Affective Priming Effect of Music on Emotional Prosody in Williams Syndrome

by

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This thesis is dedicated to my close friends and family, who dealt with my eccentric and sometimes unmanageable behavior throughout my time spent in graduate school.

Acknowledgments

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Abstract

Williams Syndrome (WS) is a rare neurodevelopmental disorder caused by a gene deletion on chromosome 7. Among a range of deficits, the areas for language and hearing are preserved. The present study examines whether emotional music influences the neural markers of emotional processing in spoken language. In addition, WS participants are compared to age-matched controls to test the hypothesis that their phenotype leads to larger musical priming. Using a cross-modal priming task, electroencephalograph (EEG) recorded participants as they listened to musical excerpts followed by spoken pseudowords. The emotions of the music either matched or mismatched the emotions of the pseudoword. Analysis of the electrophysiological data revealed an increased N400 component for mismatching conditions in both groups. Interesting differences were also found between the two groups, both in terms of latency of the mismatch effect and sensitivity to different types of emotion. Implications for language acquisition are also discussed.

Keywords: Williams syndrome, affective priming, music, emotion, prosody, EEG, ERP

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CHAPTER I

Introduction

The rapidly evolving field of neurolinguistics has used music as a conduit to test whether parts of the brain involved in processing language are dedicated only to language. As a consequence, a growing agreement is that music and language share overlapping neural networks and cognitive processes. The current project seeks to further understand emotional processing of music and spoken words in individuals with and without Williams Syndrome (WS). The research question that will be specifically addressed is whether brief emotional musical excerpts can influence processing of subsequent emotional words in individuals with WS more than typically developing (TD) individuals. Potential benefits of the proposed study may come from a better understanding of emotional processing, as well as prosody perception in language in both WS and TD populations. In addition, from a clinical point of view, potential therapeutic applications could involve relieving anxiety, improving quality of life, and helping to learn other social skills.

Music & Language

Evidence for the direct connection between music and language in the brain can be seen from an anatomical or functional perspective. Magnetoencephalography (MEG) is a method that is used for recording magnetic fields that are produced from electrical currents tied to brain activity. For example, it has been demonstrated through this system that Broca's area is not strictly devoted to language processing, as the syntactic processing of musical phrases could also activate it (Maess et. al, 2001). Broca's area is involved in auditory language comprehension and syntactic analysis, suggesting that music could have its own structure for syntax, a complex rule-based system of processing similar to language. Using music theory as a model for musical syntax, the researchers in this study presented participants with a five-chord scale of succeeding notes. When the sequences of these scales included incongruous chords based on harmonic expectancy, Broca's area showed to be strongly activated. In summary, an area of the brain that was thought to be language specific can also be activated when processing harmonic sequences in music. This finding was particularly important for the fact that it challenges the century-old idea that Broca's area was only used for language.

Like syntax, there exist other areas of language that can be connected to music, such as prosody. Prosody in spoken words guides the listener towards the emotional quality of what is being said by conveying information through rhythm and the inflection of pitch. This communication can also be observed in music, as tempo and the inflection of notes sets the mood for a piece of music. Research by Thompson, Schellenberg, & Husain (2004) has shown that being musically trained or taking music lessons can have an impact on detecting prosody in speech. In their first experiment, musically trained and untrained individuals listened to sentences spoken in happy, sad, fearful, and angry emotions. Across all the conditions, those with musical training performed better at identifying the emotion of the sentence. The second experiment followed the same procedure as the first except that they included tone sequences that were matched to the emotions of the spoken sentences. Interestingly, the musically trained group performed better at identifying sad and fearful emotions in the spoken sentences and the tone sequences than the musically untrained group. In the third experiment, a group of six-year-olds were tested after being randomly assigned to a single year of keyboard, vocal, drama, or no lessons. Results showed that the keyboard group and drama group had the highest improvement, yet it is interesting to see that keyboard lessons had a stronger impact on identifying prosody in language than vocal lessons. Overall, Thompson and researchers found across three experiments that being musically trained, even for just a single year, can evoke an increased sensitivity to the emotions expressed in the prosody of speech.

Another approach that can give us information about music and language processing is electroencephalography (EEG). This method uses a net of electrodes that, when placed on the scalp, allows the continuous recording of the electrical activity from the brain (i.e., electroencephalogram). One particular application of the EEG, known as the Event-Related Potential (ERP) method, offers researchers the opportunity to observe voltage changes that are time-locked to a specific event or stimulus. ERPs are calculated by averaging together the EEG of many trials so that random EEG activity is eliminated while the relevant activity remains. ERP components are often interpreted as reflecting many different sensory, motor or cognitive processes. One ERP component of interest for the proposed project is referred to as the N400. It is a negative peak in voltage with a maximum occurring at around four hundred milliseconds after the onset of word. This N400 is understood to reflect lexico-semantic processing (Kutas & Federmeier, 2011), as it can be elicited when a word does not match the context of the sentence in which it is presented. Many studies have found ways to make a N400 appear in linguistic settings, but not only until recently has this approach been used when looking at the cognitive processes of music. For example, an experiment by Gordon (et al., 2010) examined the N400 by using the musical theory of song. Specifically, the authors investigated whether music and language processing happened independently or interactively by providing participants with pairs of sung words with same words and same melodies, different words but same melodies, same words but different melodies, or different words and different melodies. In two separate attentional tasks, participants were instructed to perform a same/different task on either the word or the melody. Participants were slower when evaluating the music than the words. A larger N400 was found when either the words or the melody did not match. Their findings showed that semantic processing was modulated by musical melody in song and that the variations in musical features affect word processing in sung language.

