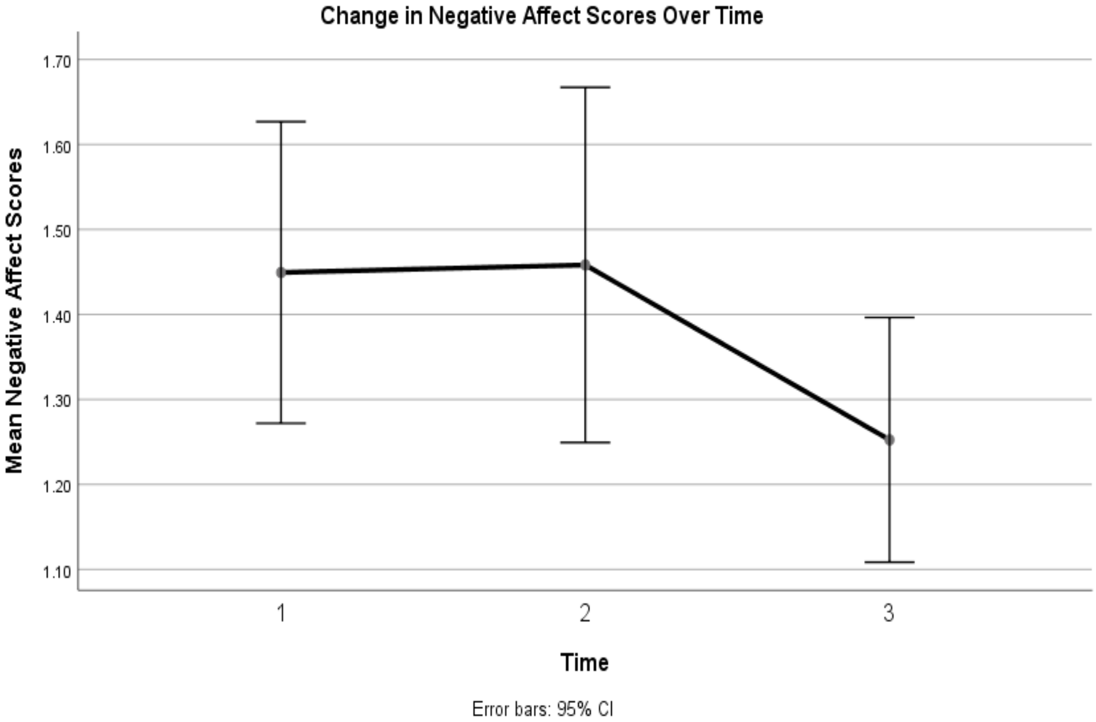

Figure 4. Changes in self-reported negative affect scores over time.

Changes in EEG Frontal Asymmetry

Cortical asymmetry for the F3 and F4 electrode sites was initially computed for the alpha band using the (ln[right – left]) transformation. Using this transformation, FAA scores of zero represent no change in asymmetry, scores greater than zero indicate greater left frontal activity (positive affective response), and scores less than zero indicate greater right frontal activity (negative affective response), assuming that alpha is inversely related to activity (Allen et al., 2004).

A repeated measures ANOVA was conducted for changes in FAA over the four time points (eyes-open baseline, eyes-open post-stressor, eyes-open during music, and eyes-open post-music). Sphericity was not met, so a Greenhouse-Geisser correction for degrees of freedom was conducted. Analyses indicated that there was not a statistically significant change in FAA scores over time, $F(1.888,45.312) = .302$, $p = .728$.

The alpha power from the F3 and F4 sites were then investigated on their own rather than the change score in order to see if there were overall changes in alpha power as a function of condition. The change score can be somewhat problematic in determining how large of a change in frontal activity is occurring and specifying exactly why the change occurred (Coan & Allen, 2004; Palmiero & Piccardi, 2017). For example, a shift in FAA to the left could be caused by either a decrease in LH alpha, in increase in RH alpha, or a combination of both. In order to examine frontal activity more closely, natural log transform variables for the raw power of F3 and F4 electrode sites were created. Another repeated measures ANOVA was conducted for changes in frontal activity over the four time points (baseline, post-stressor, during music, and post-music), with the added factor of laterality. Sphericity was not met with regard to many main effects and interactions, so Greenhouse-Geisser corrections for degrees of freedom are reported where appropriate. The results indicated that there was a marginally significant effect of time on frontal activity, $F(2.437, 58.493) = 2.645$, $p = .075$. However, there was not a significant effect of laterality on changes in frontal activity, $F(2.437, 58.493) = .314$, $p = .580$, or a significant time x laterality effect, $F(2.437, 58.493) = .302$, $p = .728$. These results demonstrate that there may be an increase in frontal activity from baseline to stressor and from stressor to music, but this change in frontal activity is not demonstrative of a change in FAA.

Next, frontal activity during the PASAT rather than post-stressor was examined due to the possibility that it may be more representative of frontal activity occurring due to negative affect. A final repeated measures ANOVA was conducted to investigate changes in frontal activity during four time points (baseline, during stressor, during music, and post-music) with the factors of time and laterality. Sphericity was met for changes in frontal activity. The results of the ANOVA revealed that there was a significant effect of time on frontal activity, *F*(3,72) = 3.064, *p* = .033, with an increase in frontal alpha activity from baseline to stressor and from stressor to music, see *Figure 4*. There was not a significant effect of laterality on changes in frontal activity, *F*(3,72) = .516, *p* = .479. Sphericity was not met for the time x laterality effect; nevertheless, there was not a significant time x laterality effect on changes in frontal activity, *F*(2.437, 58.493) = .162, *p* = .888. From these results, we can determine that there was a significant increase in frontal activity over time, but laterality did not seem to play a role in this change.

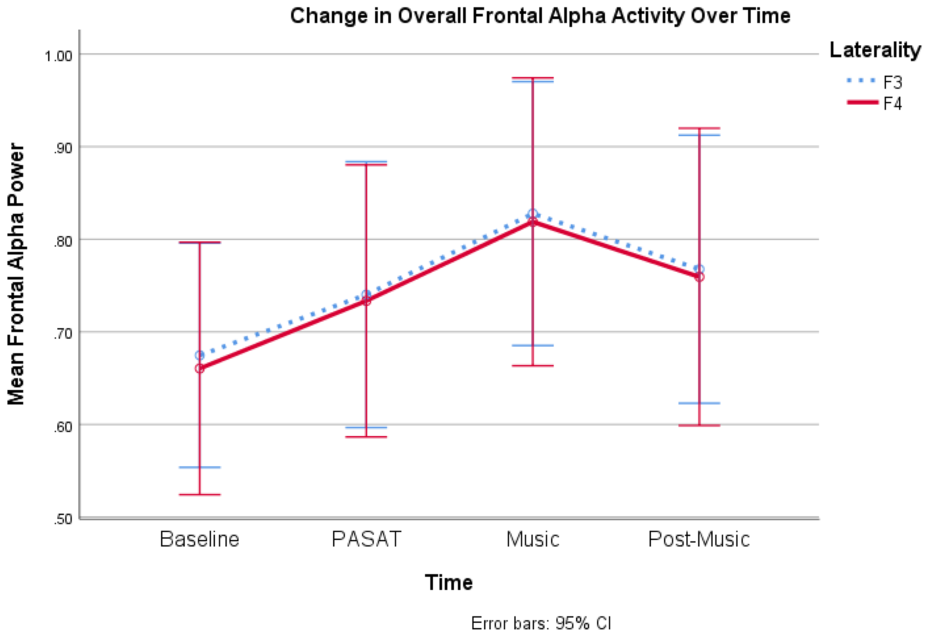

Figure 5. Overall changes in frontal alpha activity with factors of time and laterality.

