THE RELATIONSHIP BETWEEN MUSIC APTITUDE, EMPATHY, AND SENSITIVITY TO EMOTIONAL PROSODY: AN ERP INVESTIGATION

by

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Dedicated to my dog, Jazz, who sat with me while I wrote this thesis.

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ABSTRACT

Research on emotional music and emotional language suggests there is at least a partial neural overlap between these two systems. Research also suggests that high music aptitude is associated with the ability to more easily and quickly process auditory cues related to emotions. Likewise, research on empathy and processing of emotions suggests that high empathy may facilitate the ability to recognize emotions. The primary purpose of the present study was to add to this rapidly growing body of work by examining the contribution of both empathy and musical aptitude to individual differences in neural responses to emotional cues in language and music. To this end, EEG was recorded in participants while they were presented with pairs of musical prime stimuli and spoken target nonsense words that either matched or mismatched in emotional valance. Participants were asked to ignore the musical prime and judge the emotional valance of the speaker's voice during the target words. Results showed decreased P50 and larger N400 effect when words spoken with a happy intonation followed a sad music compared to a happy music. There was also a trend toward a positive relationship between the size of the P50 effect and musical aptitude. Together these results support the existence of overlapping neuro-cognitive systems for processing emotions in language and music. By contrast, no evidence was found supporting the role of empathy in the role of the processing of emotional music and prosody. Interestingly, the findings that participants were overall more accurate for sad than happy words and that the ERP effects of priming were only present for stimuli following a sad music, are in line with "the negativity bias" previously reported in the literature.

Keywords: EEG, empathy, ERP, music aptitude, prosody

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CHAPTER I: INTRODUCTION

Language and music are forms of human communication found in all cultures across the world and present semantic (i.e., related to meaning) and emotional information to others (Patel, 2008). Prosody, the patterns of intonation and stress in speech, is incredibly important during communication with others as it carries important semantic and emotional information (Besson, Magne, & Schön, 2002). Prosodic cues guide listener attention to relevant portions of the speech stream and help listeners determine what is being said and how it is being said. Both prosody and music contain changes in pitch, rhythm, meter, and melody. In particular, timbre and pitch appear to be similar in regard to perceiving emotional valance and intensity of auditory stimuli (Juslin & Laukka, 2003). Prosody also provides social cues, such as informing a listener how to respond (Aucoutuier & Canonne, 2017). For example, if at the end of a statement, a speaker's voice rises in pitch, a listener would know that he or she is expected to respond to a question. Or, if a speaker uses a fearful voice, a listener is alerted that there could be danger nearby. In music, a composer might write in a minor key or use a slow tempo to express sadness, or use a fast tempo and major key to express positive emotions (Ilie & Thompson, 2006).

Because music and prosody share similar acoustical properties, it may not be surprising that studies using neuroimaging methods also show that neural systems that process language and music overlap (Gordon & Magne, 2017). A breadth of research examining acoustic features like rhythmic sensitivity, something important in both speech and music, and music aptitude have shown that those individuals who are more sensitive to mismatched, or unexpected, stress patterns in words also score higher in music aptitude.

Studies exploring the processing of music and prosody use neuroimaging techniques to determine when or where a response occurs in the brain. To measure the time course of brain electrical activity, the electroencephalogram (EEG) can be recorded using electrodes placed on the scalp. A commonly used approach to analyzing EEG data consists of extracting the event-related potentials (ERPs), which represent the moment-by-moment brain responses time-locked to the presentation of a stimulus. Components of the ERPs are usually named using a letter indicating their polarity (N for negative or P for positive), followed by a number corresponding to the latency of their maximum amplitude (in milliseconds). For instance, in language research, a word that is semantically unexpected in a given sentence (such as the word *cry* in *the pizza was too hot to cry*) generally elicits a negative ERP component peaking around 400 ms (Kutas & Federmeier, 2011). It is thus called a N400. A larger N400 component indicates that it is harder for the meaning of a word to be processed by the brain. The amplitude of the N400 is also sensitive to the emotional valance conveyed by the prosody of a word. For instance, emotionally valanced words (e.g., "happy") elicit an increased N400 when they are spoken with a different, or mismatched, emotional prosody (e.g., a sad intonation) (Zheng, Huang, & Zheng, 2013). The meaning of the word and the tone of the voice unexpectedly differ from one another, thus requiring more neural resources to make sense of the mismatched emotions. Whereas the N400 is commonly associated with cognitive evaluation of a stimulus, the perception of emotional prosody can be detected in the ERPs as early as within the P50 latency range following stimulus presentation. The P50 is hypothesized to be associated with the sensory perception of the acoustic cues used to express emotion (Pinheiro, Vasconcelos, Dias, Arrais, & Gonçalves, 2015).

Neuroimaging studies directly comparing emotional prosody and emotional music have found several similarities in the processing of both dimensions. A 2018 study by Liu, Xu, Alter, and Tuomainen showed larger N400 waves when the emotional valance (positive or negative/happy or sad) of music and prosody differed compared to when the two stimuli expressed the same emotion. Several studies have also found evidence that musicians tend to be more sensitive to, and better at detecting, emotion in both prosody and music than non-musicians (Aucoutuier & Canonne, 2017; Nolden, Rigoulot, Jolicoeur, & Armony, 2017). Some researchers have suggested that music training may impact the time points at which the brain recognizes emotional prosody, with neuroimaging results showing musicians more quickly responding to prosodic changes than non-musicians (Pinheiro et al., 2015). Although research on the processing of emotional prosody and music has grown in recent years, research regarding music and prosody in relation to empathy remains scarce.

The ability to empathize is seen as crucial to many psychologists, as the ability to empathize with others contributes to prosocial behaviors and acts that can help others and better the world as a whole (Underwood & Moore, 1982). Empathy is the “sensitivity to, and understanding of, the mental states of others,” (Smith, 2006, p. 3). Research on empathy and music show that those who score higher on measures of empathy also report being more emotionally moved by sad music when compared to those who score lower on empathy measures (Eerola, Vuoskoski, & Kautiainen, 2016; Vuoskoski & Eerola, 2017). High empathizers, compared to low empathizers, also tend to get more enjoyment from sad music, possibly because they find more satisfaction in paying attention to emotional cues from others (Kawakami & Katahira, 2017; Taruffi & Koelsch, 2014).

Although there is little research examining the potential links between music, prosody, and empathy, it seems plausible that the three variables are somehow connected. Because of the consistent findings showing similarities between music and prosody, and findings suggesting that high empathizers experience emotions more deeply, it seems possible that those who are more sensitive to mismatched emotional sounds (e.g., happy music followed sad prosody) may also be more empathic. The aim of the present study is to examine the brain's processing of emotional music and emotional prosody and explore a possible correlation between sensitivity to emotional auditory stimuli, empathy, and music aptitude.