Exploratory Correlations

In order to compare changes in positive and negative affect with the other scales, new variables were constructed for changes in positive and negative affect scores from post-stressor to post-music timepoints, in which scores were created by subtracting positive and negative affect scores of the pre-stressor from the post-stressor scores. Correlational analyses were conducted with the new variables representing changes in affect and state anxiety over time and the ERQ, MMR, BIS/BAS, and GMSI. Due to multiple comparisons, only correlations with *p*-values < .01 were considered noteworthy. There were no significant correlations found between change in positive affect scores and any of the scales. However, there was a strong positive correlation between change in negative affect scores and the Strong Sensation subscale of the MMR, *r*(24) = .539, *p* = .005, see *Figure 6*.

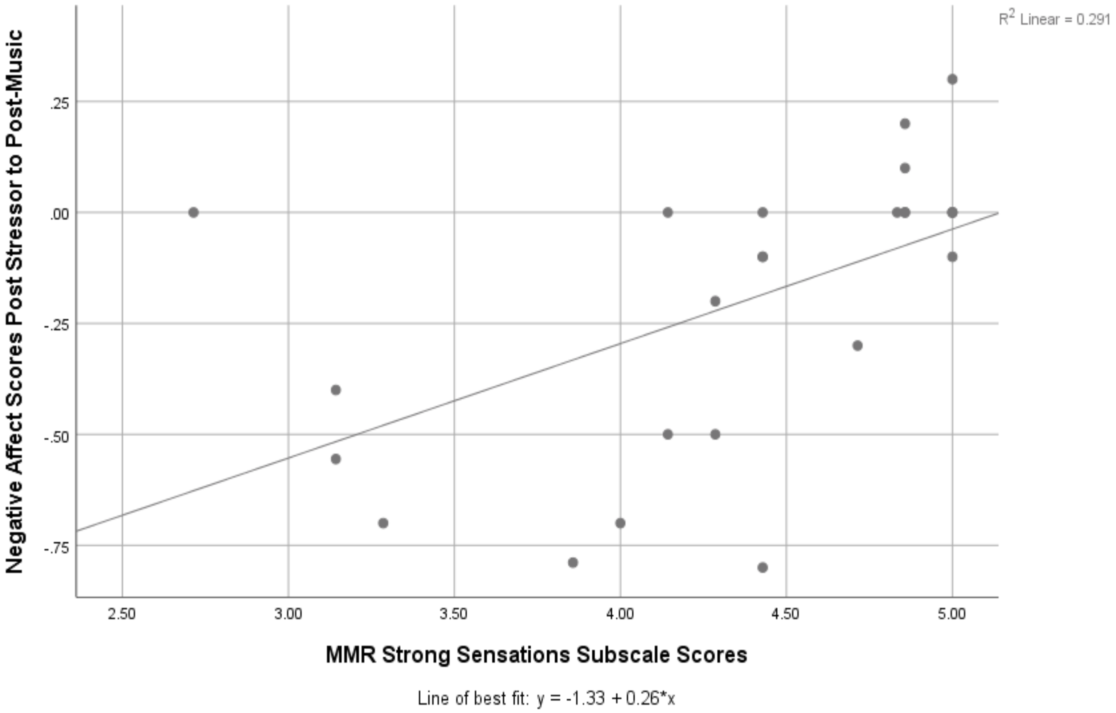

Figure 6. Strong positive correlational relationship between change in negative affect and MMR Strong Sensations subscale.

To compare the changes in average FAA from the stressor to the music with the ERQ, MMR, BIS/BAS, and GMSI, new variables were constructed by subtracting the average FAA change score during the song from the average FAA change score during the PASAT. A correlational analysis was conducted comparing the condensed time change variable and the scales ERQ, MMR, BIS/BAS, and GMSI. The results showed that there were no statistically significant correlations found.

Exploratory correlations were conducted between all of the scales (ERQ, MMR, BIS/BAS, and GSMI). Again, due to multiple comparisons, only correlations with *p*-values ≤ .01 were considered noteworthy. There was a strong positive correlation between scores on the ERQ Cognitive Reappraisal subscale and scores on the MMR Revival subscale, *r*(24) = .503, *p* = .010, see *Figure 7*. There was also a strong negative correlation between scores on the ERQ Expressive Suppression subscale and scores on the GMSI Emotions subscale, *r*(24) = -.518, *p* = .008, see *Figure 8*.

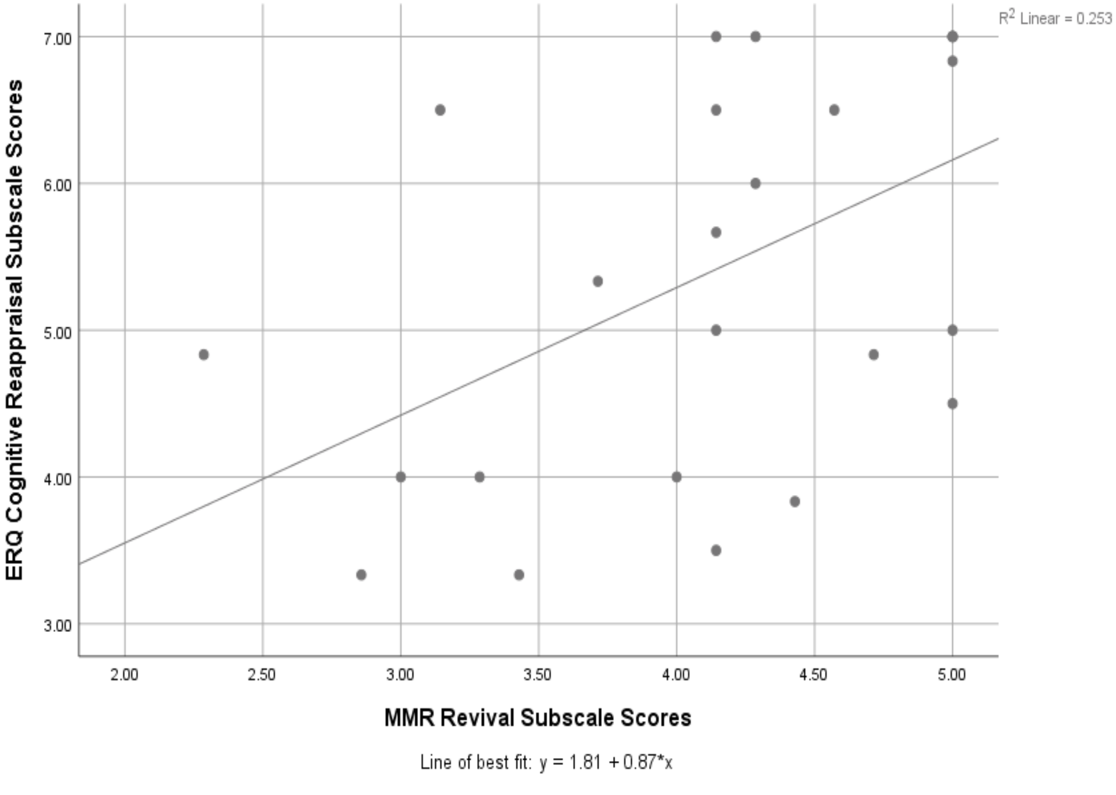

Figure 7. Strong positive correlational relationship between ERQ Cognitive Reappraisal. subscale and MMR Revival subscale.

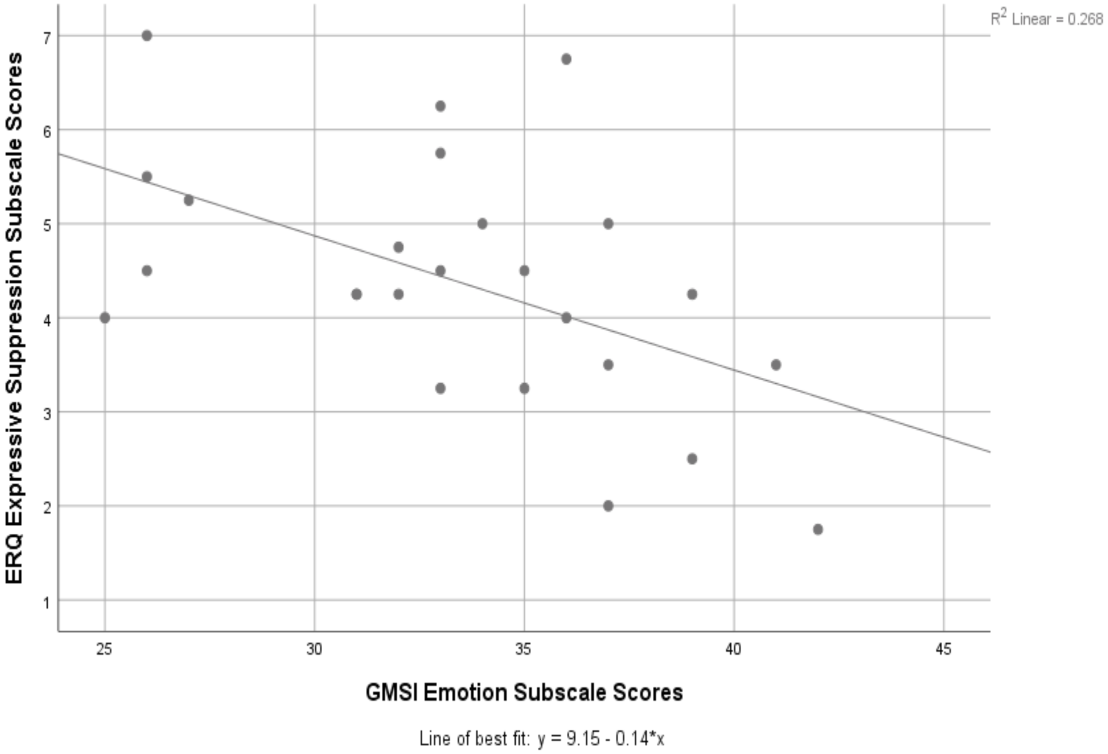

Figure 8. Strong negative correlational relationship between ERQ Expressive Suppression subscale and GMSI Emotion subscale.

IV. DISCUSSION

Listening to music is known to be useful in emotion regulation and invoking positive emotions (Chin & Rickard, 2014; Lynar, Cvejica, Schubert, & Vollmer-Conna, 2017; Papinczak, Dingle, Stoyanov, Hides, & Zolenko, 2015). It is important to investigate the neurological mechanisms that are involved in listening to music, as this kind of research can shed light on how music triggers emotional regulation processes in the listener. Learning more about how music effects the emotion regulation process can improve our understanding of the therapeutic qualities of music, as well as help to improve the efficacy of music therapy techniques, especially in the context of disordered mood. It has previously been shown that listening to music is linked to changes of activity in the PFC, implicating that FAA may be involved in this process (Arjmand et al., 2017). However, previous studies did not examine changes in FA as an individual listens to music after experiencing a stressor. The aim of the present study was to gain insight into how music moderates emotional processing after unpleasant experiences, by measuring FA at baseline, after experiencing a cognitive stressor, and while listening to music.

Several hypotheses were proposed. The first hypothesis was based on the results of previous studies that indicated that music promotes positive mood and decreases state anxiety (Chan, Chan, & Mok, 2010; Moradipinah, Mohammadi, & Mohammadil, 2009). It was expected that that the present study would show the same results with regard to music listening, mood, and state anxiety. Therefore, it was hypothesized that there would be an increase in positive affect over time and decreases in both negative affect and state anxiety as measured by self-report. The results indicated that there was a significant change in affect and state anxiety over time, providing support for the first hypothesis.

The second hypothesis was based on the results of past studies that indicated that greater right frontal activity occurs when an individual is presented with both natural and unnatural stressors (Lewis, Weekes, & Wang, 2007; Zhang et al., 2018) and Arjmand et al.'s (2017) study, which indicated that greater left frontal activity occurred when an individual listened to self-selected positive music (Arjmand et al., 2017). It was hypothesized that there would be a change in FAA from greater right frontal activity during the stressor to greater left frontal activity during the music. There was not a significant change in frontal asymmetry over time, which did not support our second hypothesis. However, there was a significant change in overall frontal activity over time, with an increase of alpha power from baseline to stressor and from stressor to music.

Exploratory correlations indicated that there was a strong positive correlation between change in negative affect and the GMSI Strong Sensations subscale, a strong positive relationship between the ERQ Cognitive Reappraisal subscale and the MMR Revival subscale, and a strong negative relationship between the ERQ Expressive Suppression subscale and the GMSI Emotion subscale. The results are discussed in further detail below.

Self-Reported Affect and State Anxiety

The first aim of the present study was to investigate if the cognitive stressor and music influenced self-reported measures of mood and anxiety. We hypothesized that over time, positive affect would increase, and negative affect and state anxiety would decrease. Our hypotheses were confirmed by the results of the repeated measures ANOVAs, as there were significant changes in self-reported affect and state anxiety over time. We found a significant increase in positive affect and a decrease in negative affect and state anxiety over time. These results were consistent with past studies that demonstrate that listening to self-selected music positively impacts mood and reduces anxiety (Chan, Chan, & Mok, 2010; Doğan & Şenturan, 2012; Hirokawa & Ohira, 2003; Lynar et al., 2017; Moradipanah, Mohammadi, & Mohammadil, 2009). Although there was a significant change in state anxiety over time, there was not a change in anxiety from baseline to post-stressor. However, there was a significant increase in negative affect and decrease in positive affect from baseline to post-stressor. These results indicate that the PASAT had a more significant effect on affect rather than state anxiety, which is not a typical response as it is often used successfully as a cognitive stressor (Ceballos, Giuliano, Wicha, & Graham, 2012).

It is interesting to note the differences in how positive and negative affect scores changed during the experiment. For positive affect scores, there was a significant decrease from baseline to post-stressor, demonstrating that the PASAT had a significant effect on lowering positive mood. From post-stressor to post-music, there was an increase in positive affect, but it was not a great increase and did not return to the level it was at in the baseline scores. For negative affect scores, there was not much of a change from baseline to post-stressor, demonstrating that the stressor didn’t significantly increase negative mood. However, there was a great decrease in negative affect from post-stressor to post-music. This demonstrates that listening to music significantly reduces negative mood. This result that different changes occurred between positive and negative affect, due to the PASAT and music conditions is noteworthy because it suggests that the stressor and the music had different effects on each. For positive affect, the PASAT seemed to have a greater effect in decreasing positive mood, while the music had a marginal effect in increasing positive mood. For the negative affect, the PASAT did not have a significant effect in changing negative mood, but the music significantly decreased negative mood. The changes in negative affect may indicate how music effects emotion regulation, in that it has more of an effect on decreasing negative mood than it does in increasing positive mood.

EEG Frontal Asymmetry

The second aim was to investigate changes in frontal asymmetry in relation to the cognitive stressor and self-selected music. It was hypothesized that there would be a change in FA from greater right frontal activity (indicating negative emotional response during the stressor) to greater left frontal activity (indicating positive emotional response during music). This was based on the results of Arjmand et al.'s (2017) study in which the participants had greater left FAA after listening to self-selected music and greater right FAA when they listened to a dissonant version of their self-selected musical piece. The results of the repeated measures ANOVA on changes in FAA over four time points (baseline, post-stressor, during music, and post-music) showed that there was not a significant change in FAA over time, which was inconsistent with the second hypothesis. These results are not consistent with the results of Arjmand et al.'s (2017) study either, which demonstrated a positive shift in asymmetry from the right to left hemisphere when participants listened to pleasant musical stimuli. It is proposed that this study may have tapped into something other than a state-based emotion regulation mechanism that Arjmand et al.'s (2017) study implicated.