Prosody and Emotion

Prosody is a widely studied area in language processing as it affects so much in human communication. The main view in the scientific community is that semantic information is processed in the brain's left hemisphere, whereas emotional information is processed primarily in the right hemisphere (Besson et al., 2002). Although each hemisphere is responsible for different functions during language processing, they communicate to help the listener decode exactly what a speaker means. Researchers using sarcastic sentences as stimuli found the right hemisphere to be heavily involved in sarcastic speech perception due to greater activity across the right side of the scalp than the left side of the scalp when prosody and sentence semantics did not match (Gibson, Atchley, Voyer, Diener, & Gregersen, 2016). This indicates that emotional valance is greatly important in the brain's interpretation of language.

In emotion language research, results consistently indicate a cross-modal priming effect in ERPs when emotions differ (Delaney-Busch & Kuperberg, 2013; Holt, Lynn, & Kuperberg, 2008; Schirmer & Kotz, 2003). When the emotion of one stimulus is different from the emotion of another stimulus, participants are inhibited in behavioral tasks regarding emotion, and larger N400 waves are typically elicited (Marin & Bhattacharya, 2010; Scherer & Larsen, 2011). This indicates that the brain is sensitive to the differences between emotions and is working harder to recognize what is different. In a 2003 study, Schirmer and Kotz used this technique to measure ERPs when semantics and prosody differed. Participants were asked to listen to emotional and neutral words spoken in emotional and neutral prosodies and to either rate word valance and ignore prosody, or to ignore word valance and rate emotional prosody. Along with faster reaction times to emotionally matched words, larger N400s were observed during the presentation of mismatching trials compared to matching trials, demonstrating the cross-modal priming effect.

Holt et al. (2008) used sentence pairs in which the prime sentence was always emotionally neutral, but the target sentence contained a word with either a positive emotional valance, negative emotional valance, or another emotionally neutral word like the first sentence. Results from the study corroborated Schirmer and Kotz (2003)'s results, indicating a larger N400 wave for emotionally matched words, especially when the second sentence contained an emotionally positive word.

Delaney-Busch and Kuperberg (2013) conducted a study with similar stimuli, except that the prime sentence contained an emotionally neutral, negative, or positive word. The N400 elicited by targets only showed differences when primes were neutral, but not when they had a positive or negative valance. By contrast, emotional words produced a larger late positivity than did neutral words, indicating that it may take the brain a little longer to process emotionally words than neutral words. Although emotional semantics clearly play a role in the perception and processing of language, emotional prosody appears to have a large effect, too.

Additional research suggests emotion processing starts as early as 50 to 200 ms (Pinheiro et al., 2015). Pinheiro et al. (2015) discuss three separate stages of emotion processing, including when and where they occur in the brain. The first stage occurs during the P50 latency range and is proposed to indicate sensory and perceptual processing of the acoustic information. The second stage involves the detection of emotional salience expressed by the voice and is reflected by differences in the P200 latency range and in temporal regions of the brain. The final stage, occurring during the N400 latency range, involves the cognitive evaluation of a stimulus, which recruits the frontal areas of the brain, namely the frontal gyrus and orbitofrontal cortex.

To further explore early sensory perception of emotional prosody, Pinheiro et al. (2015) compared P50 amplitude in musicians and non-musicians when listening to and rating the emotional valence of emotional intelligible and unintelligible (i.e., prosody only) sentences. Results showed a reduced P50 amplitude in musicians, but not non-musicians. Musicians were also faster to respond with the emotional valance of unintelligible sentences than non-musicians. The authors suggested that music training leads to more familiarity with acoustic information due to a more developed auditory neural system. As a result, musicians have more familiarity with certain sound parameters (e.g., pitch) than non-musicians, as music training has effectively trained their brains to be more sensitive to certain acoustic cues. Due to heightened auditory sensitivity, musicians more easily and more quickly process auditory information than non-musicians.

Researchers using behavioral methods to examine the effects of emotion on language have also found prosody to play a large role in processing of language via the measurement of participant reaction times and task accuracy. Nygaard and Queen (2008) asked participants to listen to semantically happy and sad words presented in mismatching and matching emotional prosodies and to repeat the words as quickly as possible. Participants were faster at repeating emotionally matching words than they were mismatching words, showing that emotionally matched words are easier to process. These results indicate that perception of a spoken word requires prosodic attention, not just semantic information.

Filippi et al. (2016) used similar stimuli and tasks to those of Nygaard and Queen (2008) in the first part of their study, but also included faces in part of the study. In the first portion of the study, participants were asked to listen to synonyms for the words "happy" and "sad" read in differing prosodies. They were asked to ignore either word meaning or prosody and to press a button to indicate the valance of word meaning or prosody. Results showed that participants were more accurate and faster to respond when asked to attend to the prosody of the word rather than the word meaning, suggesting that prosody facilitates a more rapid emotional understanding than does verbal content. In the second part of the study, participants were asked to do the same things as they were in the first portion; however, emotional faces were added as a stimulus to either be ignored or attended to. In each trial, two of the three stimuli were emotionally matched, whereas the third was emotionally mismatched. Participants were more accurate in valance ratings when asked to attend to prosody and to ignore word meaning and facial expression, even though two channels were presenting the same emotion (word and face), and one channel was presenting a separate emotion (prosody). Results from the first experiment in this study indicate that prosodic content of verbal information may be more important than its meaning, and results from the second experiment extended these findings, suggesting prosody could be more important than either facial expression or word meaning in determining emotions. Overall, the results suggest that prosody may be enough to gauge emotionality. Results from these studies indicate that auditory stimuli, such as language, vocalizations, and music, may be enough to perceive emotion.

Prosody and Music

In the last two decades, research on the neural overlap of the systems responsible for processing language and music has greatly expanded. Findings from these studies strongly indicate that there is an overlap in the neural networks and cognitive processes responsible for music and language processing. Carrus, Koelsch, and Bhattacharya (2011) used EEG to look at brain oscillatory patterns in relation to the structure of language and music when sentences and chords are were structurally incorrect. Irregularities in chords and sentence structure produced significant increases in delta-theta bands, indicating that low frequency oscillatory networks are activated during the syntactic processing of prosody and music. These findings suggest that the networks active during auditory processing may be shared in both musical and linguistic domains.

One reason for neural network overlap in prosody and music might be because prosody and music are believed to share similar acoustic features in conveying emotion.