Although there was not a significant change in FA resulting from the cognitive stressor or the self-selected music, there was a significant change in overall frontal alpha activity over time, with an increase in activity from baseline to stressor and from stressor to music. We investigated the changes in alpha power at the F3 and F4 sites during four time points (baseline, during stressor, during music, and post-music). The results of the repeated measures ANOVA indicated that there was an effect of time on increased frontal alpha activity, but no effect of laterality. These results were unexpected as they demonstrated increases in alpha activity over both electrode sites from baseline to stressor and from stressor to music. Possible explanations of these unexpected findings as they relate to other studies will be discussed below, including a reconceptualization of alpha activity as a state of attention rather than resting, and the processes of cognitive intersensory processing, trait-based emotion regulation, and creative ideation.

Alpha and Attentional Processes

Alpha activity was once thought to only occur during relaxed wakefulness and from a state called "desynchronization", which is comprised of a mix of many different high frequencies and low amplitudes and is due to fewer cortical inputs (Watson & Breedlove, 2019, p. 297). More recent research has led to a newer model based on the idea that alpha is more related to active inhibition rather than inactivity (Klimesch et al., 2007). The inhibition-timing hypothesis assumes that desynchronized alpha activity (smaller amplitudes on scalp EEG) indicates great excitability while synchronized alpha activity (larger amplitudes on scalp EEG) indicates a state of inhibition or comparatively low excitability (Klimesch, Sauseng, Hanslmayr, 2007). Furthermore, this model could help to explain the increased alpha throughout the stressor and the music as the individual may have been experiencing an increase in attention and thus, excitability during both the stressor and the music stimuli. This may also help to explain the unique changes in mood that were observed, as during the heightened states of attention, the greatest changes in negative and positive affect occurred. When the individual was experiencing the cognitive stressor, there was a significant decrease in positive affect where negative affect did not change much. During the music, there was a significant decrease in negative affect, and a marginal increase in positive affect. It is plausible that state of greater attention and excitability produce more significant effects in emotion regulation.

Recent studies have shown that there is an increase in alpha power when cognitive attentional mechanisms are engaged, indicating top-down processing is occurring (Frey, Ruhnau, & Weisz, 2015; Klimesch, 2012; Kolev, Yordanova, Schürmann, & Baţar, 1999; Uusberg, Uibo, Kreegipuu, & Allik, 2013). More specifically, oscillatory alpha activity has been indicated in information processing, playing a role in inhibiting task-irrelevant regions and gating information for the specific task at hand (Frey, Ruhnau, & Weisz, 2015). It is suggested that alpha activity is involved in two functions of attention, suppression, and selection, which enables controlled information access (Klimesch, 2012). According to this theory, alpha activity serves as a means for prioritizing the important task at hand while pushing aside information that is not useful for the current task. In relation to the present study, the engagement of attention could explain the increase of frontal alpha activity during the cognitive stressor as the individual had to focus on the arithmetic problems while blocking out unimportant information which would take away their focus on the task. It could also explain the increase in alpha during the music, as the participant was asked to listen to the song. They were told they were completing a study which involved listening to self-selected music, so it would make sense that they would listen intently to the song that they brought in for promoting happiness.

As has been previously stated, listening to music is known to have both calming and stimulating effects, demonstrating that music is not always relaxing in the traditional sense of the word (Begum et al., 2019; Lynar et al., 2017; Swaminathan & Schellenberg, 2015). Alpha activity has been shown to have a significant increase when an individual is exposed to affective content (Uusberg, Uibo, Kreegipuu, & Allik, 2013). In a study conducted by Begum et al. (2019), stimulating music was found to increase attention, soft music was shown to slightly improve attention, and depressing music reported the least attention of all participants. The type of music seems to play a role in what is being paid attention to by the participant, as Iwaki, Hiyashi, and Hori (1997) also found greater alpha activity and greater attention when participants listened to stimulating music rather than calm music. In the present study, participants were asked to bring in a song that produces positive mood when they listened to it, so they were most likely to bring something that stimulates or energizes them, rather than a relaxing song since they did not know that their affect and anxiety would be measured after a stressful task. In accordance to the theory of stimulation and affectiveness in attention and alpha activity (Klimesch, 2012), it is understandable that there would be increased alpha activity while the individual listens to self-selected music, as it something that most likely stimulates them and that they have connected with on an emotional level.

When considering alpha activity as a measure for attentional and information processing functions that may focus on affective stimuli, the results of this study can be explained more easily. Alpha activity may have increased from baseline to post-stressor because the participant had to focus on the mental task at hand, ignoring unimportant distractions. Alpha activity may have increased from the stressor to the music as the participant was listening to an affective and stimulating piece of music, which demanded their attentional processes. For a future study, it would be useful to investigate alpha activity as a measure of attentional focus while an individual performs a cognitive stressor task which demands mental effort and focus such as the PASAT. After, researchers could have participants listen to a self-selected relaxing musical piece and a self-selected stimulating musical piece. Doing so, researchers may be able to differentiate if the type of music, stimulating or relaxing, plays a role in the activation of attentional processes as seen by alpha activity after a stressful task. In relation to this explanation, cognitive intersensory processing, which is an attention-based cognitive process, could also possibly explain the increase in frontal activity during music listening.

Cognitive Intersensory Processing

In cognitive intersensory processing, frontal alpha oscillations may reflect the origins of top-down control regulating perceptual gains and alpha oscillations may provide pulsed inhibition for gamma activity and thereby facilitate cortical information flow from the sensory cortex to the frontoparietal attention network (Misselhorn, Engel, & Friese, 2019). This could explain the observation of greater alpha power from the baseline to the cognitive stressor and from the cognitive stressor to the music as the participant is acclimating and processing different kinds of auditory stimuli. In Misselhorn et al.'s (2019) study, they used a multisensory paradigm that incorporated both bottom-up and top-down processing of cross-modal attention to examine changes in alpha and gamma band activity. The paradigm was made up of visual, auditory, and somatosensory stimuli in which the participants were given either a visual-tactile or auditory-visual bimodal pair and had to respond if the pairs changed congruently (both attended stimuli increased intensity together) or incongruently (one attended stimuli increased and one attended stimuli decreased in intensity). This was a very challenging task, and the researchers purport that because of this, there was an increase in alpha power in frontal regions indicating that this is the origin of top-down orienting. Cross-modal binding was related to increases in alpha power in the right parietal cortex, representing the bottom-up modulatory signal underlying intersensory reorienting. These findings indicate that alpha band dynamics indicate selective cortical routing beyond sensory cortex to the frontoparietal attention network (Misselhorn, Engel, & Friese, 2019). This relates to the present study as it may explain why alpha power was affected by time and not laterality.

With the present study, intersensory processing mechanisms may have been tapped into from the baseline to post-stressor and from the stressor to the music, in that alpha activity changes in response to the reorienting and top-down processing occurred in the frontal regions in response to a change in auditory stimuli. Since the auditory stimuli was self-selected, it is proposed that intersensory processing would begin as the stimuli could produce a variety of sensations in the listener, possibly bringing up mental visual imagery or activating stored memories. For a future study, it would be interesting to examine each of these components separately to determine if intersensory processing occurs in relation to stressful cognitive tasks and/or during music. To investigate the relationship between a stressful cognitive task and intersensory processing, researchers could conduct a study in which participants complete a difficult and stressful task, such as the PASAT, while EEG is being recorded in the frontoparietal electrode sites. Alpha activity could be investigated pre- and post-task to determine if there is a change in alpha activity and when the change occurs to determine if and when intersensory processing begins. To investigate the effect of music on intersensory processing, researchers could conduct a study in which they look at the how different modes of auditory stimuli, or different kinds of music affect alpha activity in the frontoparietal sites to determine if and when intersensory processing begins with the exposure of different auditory stimuli. In opposition to this theory, the increase in alpha activity may have been caused by a trait-based mechanism rather than state-based.

Trait-Based Emotion Regulation

Another possible explanation for increased alpha activity but not increased FAA, is that by adding in a cognitive stressor we may have tapped into asymmetry that is more enduring or trait-based rather than state-based. By adding in the cognitive stressor, our results may differ from Arjmand et al.'s (2017) original study because the stressor may have prompted state-based emotion regulation and FAA response that would not occur if the participant only listened to music in a neutral emotional state (i.e., without a prior stressor). For example, Quaedflieg, Meyer, Smulders, & Smeets (2014) conducted a study in which they investigated the role of FAA in stress and affective responding. Frontal asymmetry was measured at baseline and following an acute stressor were measured in the standard 8 – 13 Hz alpha band as well as the individualized alpha frequency (IAF) band, which is determined by the dominant frequency rhythm at the 5 – 15 Hz at the PZ electrode site for any given individual. Salivary cortisol values were also obtained before and after the acute stressor. The results of this study indicated that the baseline IAF-based FAA was associated with the stress-induced cortisol response, in that increased left frontal activity predicted smaller total cortisol response. Frontal left activity (F7 and F8 electrode sites) at baseline was found to predict behavioral activation measured with the BIS/BAS scales. FAA was unaffected by the stress-induced cortisol response. The results of this study may lend explanation to the present study in that baseline alpha recordings could indicate emotion-regulation traits associated with the BIS/BAS, which in turn could predict the effect that the music has on the individual. However, the present study did not find any correlations with the BIS/BAS scores and change in FAA or overall activity, which may have been due to a lack of statistical power.

In relation to the present study, there may not have been a significant change to overall FAA after the stressor because FAA may not change as a function of current affective state. Although no significant correlations were found in our analysis between baseline FAA and the BIS/BAS scales, there may be a connection between behavioral response to stress and FAA. For future studies, examining different frontal electrode sites, such as more lateral sites like F7 and F8, and/or looking at IAF-based FAA may be more informative for studying a potential trait-like characteristic that moderates the stress response as it proved to be an effective means for measuring FAA in Quaedflieg et al.'s (2014) study. Future studies should also include more focus on the BIS/BAS, in order to resolve if there is a connection between trait-based emotion regulation styles and frontal alpha activity after being exposed to a cognitive stressor. Because of the small number of participants in the present study, there was not enough power to make these comparisons, so it is recommended that future studies have a larger sample size. Conversely, creative ideation may play a role in increasing frontal alpha activity to music, which is a state-based cognitive mechanism.

Alpha and Creative Ideation

Another possible explanation for increases in frontal alpha power over time may be due to an increase in creative ideation during the stressor and the music. Schwab, Benedek, Papousek, Weiss, and Fink (2014) investigated time-related changes to alpha activity during the process of creative ideation. In this study, participants completed a task in which they were given a selection of everyday items, such as shoes or toothpaste, and had to come up with original and unconventional uses for the products while EEG was recorded. EEG alpha activity during the task was compared to resting EEG. The results of the study indicated that there was an increase in alpha power at the beginning of idea generation, followed by a decrease and a final re-increase prior to responding that was located mainly in the temporal and parietal lobes of the right hemisphere. The decrease in alpha activity observed after the music during the final rest period may have occurred because the switch to a different processing mode could have acted as a distraction, thus stopping creative ideation.

In the present study, reorienting and change in frontal alpha activity could have occurred during the PASAT, as creative ideation may have been used while the individual is determining ways to come up with the arithmetic answers more quickly and efficiently as the time between numbers being presented sped up, as creative ideation has been shown to increase effectiveness in problem solving (Basadur, Graen, & Green, 1982). Music has also been shown to increase creative ideation in previous studies (Gültepe & Coskun, 2016; Ritter & Ferguson, 2017), which could explain the observation of increased alpha during music listening. For a future study, researchers could examine the effects of music on creative ideation by having participants listen to different kinds of music, stimulating and relaxing, and have them complete a problem-solving or creative thinking task, such as the Alternate Uses Task. It is recommended to look at parietal electrode sites as well as frontal sites when looking at the different kinds of attended auditory stimuli, at the parietal cortex seems to be involved in creative ideation.

Exploratory correlations

The final aim of this study was exploratory in nature. First, possible correlations between the MMR, ERQ, BIS/BAS, and GMSI with self-reported measures of affect and state anxiety were investigated. When looking at correlations between the scales and self-reported measures of affect and anxiety, a strong positive correlation between changes in negative affect and the Strong Sensations subscale of the MMR was observed. The subscales of the MMR represent different regulatory strategies individuals use to improve mood by listening to music and the Strong Sensations subscale is defined as searching for intense emotional experiences through music (Saarikallio, 2008). This relationship indicates that individuals who search for intense emotional experiences while listening to music were more likely to have greater changes in negative affect due to listening to music.

Next, correlations between the MMR, ERQ, BIS/BAS, and GMSI with changes in averaged alpha activity over the F3 and F4 electrode sites were examined. No significant relationships were observed, suggesting that there is not a relationship between frontal alpha activity and any of the scales. Correlations between the MMR, ERQ, BIS/BAS, and GMSI scales with the overall FA score were also conducted, and no significant correlations were found. This indicates that there is not a relationship between FAA and any of these scales, indicating that the self-report variables should be more state-based.

Finally, exploratory correlations were run between the MMR, ERQ, BIS/BAS, and GMSI scales. A strong positive correlation was found between the Cognitive Appraisal subscale of the ERQ and the Revival subscale of the MMR. Cognitive reappraisal is an emotion regulation strategy which involves lessening the emotional impact of a situation by reframing the initial perception of the event (Gross & John, 2003). The Revival subscale of the MMR is defined as a personal renewal regulatory strategy that individuals utilize when listening to music for relaxation and attaining new energy after being stressed or tired (Saarikallio, 2008). Therefore, this relationship indicates that individuals who use a reappraisal strategy when experiencing something unpleasant are more likely to use music as a means of attaining relaxation and renewed energy after experiencing stress.

Exploratory correlational analyses also found a strong negative relationship between the Expressive Suppression subscale of the ERQ and the Emotions subscale of the GMSI. Expressive suppression is an emotion regulation strategy which involves attempting to hide, inhibit, or reduce ongoing emotion-expression behavior when going through an unpleasant experience (Gross & John, 2003). The subscales of the GMSI represent different dimensions of musical skills and behavior and the Emotions subscale is defined as the sophisticated emotional engagement with music, e.g. ability to talk about emotions that music expresses (Müllensiefen, Gingras, Musil, & Stewart, 2014). The relationship between these two subscales indicates that individuals who suppress their emotional expression are less likely to have a strong emotional connection to the music that they listen to.

Limitations and future directions

There were several limitations to the present study which may have contributed to our unexpected results. First, the PASAT may not have acted as an effective means for causing cogntive stress in the participants. Secondly, the small sample size and demographics of the sample could have acted as a hindrance for generalizability of the results of our study to the general population. Finally, having participants choose their own musical pieces to listen to limits the control over the stimulus and therefore, the effects the stimulus will have on the participant. The limitations will be reviewed in further detail below

The manipulation check demonstrated that there was not a significant increase in stress from baseline to post-stressor, as was anticipated. This could have played a role in why there was not a significant increase in right FA as stress has been shown to produce in past studies (Lewis, Weekes, & Wang, 2007; Tops et al., 2005). However, the PASAT did have a significant effect on mood, particularly in decreasing positive affect. As this study was based on emotion regulation, this result was expected, but there was not a significant change in negative affect from baseline to post-stressor. From the results of the manipulation check, it can be assumed that the desired results of the cognitive stressor were not achieved and although there was a significant decrease in positive affect. Future studies on FAA should use a cognitive stressor that has a greater effect on state anxiety in order to attain more significant changes in anxiety and negative affect.