In a meta-analysis of language and music studies, Juslin and Laukka (2003) determined that a large number of different acoustic features are similar when both speakers and musicians attempt to convey emotion, including intensity, tempo, pitch, and timbre. Pitch, intensity, and speech rate are features commonly manipulated by speakers to express different emotional prosodies (Chen, Zhao, Jiang, & Yang, 2011). Rhythm is another important acoustic feature of both music and language has also been found to be similar in the two domains. Quinto, Thompson, and Keating (2013) found that rhythm also tends to operate similarly in emotional musical phrases and emotional prosodic sentences. Pitch appears to be of particular importance in conveying emotion both music and prosody. Curtis and Bharucha (2010) used auditory-presented bisyllabic words with differing emotional prosodies, and asked participants to rate perceived emotions of the words and short emotional music excerpts. After conducting analyses to determine acoustic features between the two types of stimuli, the researchers found that pitch appeared to be the most similar acoustic property in the two domains, specifically the minor third which is commonly used to express sadness in music. Results from Curtis and Bharucha's (2010) study provide further evidence in the link of acoustical processing of both emotional speech and emotional music in terms of pitch perception.

In an ERP study, Schön, Magne, and Besson (2004) compared musicians' and non-musicians' pitch perception abilities and found evidence of neural overlap in the processing of prosodic and musical pitch. Participants were asked to listen to musical melodies and French sentences, some of which had a pitch manipulation of the final word or note. Participants were to determine if the pitch of the final word or note was correct in context of the whole sentence or melody. Musicians were better at detecting the smaller of the two pitch violations (i.e., 1/5 step above the correct pitch versus 1/2 step above the correct pitch) than non-musicians in both language and music conditions. Importantly, pitch manipulations in both music and language elicited similar ERPs in both musicians and non-musicians, indicating that is pitch greatly influential in linguistic and musical understanding. These findings also provide support for the argument that music-training influences pitch perception in spoken language, as musicians were better able to detect pitch violations non-musicians.

Because music training positivity correlates with music aptitude (Swaminathan, Schellenberg, & Khalil, 2017), the argument could also be made that those with higher music aptitude are also more sensitive to pitch and possibly other violations than those with low music aptitude. Research indicates that higher levels of musical aptitude are associated with greater phonological awareness in spoken language (Magne, Jordan, & Gordon, 2016). This means those with higher music aptitude are also likely more sensitive to differences in prosody. Taken together, research on similarities in acoustic features and structure of language and music seem to be processed similarly by the brain, including when emotion is a variable of interest.

Researchers who compare the processing of emotional music and language between musicians and non-musicians typically find musicians are better at recognizing emotions across multiple modalities (Aucoutuier & Canonne, 2017; Nolden et al., 2017). Aucoutuier and Canonne (2017) examined the difference between musicians and non-musicians in their abilities to determine social emotions communicated with musical duets, in an attempt to parallel turn taking in conversations. Two musicians who did not know each other prior to the study were asked to record improvised duets based on specific social emotions, like “caring” or “domineering.” One musician would play the emotion they were asked to, and the other musician would play back what they felt was an appropriate response. Participants were asked to determine the emotion being communicated in the duet. Although both musicians and non-musicians were successful in the task, musicians performed significantly better. In a follow-up experiment, non-musician participants were asked to listen to the duets again, but this time, participants either heard both musicians’ parts in the duet or only the first musician’s part. Results showed that participants performed significantly better when presented with both parts of the duet, compared to only one part of the duet. These results support the idea that musical acoustic properties are similar to speech prosody, as musical turn taking likely parallels turn taking in conversations, at least in terms of the emotional cues involved in speech and music.

Nolden et al. (2017) found converging results with those found by Aucoutuier and Canonne (2017) with the inclusion of prosodic sentences as a stimulus. In an EEG study, the researchers examined the difference between musicians and non-musicians in emotional processing of music, pseudo sentences, and human vocalizations (e.g., yells, screams, sighs). Oscillatory brain activity was recorded as participants listened to the three different types of stimuli. Results indicated more brain activity as a result of the emotional stimuli in musicians than non-musicians, as more cortical activity was recorded across musicians’ scalps than non-musicians. Analyses of oscillatory activity indicated that there were category differences in theta and alpha bands, due to larger brain responses to the processing of music and speech than vocalizations. Greater activation of theta and alpha bands was seen in musicians than non-musicians, as well.

These results corroborate with others in the study of emotion processing by musicians: those with musical expertise not only seem to be more perceptive of emotion in music, but also in speech, indicating a neural overlap in the processing of music and language.

Research examining prosody and music has also been conducted using matching and mismatching emotional music and words as stimuli. In an ERP study by Koelsch et al. (2004), participants heard either a sentence or a musical excerpt, followed by the visual presentation of a word. When the target word's meaning was different than the meaning of the sentence, a larger N400 was recorded than when the semantics of the two stimuli matched. The same N400 effect was also recorded when music was used as a prime, indicating that music, like language, can affect semantic understanding. Liu et al. (2018) also used ERPs to examine the similarities between emotional music and prosody. Participants listened to 500 ms long emotional music bursts, followed by semantically neutral sentences spoken in different emotional prosodies. When music and speech were emotionally mismatched, larger N400 responses were recorded, indicating that participants noticed, at least unconsciously, that the emotional valances of two stimuli were not the same. Although other studies have shown that music can be used in emotion research, Liu et al. (2018) are the first to show that even extremely short musical stimuli can prime emotion – enough so that emotional differences are recognized in the brain.

Prosody, Music, and Empathy

Although there are a large number of studies documenting the relationship between prosody and music, very few have examined how they relate to empathy. Most of the research on the relationship between empathy and emotional processing of auditory inputs uses music stimuli. Many of these studies either ask participants to judge the emotional valance of a piece of music or ask them whether they did or did not enjoy the piece of music. Taruffi and Koelsch (2014) examined the relationship between trait empathy and self-reported enjoyment of a sad piece of music and found that participants who score high in trait empathy (high empathizers) also seem to enjoy and feel moved by sad music compared to those low in trait empathy (low empathizers); however, the same was not true when using happy music. Being moved is a highly social emotional activity that helps promote pro-social behavior via feelings of empathy for another (Zickfeld, Schubert, Seibt, & Fiske, 2017). Based on their findings, Taruffi and Koelsch (2014) suggested that sad music might be frequently used to regulate negative emotions, especially by high empathizers. Likewise, Eerola et al. (2016) found a positive correlation between high empathizers and the enjoyment of sad music. Because the music used in this study was unfamiliar to all participants and was purely instrumental, the authors suggested that a piece of music does not have to contain lyrics, be familiar, or be tied to a memory in order for people to find it moving. In a very similar study a year later, Vuoskoski and Eerola (2017) found more evidence that high empathizers tend to feel the emotion expressed in the music more intensely than low empathizers. Although all of this research provides evidence that sensitivity to sad music is particularly high for high empathizers, other research has aimed to look at differences in empathizing ability and musical training.

In line with research showing that musicians are particularly adept at emotion recognition, findings suggest they may also have advantages in emotion-based skills, such as empathy. Because musicians are asked to emote as they play, they might be especially skilled in the ability to not only show emotion but also to detect it. Orchestras, small ensembles, and even duet pairs in music performance all have to listen to the emoting of those they are playing with. This allows them to produce a rich emotional conversation between instruments or voices. Musicians must identify auditory emotions produced by others and choose the appropriate emotional response. Parsons et al. (2014) examined the relationship between empathizing ability and music training. Participants were asked to listen to two infant cries and determine which one sounded more in distress. The pitch of one of the cries was altered digitally via a computer to sound more or less distressed than the other cry. Musicians not only scored higher on an empathy questionnaire, but they also performed significantly better on the distressed cry discrimination task than did non-musicians.

In a study by Huberth et al. (2018), musicians were asked to play piano duets while their EEG was recorded. All of the duets were composed to be played in a turn-taking fashion and were memorized prior to the performance. In addition, the duets contained incorrect notes, which were added to examine the amount of feedback-related negativity (FRN) present when a “mistake” in the music was played. Results indicated that scores on an empathy questionnaire negatively correlated with the size of the musicians’ FRN elicited in response to their own mistakes, suggesting that highly empathic musicians are more focused on what and how their duet partner plays than on their own performance. In sum, results from Huberth et al. (2018) show that high empathizers focus more on others than themselves during music making activities, whereas Parsons et al. (2014) provides evidence that musicians might be more empathetic than non-musicians.

To date, very little research has been conducted examining the relationship between emotional prosody and empathy. Regenbogen et al. (2012) examined the relationship of empathy and emotion detection when emotions portrayed by an actor differed in speech content (semantics), prosody, or facial expression. Results, however, did not indicate a significant relationship between empathizing ability and preferences for a specific emotional channel (i.e., via speech content, prosody, or facial expression). In a study designed to examine the relationship between reaction to stereotype violations by speakers and participant empathizing ability, van den Brink et al. (2012) recorded ERPs while participants listened to sentences that either had semantic violations (e.g., "I brush my teeth with *toothpaste/horse* every day.") or pragmatic violations (e.g., "Every night before bed I drink a glass of wine," spoken by a small child). Consistent with research using mismatched stimuli, sentences with semantic violations produced increased N400 effects. A similar N400 effect was also seen in sentences with pragmatic violations. In addition, a strong correlation was found between empathy and N400 response to pragmatic violations, suggesting that empathy may be an important factor in how people interpret speech. Interestingly, those with higher empathy scores appeared to adjust to the violations, as their N400 decreased in size as the experiment progressed. This finding suggests that those with high empathy use more stereotyping thought processes when listening to another speak, yet they can adjust their expectations of what a speaker might say. Although this study did not examine the relationship between prosody and empathy specifically, the fact that high empathizers reacted more strongly to pragmatic violations in speech indicates that there may very well be a connection between empathy and higher reactivity to the speech from others. Taken together, all of the studies examining the relationship between empathy and prosody or empathy and music indicate that high empathizers may be more emotionally affected by and sensitive to auditory stimuli, whether in music or speech.

Present Study

The primary purpose of the present study was to provide further evidence that the brain processes emotional prosody and emotional music similarly. Studies examining the link between prosody and music consistently show similarities between the two, providing a strong argument that the neural networks responsible for each might be overlapping. Pitch and rhythm have been shown to elicit similar EPRs with both musical and prosodic content (Quinto et al., 2013; Schön et al., 2004). Brain oscillation patterns are also very similar in both prosody and music processing (Carrus et al., 2011). ERP research examining emotionality in prosody has also produced some notable findings, indicating the brain senses and evaluates emotional prosody between approximately 50 and 400 ms (Pinheiro et al., 2015). Research on the effect of emotionality on the processing of auditory stimuli frequently does not include both prosody and music, though. Only one study to date has examined this potential effect and reported larger N400 responses when prosodic emotion of a semantically neutral sentence differed from the emotionality of a music excerpt (Liu et al., 2018). To test this, participants listened to short excerpts of either happy or sad music, followed by nonsense words spoken in a happy or sad prosody. Using nonsense words instead of sentences removes the potential interference that semantics can cause when looking specifically at prosody. Using words rather than sentences also allows for a more accurate measure of when a brain response occurs, as the stimulus is much shorter.

Another purpose of this study was to examine the potential correlation between musical aptitude and sensitivity to differences in emotionality of music and prosody, as well as brain sensitivity to differences in emotional music and prosody and empathy. Behavioral research indicates that musicians, who typically score high on measures of music aptitude, are better at recognizing emotions than non-musicians (Aucoutuier & Canonne, 2017). EEG provides neuroimaging to back these behavioral findings, indicating that musicians show more oscillatory activity during emotional music and prosody listening compared to non-musicians. This activity is also more widely distributed over the scalp of musicians than non-musicians (Nolden et al., 2017). Research on music and empathy consistently shows high empathizers enjoy sad music and even use it as a tool to help them invoke or diminish negative emotion (Eerola et al., 2016; Taruffi & Koelsch, 2014). Musicians, who tend to be more sensitive to emotional auditory stimuli, score higher than non-musicians on measures of empathy (Huberth et al., 2018).

Based on the previous literature, the main hypotheses of the present study were as followed:

1) A larger N400 would be elicited when music and prosody mismatched emotionally, compared to when music and prosody matched emotionally.
2) Participants with a larger N400 when music and prosody differ would also score higher on a measure of music aptitude.
3) Participants with a larger N400 in mismatching conditions would also score higher on a measure of empathy.

CHAPTER II: METHOD

Participants

Twenty undergraduate college students took part in the experiment; however, five participants were removed from final data analysis. One participant was removed due to a malfunction with the EEG stimulation software during data collection, and the other four participants were removed due to excessively noisy EEG data. Excessively noisy was defined as those with less than 50% clean EEG segments. Noisy EEG can lead to type 1 and type 2 errors, as an accurate ERP cannot be extracted from the data. The remaining 15 participants (10 females, 5 males) were included in the analysis of the data. The average age of participants was 19.67 years (*SD* = 2.23 years). All participants were right-handed, native English speakers. The study was approved by the Institutional Review Board at Middle Tennessee State University, and written consent was obtained from each participant prior to the start of the experiment (see Appendix A). Participants were recruited from the MTSU Psychology Research Pool and received course credit for their participation in the study.