The demographics of the sample may have produced results that are not generalizable to the general population, as the majority of our sample were below the age of 25 years. The frontal lobe begins development in early childhood and continues up to 25 years of age (Tanaka et al., 2012), and it plays a key role in cogition, including the organization and coordination of brain functioning, goal-directed behavior, and emotion-regulatory behaviors (Etkin, Büchel, & Gross, 2015; Romine & Reynolds, 2005). If the frontal lobe is not fully developed or deficient, the emotion regulatory responses may be either excessive or insufficient in response to emotion- or stress-inducing scenarios (Etkin, Büchel, & Gross, 2015). According to the United States 2019 Census, 71.5% of the population consists of adults 18 to 65 years of age, therefore the majority of the general population is 25 years and up, meaning the present study's results may not be representative of the general population and how they may respond to the stimuli presented in this study. It is recommended that future samples consist of more evenly distributed ages representative of the general population.

There could also be gender differences in frontal activity response to emotional and stressful stimuli given a larger sample size with more evenly distributed gender, as several past studies have indicated that gender may play a role in emotion perception and automatic stress response. In the present study, gender differences were not included in the analyses as there were far fewer males than females in the sample. Past studies have shown that semantic processing in women is more susceptible to influences from emotional auditory stimuli than semantic processing in men (Schirmer, Zysset, Kotz, & Yves von Cramon, 2003), which may explain why the results showed significant changes in mood over time. In another study, participants completed a cognitive stress task in which they completed arithmetic tasks, and results showed that males had greater activity in the right PFC while females had a greater limbic system response (Wang et al., 2007).

If there are gender-specific stress responses to psychological stressor tasks, this could explain why there was not greater right frontal alpha activity post-stressor as our sample was comprised mainly of women.

Being college students, the participants could have more or less general anxiety than individuals who are not currently attending university (Bayram & Bilgel, 2008; (Eisenberg, Gollust, Golberstein, & Hefner, 2007). This could effect the stress reaction in response to the PASAT because they may begin the study with higher or lower states on anxiety, which would skew their stress responses to be either higher or lower than the general population. In the future, aiming for a larger sample size with a more diverse group (i.e., larger range of ages, both students and non-students, and more equal dispersion of gender) of participants would help to increase the generalizability and overall power of the study's results.

Secondly, having participants choose their own musical pieces to listen limits the control over the stimulus and therefore, the effects the stimulus will have on the participant. Choosing one's own song was an important feature of this study as we were investigating the role of self-selected music in emotion regulation and FAA, however, in future studies it may be useful to have set musical pieces which are known to produce positive affect. The type of song that participants chose may have made an effect on how the music made them feel emotionally. For example, for one participant, a "positive" piece of music could be an energizing song where for another participant, a "positive" song could be a relaxing piece of music. Therefore, the way in which the participant perceived the instructions on how to choose their song could be better specified in future studies or participants could choose a piece of music that they prefer out of a selection of songs that the researchers chose. Participants could listen to all of the musical pieces provided and determine which of them that they would want to listen to, creating more control of the stimulus while still giving the participants choice of preference. In other studies, letting participants choose a choice of song from researcher-chosen musical pieces which are known to improve mood have shown to be useful in controlling the stimulus to give the desired affective response. Future studies could focus on genre and perceived valance of the self-selected music by analyzing the data post-hoc, as this study did not have enough power to make these comparisons.

In the present study, alpha activity was investigated as per previous studies, however it may be useful to look at other frequency bands as it may be more representative of the neurological mechanisms which deal with emotion regulation, anxiety reduction, and intersensory processing. Gamma activity would be interesting to investigate, as it has been indicated to be involved cognitive intersensory processing (Misselhorn, Engel, & Friese, 2019). Frontal midline theta activity has been shown to increase while listening to music, and sustained changes to resting EEG theta activity can be seen after three months of music therapy suggesting that frontal midline theta activity is involved in anxiety reduction (Fachner, Gold, & Erkkilä, 2013). Looking into other frontal sites (F7 and F8) may help with understanding of trait-like characteristics that are related to stress responding (Arjmand et al., 2017; Quaedflieg, Meyer, Smulders, & Smeets, 2014). Looking into frontoparietal and parietal sites may also be useful in investigating cortical information flow and creative idea generation (Misselhorn, Engel, & Friese, 2019; Schwab et al., 2014).

Conclusions

It is widely accepted that music promotes an emotion regulatory response to occur which promotes positive emotions and decreases anxiety (Chin & Rickard, 2014; Lynar et al., 2017; Moradipanah, Mohammadi, & Mohammadil, 2009; Papinczak et al., 2015). Neuroimaging studies on music and emotion have indicated the PFC as being the primary location where activity occurs during musical and emotional processing (Daly et al., 2014; Koelsch, 2014; Tsang et al., 2001). Arjmand et al.'s (2017) study suggested that greater left FA in alpha activity occurs when an individual listens to music that they enjoy. Furthering Arjmand et al.'s study, the present study's aim was to investigate frontal alpha asymmetry during the emotion regulation process that occurs when listening to self-selected music after a cognitive stressor. It was predicted that there would be greater right FAA during the stressor and greater left FAA during the musical stimuli. It was found that there was no overall change in FAA resulting from the stressor or the stimuli. However, there was a significant change in frontal activity over time, from baseline to stressor and from stressor to music, followed by a decrease in alpha activity post-music.

There are several ways to interpret and explain the results of this study, but most importantly, it may be necessary to reframe the idea of alpha activity. As was previously stated, alpha activity has been shown to be involved in attention and information processing, indicating an alert state of cognition. It is proposed that music is not relaxing in the traditional sense of the word, in that it calms the mind to a meditative and calming state, but seems to be representative of an active state of attention, possibly in which creative ideation and intersensory processes occur. By including the cognitive stressor in this study, we may have tapped into an emotion regulatory mechanism that is not state dependent but is more likely trait-dependent. Correlations were ran between resting right and left FA and the BIS/BAS scales and no significant relationships were found, which would have lent credence to the theory of trait-based tendencies towards approach or avoidance emotional responses. However, this may be due to the study not having sufficient power to demonstrate a trait-related mechanism in emotion regulation.

Future studies on the emotion regulatory mechanisms involved with listening to music should investigate increased frontal alpha activity as a more accurate depiction of what is occurring during the emotion regulation process while listening to music, as the commonly used FAA transformation does not specifically inform how and where the change is occurring. Researchers should focus on alpha activity as a measure of the attentional processes that are involved while listening to self-selected music, as it seems that what an individual considers to be “feel-good” music influences mood by acting as a stimulating motivator for mood enhancement. Future studies should also look further into trait-dependent characteristics, intersensory processing, and creative ideation as they may play a role in the changes in alpha activity which occur while experiencing a cognitive stressor and listening to music. The present study presents a new framework for looking at alpha activity as an attentional measure that occurs while listening to music, and proposes that further investigation into this phenomenon be conducted to promote a better understanding of the neural mechanisms involved in music listening.

APPENDIX SECTION

APPENDIX A: BEHAVIORAL AVOIDANCE/INHIBITION SCALES

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each

item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not

leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be.

Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your

responses. Choose from the following four response options:

1 = very true for me

2 = somewhat true for me

3 = somewhat false for me

4 = very false for me

1. A person's family is the most important thing in life.

2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.