Measures

Behavioral measures. The *Brief Mood Introspection Scale* (BMIS; Mayer & Gaschke, 2013) was given to each participant at the beginning of the study as a screening tool. The BMIS contains a list of 16 adjectives of different emotions (e.g., lively, sad, loving) that participants are asked to rate, on a four-point scale, how much the emotion fits their current mood. This scale is designed to collect a quick measure of mood prior to the beginning of the experiment, with possible scores ranging from 16 to 64.

The *Advanced Measures of Music Audiation* (AMMA; Gordon, 1989) was used to assess participants' musical aptitude. The AMMA is a standardized (Gordon, 1990) paper and pencil measure that allows researchers to determine a person's innate ability to recognize changes in pitch and rhythm in melodies. In the AMMA, participants are asked to listen to 30 pairs of melodies and decide whether the two melodies of each pair are the same. If participants detect a variation between the two melodies, they are further prompted to judge whether the difference was tonal or rhythmic in the second melody. Melodies vary tonally or rhythmically, but never both ways. Including recorded instructions presented at the beginning of the task, the AMMA takes approximately 16 minutes to complete.

The *Basic Empathy Scale for Adults* (BES-A; Carré, Stefaniak, D'Ambrosio, Bensalah, & Richard-Besche, 2013) was used to asses participants' ability to empathize. The BES-A contains 20 items in total, and possible scores range from 20 to 100. Participants are asked to read a statement and use a five-point Likert scale, with five being the highest, to rate how much they feel the statement fits their usual behavior and feelings (e.g., "After being with a friend who is sad about something, I usually feel sad").

ERP stimuli. A total of 32 musical excerpts from classical pieces served as affective primes. The musical excerpts were adapted from a previous study in which they were rated for emotional valence and arousal (Peretz, Gagnon, & Bouchard, 1998). Half of the excerpts ($n = 16$) were rated as happy and half ($n = 16$) were rated as sad.

A total of 128 nonsense words from Pridmore (2015) served as the target stimuli. The words were created using the software Wuggy (http://crr.ugent.be/programs-data/wuggy). A female, native English speaker with training in vocal performance recorded two versions of each word: one version spoken with a happy prosody and another version spoken with a sad prosody.

Four experimental conditions were created by manipulating independently the emotional valences of the prime musical excerpt and target word prosody: (a) happy music/happy prosody (HMHP); (b) happy music/sad prosody (HMSP); (c) sad music/sad prosody (SMSP); and (d) sad music/happy prosody (SMHP). To prevent any potential repetition effect, four lists of stimuli were created using a Latin square design so that each word appeared only once for each participant, but in all conditions across all participants.

Procedure

Participants were first asked to read and sign an informed consent form. They were then asked to complete the BMIS (Mayer & Gaschke, 2013). Participants in the experiment with an overly negative mood may show a bias to the way they rate the emotional valance of speech stimuli during the ERP task, as there tends to be more attention paid to negative-emotion stimuli (Carretié, Mercado, Tapia, & Hinojosa, 2001); therefore, a threshold score of 40 was set. All participants scored above the threshold for inclusion in the study. Following completion of the BMIS, head measurements for each participant were taken to determine the correct size net. The AMMA (Gordon, 1989) and EEG task were counterbalanced across participants to account for any effect one task may have on the other. The melodies and words in both tasks were presented to participants over headphones in a sound-dampening room.

Prior to starting the EEG, participants were provided with some basic information and instructions about how EEG works and what behaviors to avoid doing during the experimental session. Because EEG records all muscle movements, participants were asked to avoid blinking and movement during stimulus presentation. During this portion of the experiment, participants were asked to press a button following each presented word, indicating whether they thought it sounded happy or sad. The presentation of each musical excerpt lasted 500 ms, followed by an interstimulus interval of 250ms. From the beginning of the presentation of a word, participants had 2000ms to rate the word's emotional valance. Participants heard 32 pairs of musical excerpts and nonsense words per condition. After EEG data was collected, participants were then asked to complete the BES-A (Carré et al., 2013) before being debriefed. The entire experimental session lasted 60 to 90 minutes.

EEG Data Acquisition

The EEG was recorded continuously from 32 Ag/AgCl electrodes embedded in a GSN Hydrocel net (EGI, Eugene, OR) placed on the scalp with Cz at the vertex, connected to a NegAmps 400 amplifier, and using NetStation 5 on a Mac Pro computer. Data was referenced online to Cz, and acquired at a frequency of 1000Hz. Electrode impedances were kept below 50kOhm. NetStation Viewer and Waveform tools were used for preprocessing of the EEG data. The data was first filtered offline with a bandpass of 0.1 to 30 Hz and then re-referenced offline to the average of the left and right mastoid sensors. The vertical and horizontal electrooculograms (EOG) were also recorded so that eye blinks and vertical movements could be detected and corrected offline during data processing.

CHAPTER III: RESULTS

Behavioral Data

Bar graphs comparing HMHP, SMHP, SMSP, and HMSP conditions for accuracy rate and reaction time are shown in Figure 1. Overall, participants performed well on the emotional prosody decision task. Participants demonstrated better accuracy for sad prosody (SMSP *M* = 96%, *SD* = 3.34; HMSP *M* = 95%, *SD* = 5.78) than they did for happy prosody (HMHP *M* = 92%, *SD* = 5.89; SMHP *M* = 89%, *SD* = 8.54), along with a faster reaction time for sad prosody (SMSP *M* = 1102 ms, *SD* = 164; HMSP *M* = 1117 ms, *SD* = 195) than for happy prosody (HMHP *M* = 1137 ms, *SD* = 235; SMHP *M* = 1152 ms, *SD* = 238).

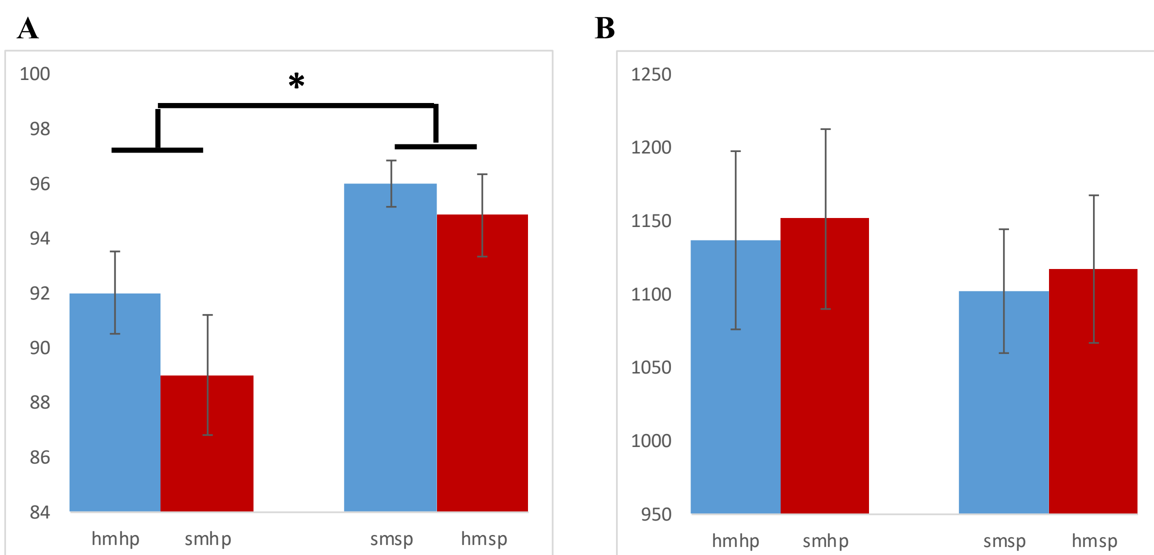

Figure 1. Behavioral performances in the four experimental conditions (HMHP, SMHP, HMSP, SMSP). *A:* mean accuracy rate (percent). *B:* mean reaction times (in ms). Error bars represent the standard errors for each condition.

Two-way repeated measures ANOVAs were computed on participants' accuracy rates and reaction times, using match (matching verses mismatching condition) and prosody (happy versus sad spoken words) as within-subject factors. A familywise alpha of .05 was used for all analyses. Results of the analysis on the accuracy rates revealed a significant main effect for prosody, F (1, 14) = 5.34, p = 0.04. There was no significant main effect of match, F (1, 14) = 3.14, p = 0.10, or match by prosody interaction, F (1, 14) = 1.38, p = 0.26. Results of the ANOVA for reaction times did not reveal a main effect of match, F (1, 14) = 1.25, p =0.28, or prosody, F (1, 14) = 2.62, p = 0.13, and there was not a significant interaction between match and prosody, F (1, 14) = 0.00, p = 0.98.

Electrophysiological Data

Statistical analyses of the ERPs were performed using MATLAB and the FieldTrip open source toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2011). Planned comparisons between the ERPs elicited by matching emotions and mismatching emotions were performed using a cluster-based permutation approach (SMHP *vs* HMHP & HMSP *vs* SMSP). The advantages of this non-parametric data-driven approach does not require the specification of any latency range or region of interest a priori, while also offering a solution to the problem of multiple comparisons (Maris & Oostenveld, 2007).

The cluster-based permutation tests revealed two significant differences between HMHP and SMHP conditions over the left centro-frontal electrodes. The first difference was located between 78 and 104 ms (p = 0.03) and reflected a smaller P50 component for SMHP than HMHP (see Figure 2A). The second significant difference occurred between 522 and 588 ms (p = 0.03) and reflected a larger N400 component for SMHP than for HMHP (see Figure 2B). By contrast, the analyses did not reveal any significant ERP differences between the SMSP and HMSP.

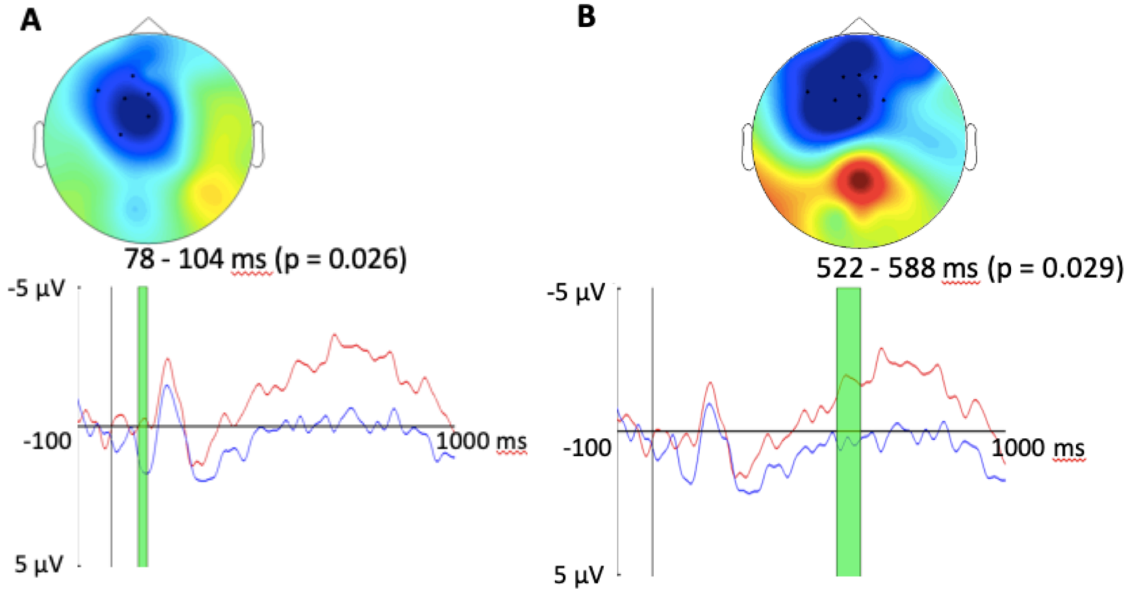

Figure 2. Grande-average ERP time locked to the onset of the target word spoken with a happy prosody, following either happy music (HMHP, blue trace) or sad music (SMHP, red trace). The green rectangle represents the time range of the significant difference between conditions corresponding to the P50 (panel A) and N400 (panel B) components. Topographic maps show the scalp distribution of the mean amplitude difference within each latency range.

Brain-Behavior Relationship

Descriptive statistics for all variables can be found in Table 1.

Table 1

Descriptive Statistics for All Variables

Measure	*M*	*SD*	Min	Max
AMMA	49.93	10.96	33	68
BES-A	45.93	10.60	34	68
P50 Difference	1.13	2.18	-1.83	5.13
N400 Difference	1.34	2.01	-1.37	5.15

Note. *M* = mean, *SD* = standard deviation, Min = minimum, Max = maximum.