3. I go out of my way to get things I want.

4. When I'm doing well at something I love to keep at it.

5. I'm always willing to try something new if I think it will be fun.

6. How I dress is important to me.

7. When I get something I want, I feel excited and energized.

8. Criticism or scolding hurts me quite a bit.

9. When I want something I usually go all-out to get it.

10. I will often do things for no other reason than that they might be fun.

11. It's hard for me to find the time to do things such as get a haircut.

12. If I see a chance to get something I want I move on it right away.

13. I feel pretty worried or upset when I think or know somebody is angry at me.

14. When I see an opportunity for something I like I get excited right away.

15. I often act on the spur of the moment.

16. If I think something unpleasant is going to happen I usually get pretty "worked up."

17. I often wonder why people act the way they do.

18. When good things happen to me, it affects me strongly.

19. I feel worried when I think I have done poorly at something important.

20. I crave excitement and new sensations.

21. When I go after something I use a "no holds barred" approach.

22. I have very few fears compared to my friends.

23. It would excite me to win a contest.

24. I worry about making mistakes.

Items other than 2 and 22 are reverse-scored.

BAS Drive: 3, 9, 12, 21

BAS Fun Seeking: 5, 10, 15, 20

BAS Reward Responsiveness: 4, 7, 14, 18, 23

BIS: 2, 8, 13, 16, 19, 22, 24

Items 1, 6, 11, 17, are fillers.

The fact that there are three BAS-related scales and only one BIS-related scales was not planned or theoretically motivated. The factors emerged empirically, from an item set that was intended to capture diverse manifestations of the BAS, according to various theoretical statements. It is likely that a broader sampling of items on the BIS side would also have resulted in more than one scale. I do not encourage combining the BAS scales, however, because they do turn out to focus on different aspects of incentive sensitivity. In particular, Fun Seeking is known to have elements of impulsiveness that are not contained in the other scales.

APPENDIX B: EMOTION REGULATION QUESTIONNAIRE

We would like to ask you some questions about your emotional life, in particular, how you control (that is, regulate and manage) your emotions. The questions below involve two distinct aspects of your emotional life. One is your emotional experience, or what you feel like inside. The other is your emotional expression, or how you show your emotions in the way you talk, gesture, or behave. Although some of the following questions may seem similar to one another, they differ in important ways. For each item, please answer using the following scale:

1 = **strongly disagree** 2 3 4 = **neutral** 5 6 7= **strongly agree**

1. ____ When I want to feel more *positive* emotion (such as joy or amusement), I *change what I'm thinking about*.

2. ____ I keep my emotions to myself.

3. ____ When I want to feel less *negative* emotion (such as sadness or anger), I *change what I'm thinking about*.

4. ____When I am feeling *positive* emotions, I am careful not to express them.

5. ____When I'm faced with a stressful situation, I make myself *think about it* in a way that helps me stay calm.

6. ____ I control my emotions by *not expressing them*.

7. ____When I want to feel more *positive* emotion, I *change the way I'm thinking* about the situation.

8. ____ I control my emotions by *changing the way I think* about the situation I'm in.

9. ____When I am feeling *negative* emotions, I make sure not to express them.

10. ____When I want to feel less *negative* emotion, I *change the way I'm thinking* about the situation.

Scoring:

Items 1, 3, 5, 7, 8, 10 make up the Cognitive Reappraisal facet.

Items 2, 4, 6, 9 make up the Expressive Suppression facet.

Scoring is kept continuous.

Each facet's scoring is kept separate.

APPENDIX C: MUSIC IN MOOD REGULATION SCALE

1. When I'm busy around the house and no one else is around, I like to have some music on the background (E)

2. When I'm going out (for example for school, hobbies, or a party), I listen to music to get myself in the right mood (E)

3. I listen to music to make cleaning and doing other housework more pleasant (E)

4. I usually put background music on to make the atmosphere more pleasant (E)

5. When I'm tired out, I rest by listening to music (R)

6. Listening to music doesn't help me to relax (R) (r)

7. I listen to music to perk up after a rough day (R)

8. When I'm exhausted, I listen to music to perk up (R)

9. When I'm exhausted, I get new energy from music (R)

10. I listen to music to get a breathing space in the middle of a busy day (R)

11. Listening to music helps me to relax (R)

12. I feel fantastic putting my soul fully into the music (SS)

13. Music has offered me magnificent experiences (SS)

14. Music offers me unforgettable moments (SS)

15. Music does not evoke strong emotional experiences in me (SS) (r)

16. I want to listen to music that evokes feelings in me (SS)

17. I want to feel the music in my whole body (SS)

18. Sometimes music feels so great that I get goose bumps (in a positive sense) (SS)

19. When stressful thoughts keep going round and round in my head, I start to listen to music to get them off my mind (Div)

20. For me, music is a way to forget about my worries (Div)

21. Listening to music helps to block out disturbing factors from my mind (Div)

22. When I feel bad, I try to get myself in a better mood by engaging in some nice, music-related activity (Div)

23. I can't push my worries aside with the help of music (Div) (r)

24. When I get angry, I give vent to my anger by listening to music that expresses my anger (Dis)

25. When everything feels miserable, I start to listen to music that expresses these feelings (Dis)

26. When I'm angry with someone, I listen to music that expresses my anger (Dis)

27. When I'm really angry, I feel like listening to some angry music (Dis)

28. When I'm angry, I almost never listen to angry music (Dis) (r)

29. When everything feels bad, it helps me to listen to music that expresses my bad feelings (Dis)

30. Music has helped me to work through hard experiences (MW)

31. Music helps me to understand different feelings in myself (MW)

32. Listening to music takes me back and gets me thinking about different things that have happened to me (MW)

33. Music inspires me to think about important issues (MW)

34. When I'm distressed by something, music helps me to clarify my feelings (MW)

35. When something is troubling me, I find solace in music (S)

36. I listen to music to find solace when worries overwhelm me (S)

37. Listening to music doesn't comfort me in my sorrows (S) (r)

38. When everything feels bad, music understands and comforts me (S)

39. Music is like a friend who understands my worries (S)

40. When I'm feeling sad, listening to music comforts me (S)

Note. (r)=reversed item. Subscales: (E)=Entertainment, (R)=Revival, (SS)=Strong Sensation, (Div)=Diversion, (Dis)=Discharge, MW)=Mental Work, and (S)=Solace Responses are made on a 5-point Likert-scale ranging from *Strongly disagree to Strongly agree*.

APPENDIX D: POSITIVE AND NEGATIVE AFFECT SCHEDULE

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word**.** **Indicate to what extent you feel this way right now, that is, at the present moment OR indicate the extent you have felt this way over the past week (circle the instructions you followed when taking this measure):**

1	**2**	**3**	**4**	**5**
Very Slightly or Not at All	**A Little**	**Moderately**	**Quite a Bit**	**Extremely**

1. Interested
2. Distressed
3. Excited
4. Upset
5. Strong
6. Guilty
7. Scared
8. Hostile
9. Enthusiastic
10. Proud
11. Irritable
12. Alert
13. Ashamed
14. Inspired

15. Nervous

16. Determined

17. Attentive

18. Jittery

19. Active

20. Afraid

Scoring Instructions:

Positive Affect Score: Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19. Scores can range from 10 – 50, with higher scores represent-ing higher levels of positive affect. Mean Scores: Momentary = 29.7 (SD = 7.9); Weekly = 33.3 (SD = 7.2)

Negative Affect Score: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. Scores can range from 10 – 50, with lower scores represent-ing lower levels of negative affect. Mean Score: Momentary = 14.8 (SD = 5.4); Weekly = 17.4 (SD = 6.2)

APPENDIX E: STATE-TRAIT ANXIETY INVENTORY

STAIS-Y2

A number of statements that people have used to describe themselves are given below. Read each statement and then write the number in the blank at the end of the statement that indicates how you feel right now, that is, at this moment.