Pearson correlations were computed to investigate the relationship among all variables included in the study. An alpha level of 0.05 was used for all tests. As can be seen in Table 2, there was a significant positive correlation between the mean P50 difference and mean N400 difference.

Table 2

Correlations Among All Variables

Measure	1	2	3	4
1. AMMA	_			
2. BES-A	0.14			
3. P50 Difference	0.48	0.11		
4. N400 Difference	0.22	-0.14	0.55*	_

Multiple regression analyses were conducted with music aptitude and empathy as predictor variables, and the mean ERP differences as outcome measures. One regression analysis was computed for the early effect (i.e., decreased P50) and another for the late effect (i.e., increased N400). To that end, indices of early (P50) and late (N400) sensitivity to cross-modal priming of sad emotional valence were calculated for each participant by computing the mean ERP amplitude in latency range and electrode locations based on the existing literature and visual inspection of the data. The selected latency ranges were 50-150 ms and 200-600 ms, for the P50 effect and N400 effect, respectively. For both ERP effects, mean amplitudes were computed from four midline electrodes located over centro-frontal scalp regions. When P50 was the outcome variable and music aptitude and empathy the predictors, the regression model was not significant, $R^2 = 0.27$, F (2, 14) = 2.20, $p = 0.15$ (see Table 3). Although the model was not significant, Cohen's f^2 of 0.37 met the criteria for a large effect size (Cohen, 1992, classifies f^2 as small/medium/large if $F^2 > 0.02$, 0.15 or 0.35, respectively).

Table 3

Multiple Regression Coefficients for The Mean Early Negative Effect

Source	*B*	*SE*	*β*	*t*	*p*
Constant	-5.68	3.70		-1.53	0.15
Empathy	0.04	0.05	1.02	0.73	0.48
Music Aptitude	0.10	0.05	1.02	2.05	0.06

B: unstandardized coefficient; *SE:* standard error; *β*: standardized coefficient; *t*: *t*-value; *p*: *p*-value

When N400 was the outcome variable and music aptitude and empathy predictors, the regression model was again not significant, $R^2 = 0.06$, $F\ (2, 14) = 0.39$, $p = 0.68$ (see Table 4). Cohen's f^2 was 0.06, which corresponded to a small effect size.

Table 4

Multiple Regression Coefficients for The Mean Late Negative Effect

Source	*B*	*SE*	*β*	*t*	*p*
Constant	0.48	3.86		0.12	0.90
Empathy	-0.02	0.05	1.02	-0.41	0.69
Music Aptitude	0.04	0.05	1.02	0.72	0.49

B: unstandardized coefficient; *SE:* standard error; *β*: standardized coefficient; *t*: *t*-value; *p*: *p*-value

CHAPTER IV: DISCUSSION

The primary aim of the study was to examine the neural overlap in the processing of emotional music and emotional prosody. In addition, the present study sought to determine whether musical aptitude and empathy affect emotional processing in music and language. The results can be summarized as follows. A smaller P50 and a larger N400 were elicited only by a sad music followed by a happy word (i.e., SMHP). Participant accuracy rate on the emotion decision task were better for sad words than happy words, regardless of whether or not the musical prime matched the emotion. Finally, musical aptitude and empathy were not significant predictors of the size of the P50 or N400 effect elicited by the SMP condition. These findings are discussed in turn in the sections below.

Effect of Music Emotional Valance on Neural and Behavioral Responses to Prosody

During the cross-modal task, larger N400 and smaller P50 were elicited only when sad music preceded happy prosody (SMHP). The P50 effect has been linked to the initial sensory perception of the emotional acoustic cues, whereas the N400 effect is more closely linked to the cognitive evaluation of the emotional valance (Pinheiro et al., 2015). Both the P50 and N400 effects were larger over fronto-central regions of the scalp. These results are in line with past research indicating that neural emotion processing occurs in the central-frontal locations of the brain (Pinheiro et al., 2015). In addition, these findings provide support for the main hypothesis of this study, and are consistent with past research, suggesting that neural systems for language and music processing partially overlap (Carrus et al., 2011; Gordon & Magne, 2017; Liu et al., 2018; Nolden et al., 2017; Pinheiro et al., 2015).

Although there was a lack of effect of musical prime on sad prosody words, lack of any significant difference for sad prosody is not all that surprising. Converging evidence points toward a preference for sad emotion, otherwise known as the negativity bias (Carretié et al., 2001; Marin & Bhattacharya, 2010). The negativity bias hypothesis proposes that people show preference for negative emotion because of self-preservation instincts. Negative emotions include, for instance, fear and anger, both of which are important to recognize from a survival standpoint. By contrast, whereas positive emotion can be nice, it does not share the same important survival information. Further, research using cross-modal priming paradigms has indicated the effect of the prime is stronger when the prime is negative, and, under certain circumstances, positive priming may even be ineffective (Scherer & Larsen, 2011). For instance, participants who report being deeply negatively affected by a negative prime tend to rate neutral and positive emotion targets as more negative than they actually are (Bouhuys, Blome, & Groothuis, 1995).

In line with the negative bias hypothesis, behavioral data from the EEG portion of the experiment showed that the emotional valance of the prosody had an effect on participant accuracy at recognizing emotions. Participants were significantly more accurate for sad prosody than they were for happy prosody.

Relationships Between Cross-Modal Priming, Empathy, and Music Aptitude

Participants with higher music aptitude were expected to have a larger N400 amplitude when music and prosody emotion were mismatched compared to participants with lower music aptitude. Likewise, participants with higher empathy were expected to have a larger N400 amplitude when music and prosody emotion were mismatched compared to those with lower empathy. A multiple regression was computed with music aptitude and empathy as predictors and the mean late negative effect (N400) as the outcome variable and was found to be non-significant. Another multiple regression computed with the mean late negative effect (P50) as the outcome was also not significant, though there was a trend towards a moderate positive correlation. This trend could be explained by the early processing of sensory information that occurs around the time of the P50, as has been found in previous research on emotional prosody (Pinheiro et al., 2015). Yet, overall, results from this part of the study did not support the hypotheses about the behavioral measures, nor are they in line with past research. There is a fairly substantial body of research comparing musicians to non-musicians, and, therefore implicitly music aptitude, that consistently shows musicians to be more sensitive to differences in emotional stimuli (Aucoutuier & Canonne, 2017; Nolden et al., 2015; Pinheiro et al., 2015). Research on empathy and sensitivity to emotion, although not as substantial, indicates that those with high empathy show signs of more sensitivity to emotional stimuli (Parsons et al., 2014), more enjoyment of sad music (Kawakami & Katahira, 2017; Taruffi & Koelsch, 2014), and more reported feelings of being moved by sad music (Eerola et al., 2016; Vuoskoski & Eerola, 2017) than those with low empathy. Based on previous findings suggesting high empathizers enjoy sad music more than low empathizers, and the negativity bias, one might expect to see high empathizers have a stronger reaction to SMHP than low empathizers, but this result was present in the data. There could be a number of reasons for the lack of significance that are now discussed in the next section.

Limitations and Future Directions

There are several potential limitations to this study, the first and biggest being small sample size. Many EEG studies use closer to 30 participants, twice the number of participants in this experiment. The relationship between music aptitude and the mean negative effect trended toward a significant correlation, enough so it seems plausible the relationship would become significant with the addition of more participants. The behavioral task during the EEG portion of the experiment could be another limitation of this study, as asking participants to ignore the prime and focus only on the target may have eliminated any priming effect if participants were easily able to ignore the prime. This could explain a lack of significance in some of the results of this study. Future studies using the same or very similar stimuli could test if ignoring the prime truly does cause it to lose its effectiveness by having participants attend to both the prime music and target word. Likewise, future research could reverse the prime and target in an attempt to determine if emotional prosody has a larger effect on emotional music. Perhaps there is more sensitivity to prosody than music, seeing as it is so important to human communication.

Another potential limitation is the choice of scales, namely the BES-A (Carré et al., 2013). The BES-A was created and originally tested in French, and although it has been translated to a variety of languages and tested in those different languages, it is not normed. This makes it very difficult to directly compare empathy scores with scores from the AMMA (Gordon, 1989), which was standardized with a US population. There was also a relatively low variance of scores on the empathy scale, with all but three participants scoring within 15 points of one another. A final potential limitation of the

BES-A is that it does not specify how to calculate sub-scores of cognitive and emotional empathy from an overall score of empathy. Empathy is thought to be divided into two sub-categories: cognitive empathy and emotional empathy. Cognitive empathy is the ability to take another's perspective and understand how they feel and why they feel the way they do, essentially "putting oneself in another's shoes." Emotional empathy is usually described as vicarious sharing in the emotions of others (Smith, 2006). Emotional empathy is less well understood than cognitive empathy because it is challenging to measure a phenomenon that is unconscious much of the time. It could be that either emotional empathy or cognitive empathy independently effect sensitivity to emotional music and prosody, and so it may beneficial to examine empathy as two different types of empathy rather than one in the future. There are some empathy measures that look at multiple dimensions of empathy. The *Interpersonal Reactivity Index* (IRI; Davis, 1980) has four sub-scales; however, it gives two separate scores of types of cognitive empathy and two different scores of types of emotional empathy, not allowing for one score for each type of empathy (Davis, 1980). However, it might be interesting to compare the IRI's four sub-scales of empathy to sensitivity to emotional music and prosody, as it could be a very specific empathizing ability that relates to sensitivity to emotional sounds.

On a similar note, the AMMA may have also been a limited measure of music aptitude for similar reasons the BES-A may have been for empathy. The AMMA offers a simple view of music aptitude, only measuring two dimensions of music: rhythm and tonality. These are both very important dimensions of music, but there are multiple other dimensions as well, such as timbre, harmony, meter and beat perception. It would thus be interesting to determine which, if any, of these musical dimensions relate to sensitivity to emotional music and prosody as well as with specific sub-scales of the IRI.

Conclusion

Overall, results from the present study provided partial support for previous findings. Results indicated that the neural systems of prosody and music processing partially overlap, as indicated by the significant difference for happy prosody when proceeded by happy or sad music. Further supporting previous research, results showed a smaller P50 and larger N400 were elicited for happy prosody when preceded by sad music. Taken together, findings from the present study provided further evidence that there is a negativity bias for sad auditory stimuli, but did not support a link between emotional processing, musical aptitude, and empathy.

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APPENDICES

Appendix A

IRB

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010A Sam Ingram Building,
2269 Middle Tennessee Blvd
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MIDDLE TENNESSEE STATE UNIVERSITY

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Thursday, March 21, 2019

Principal Investigator	**Jessica Steele** (Student)
Faculty Advisor	Cyrille Magne
Co-Investigators	NONE
Investigator Email(s)	*jrs2bw@mtmail.mtsu.edu; cyrille.magne@mtsu.edu*
Department	Psychology
Protocol Title	***Relationship between music, prosody, and emotion***
Protocol ID	**19-2193**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the categories: *(4) Collection of data through noninvasive procedures* **(PRIMARY)** and *(7) Research on individual or group characteristics or behavior* **(SECONDARY)**. A summary of the IRB action and other particulars in regard to this protocol application is tabulated below:

IRB Action	**APPROVED for ONE YEAR**		
Date of Expiration	**3/31/2020**	Date of Approval	3/21/19
Sample Size	100 (ONE HUNDRED)		
Participant Pool	Primary Classification: **General Adults (18 or older)** Specific Classification: **MTSU students**		
Exceptions	Use of MTSU SONA permitted		
Restrictions	**1. Mandatory signed informed consent; the participants must have access to an official copy of the informed consent document signed by the PI.** **2. Data must be deidentified once processed.** **3. Identifiable data must be destroyed as described in the protocol. This includes audio/video data, photo images, handwriting samples, contact information and etc.**		
Comments	NONE		

This protocol can be continued for up to THREE years (**3/31/2022**) by obtaining a continuation approval prior to **3/21/2020**. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Post-approval Actions

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

Continuing Review (**Follow the Schedule Below:)**

Submit an annual report to request continuing review by the deadline indicated below and please be aware that **REMINDERS WILL NOT BE SENT.**

Reporting Period	Requisition Deadline	IRB Comments
First year report	2/28/2020	NOT COMPLETED
Second year report	2/28/2021	NOT COMPLETED
Final report	2/28/2022	NOT COMPLETED

Post-approval Protocol Amendments:

Only two procedural amendment requests will be entertained per year. *In addition, the researchers can request amendments during continuing review. This amendment restriction does not apply to minor changes such as language usage and addition/removal of research personnel. .*

Date	Amendment(s)	IRB Comments
NONE	NONE.	NONE

Other Post-approval Actions:

Date	IRB Action(s)	IRB Comments
NONE	NONE.	NONE

Mandatory Data Storage Requirement: All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study has been closed. Subsequent to closing the protocol, the researcher may destroy the data in a manner that maintains confidentiality and anonymity.

IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

Click here for a detailed list of the post-approval responsibilities.
More information on expedited procedures can be found here.