There is no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best

1= Not at all

2= Somewhat

3 = Moderately so

4 = Very much so

1. I feel calm
2. I feel secure
3. I am tense
4. I feel strained
5. I feel at ease
6. I feel upset
7. I am presently worrying over possible misfortunes
8. I feel satisfied
9. I feel frightened
10. I feel comfortable
11. I feel self-confident
12. I feel nervous

13. I am Jittery

14. I feel indecisive

15. I am relaxed

16. I feel content

17. I am worried

18. I feel confused

19. I feel steady

20. I feel pleasant

STAIT-Y2

A number of statements that people have used to describe themselves are given below. Read each statement and then write the number in the blank at the end of the statement that indicates how you feel <u>in general</u>.

There is no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best

1= Not at all

2= Somewhat

3 = Moderately so

4 = Very much so

1. I feel pleasant
2. I feel nervous and restless
3. I feel satisfied with myself
4. I wish I could be as happy as others seem to be

5. I feel like a failure
6. I feel rested
7. I am calm, cool, and collected
8. I feel that difficulties are piling up so that I cannot overcome them
9. I worry too much over something that really doesn’t matter
10. I am happy
11. I have disturbing thoughts
12. I lack self-confidence
13. I feel secure
14. I make decision easily
15. I feel inadequate
16. I am content
17. Some unimportant thoughts runs through my mind and bothers me
18. I take disappointments so keenly that I can’t put them out of my mind
19. I am a steady person
20. I get in a state of tension or turmoil as I think over my recent concerns and interests

APPENDIX F: PACED AUDITORY SERIAL ADDITION TASK

DESCRIPTION

The Paced Auditory Serial Addition Test (PASAT) is a measure of cognitive function that specifically assesses auditory information processing speed and flexibility, as well as calculation ability. It was initially developed by Gronwall in 1977 (1) to monitor the recovery of patients who had sustained mild head injuries. Stimulus presentation rates were adapted for use with MS patients by Rao and colleagues in 1989 (2), and the measure has been widely used in MS studies during the last decade. The PASAT is presented on audiocassette tape or compact disk to control the rate of stimulus presentation. Single digits are presented either every 3. (3. PASAT) or every 2. (2. PASAT) and the patient must add each new digit to the one immediately prior to it. The test result is the number of correct sums given (out of 60 possible). To minimize familiarity with stimulus items in clinical trials and other serial studies, two alternate forms have been developed; the order of these should be counterbalanced across testing sessions.

MATERIALS NEEDED

An audiocassette tape or CD player, audiocassette tape or CD with PASAT stimuli, clipboard, PASAT Record Forms to administer the test. ***Note:*** audiocassette tapes stretch after 50-75 presentations and should be replaced with new tapes.

DISCONTINUE RULES

1. If the patient cannot get at least two answers correct (consecutive or not) on any one of the three 3. practice sequences.
2. If the patient cannot get at least one answer correct on PASAT-3. test, do not administer the 2. test.

This patient is considered unable to perform the test.

ADMINISTRATION

Verify that you have the correct Record Form (Form A or B) *before* you start reading the instructions for the 3. Practice Trial to the patient.

PASAT-3" Practice Trials

For Part 1 (stimuli every 3.) say, ***"On this tape you are going to hear a series of single digit numbers that will be presented at the rate of one every 3 seconds. Listen for the first two numbers, add them up, and tell me your answer. When you hear the next number, add it to the one you heard on the tape right before it. Continue to add the next number to each preceding one. Remember, you are not being asked to give me a running total, but rather the sum of the last two numbers that were spoken on the***

tape."

Then give the following example: ***"For example, if the first two numbers were '5' and '7,' you would say '12.' If the next number were '3,' you would say '10.' Then if the next number were '2,' you would say '5.'*** If the patient is having difficulty understanding these instructions, write 5, 7, 3, and 2 on a sheet of paper and repeat the instructions, demonstrating how the task is done.

Then say, ***"This is a challenging task. If you lose your place, just jump right back in - listen for two numbers in a row and add them up and keep going. There are some practice items at the beginning*** *of* ***the tape. Let's try those first."*** Play the sample items, stopping the tape after the last practice item.

Repeat the practice items, if necessary, until the subject understands the instructions (up to three times).

You should always administer *at least one* practice trial before administering the actual test. If the patient begins to give you a running total, stop the practice immediately and explain the task again, emphasizing that he/she is not to give you a running total. Then start the practice items again from the beginning. If the patient begins adding each number to the number two previous to it, again stop the practice immediately, explain the correct way to do the task, and start the practice items from the beginning. If the patient merely makes a math error, do not stop the tape; continue with the practice items. After two consecutive .no responses,. prompt him/her to resume by saying, ***"Jump back in with the next two numbers you hear."***

Administer the practice sequence a *maximum of three times.* Record answers in the space provided on the back of the PASAT Record Form.

PASAT-3"

Once it is clear that the patient possesses sufficient understanding of the task, begin Part 1. Before starting Part 1, remind him/her: ***"Remember, if you get lost, just jump back in because I can't stop the test once it has begun."*** Discourage talking and oral calculations during the test; only the patient.s answers should be spoken out loud. The patient may need prompting to continue the test if she/he gets lost. After five consecutive .no responses. redirect the patient quickly by saying, ***"Jump back in,"*** but do not stop the tape.

PASAT-2" Practice Trials

Before Part 2 (stimuli every 2.) say, ***"There is a second part to this test, identical to the first, except that the numbers will come a little faster, one every 2 seconds. Let's try some practice items."*** Emphasize that the patient.s task is the same, but that it is important to try to get his/her answer out as quickly as possible so as to hear the next number spoken on the tape. Every visit, *at least one* 2. practice trial must be administered before administering the 2. test. Allow *up to three* practice trials.

PASAT-2”

After the practice items, proceed directly with the 2. administration. If the patient completed the 3. PASAT, the 2. version is to be administered regardless of the patient.s performance on the 2. practice items.

Completing the PASAT Record Form

Place a check next to all correct answers. Write in any incorrect responses in the space provided. Place a dash when no response was given. If the patient corrects him/herself after giving a response, count the amended answer as the response. The *amended* response is the one that will be used in determining total correct, regardless of whether it was the correct or incorrect response. *Slash through the old response and write in ‘SC’ with a circle around it to indicate that the patient self-corrected.*

Each section of the PASAT has a maximum of 60 correct answers (i.e. 61 digits are presented for each part). Count the total number correct (number of circled answers) for PASAT-3. and record on the PASAT Record Form. Repeat the same scoring procedure for PASAT-2.. (Additional scores can also be computed to examine patterns of responses on the PASAT, but these are beyond the scope of this manual.)

Finally, record any circumstances that you believe may have affected the patient.s performance. These are factors that may have affected the trial, but were not severe enough to necessitate repetition of the trial. Examples include, but are not limited to, the following:

. Subtle noises outside of the testing room
. Patient reports frustration or mild distress
. Patient talked during test (other than to give answers)

If a trial must be repeated, indicate this and specify the reason why it had to be repeated. Examples of reasons to repeat a trial include, but are not limited to the following:

- Test interrupted (e.g. someone walked into the room or other major disturbance)
- Examiner error, such as starting the tape in the wrong place or using the wrong form.

Record only totals for the **successfully completed** PASAT-3. and PASAT-2..

If the patient is unable to perform the PASAT (i.e., cannot get at least two correct on any 3. practice and at least one correct on the test portion), the examiner should indicate .Unable to complete due to cognitive limitations. and record any specific observations. If the patient did not complete a trial for any other reason, record the reasons for this as well (e.g., patient refused to complete test, examiner forgot to administer PASAT2., etc.).

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