Another path that has been taken when comparing music and language is by looking at studies that involve exploring the effect of musical expertise. Using EEG, Schon, Magne, & Besson (2004) looked at these differences between musicians and non-musicians by having them listen to melodies and sentences and instructing them to decide whether the pitch of the last note or word was correct. The results of this study showed that musicians were better at detecting pitch violations in music as well as in language, and that both the music and language conditions showed similar brain responses. This evidence suggests that musical training may be useful in the practice of language therapy, as it has the potential to strengthen the brain areas associated with processing pitch frequencies. The same researchers replicated the results of this study with samples of musician and non-musician 8-year-old children (Magne, Schon, & Besson, 2006). These studies are interesting in the way that they show differences between musicians and non-musicians, and that they can provide us with a gateway to understanding how the cognitive domains of music and language operate. The interactions witnessed in these studies between words and melodies provide evidence for the idea of an overlapping neural network between music and language for syntax, semantic information, and prosody.

Emotional Processing

Recent research suggests that emotion could be what binds music and language together (Salimpoor et al., 2011). Music's ability to captivate our emotions is the main reason why people enjoy listening to it. People generally acknowledge music's modulating effects on their emotions and state of mind, however, mechanisms involved in these processes are not yet well known. In an attempt to explain why music is held in such high value in all human societies, Salimpoor and his colleagues wanted to examine the effects of emotions in music by looking at the dopaminergic system. They concluded that feelings of pleasure and reward are controlled by dopamine activity in the mesolimbic system, which has been attributed to motivation and reinforcements for behavior. The findings of this study showed that peak or high feelings of pleasure can lead to dopamine release in the striatal system, and that the expectancy of a reward can result in dopamine activity in other brain areas separate from peak pleasure experiences.

Another interaction in emotional processing we find is that the music we choose to listen to can influence emotional processing in other cognitive domains. A study by

Vuoskoski & Eerola (2011) investigated this relationship by comparing participants' personality type to their musical preference. Personality traits predispose a person to specific mood states, even though the interactions between the two are rather complex. Music stimuli may allow a person to explore self-referential aspects of emotions, providing an effective way to look at mood and personality in emotional processing. The researchers concluded that mood and personality traits play an important role in the emotional processing of music, yet the scope of this finding may be limited by what little we know about the differences in emotional processing across individuals.

A good example of how one can see the impact emotions have on the perception of music is when looking at an emotional disorder such as alexithymia, a deficit in recognizing or expressing emotions (Goerlich et al., 2011). Individuals with alexithymia were tested on the behavioral and electrophysiological level as they listened to affective music or speech followed by congruent or incongruent visual stimuli. Compared to control samples, participants with alexithymia had significantly smaller N400 amplitudes when the stimuli targets were incongruent. On the behavioral level, individuals with alexithymia also showed a lower affect when evaluating the emotion of music or speech. As the ratings of alexithymia increased, the influence of the affective music or words decreased. A better understanding of how music can alter emotional states should be at the forefront in the field of emotion research as knowledge of these types of processing could be utilized in a therapeutic setting to help clinical populations.

Evidence for the connections between music and other domains has been demonstrated in TD individuals using the affective priming paradigm. In one study, a short, happy or sad musical excerpt was followed by an emotionally congruent or incongruent target auditory word or visual picture. When the musical prime and target were the same emotion, reaction times to identify the target were reduced (Järvinen-Pasley et al., 2010). Research using these paradigms has shown a distinct neural marker (N400), usually associated with lexico-semantic processing, is increased in the size of negativity when the emotions of the prime and target don't match. In this present study, it is our principal interest to see how individuals with WS fare when compared to TD individuals using this affective priming paradigm.

Williams Syndrome

A disorder that can show the unique interplay between music and language processing is Williams Syndrome (WS). WS is a neurodevelopmental disorder caused by the deletion of genes in chromosome 7 (Hillier et al., 2003). It has a prevalence of 1/7,500 in the general population (Strømme et al., 2002), and is distinguished by a distinct behavioral and cognitive phenotype. Physical abnormalities include problems with tissue connectivity, droopy eyes, large lips, an upward-tipped nose, and widely spaced teeth (Lashkari et al., 1999). Individuals with WS have problems with planning, problem solving, and spatial reasoning, and typically have low non-verbal IQ, Attention Deficit Disorder, and an IQ score that ranges on average from 40 – 60 (Leyfer et al., 2006; Sercy et al., 2004). Among these cognitive deficits, WS individuals tend to show hypersociability when communicating with others (Jones et al., 2000), which is unique insofar that other disorders associated with such low IQ scores have the opposite social characteristic. Whether the hypersociability trait is a direct deficit or strength is subjective; as the understanding of socio-cultural concepts will help one get about in the world, yet naivety could lead others astray. Other strengths include linguistic capability, facial processing, and auditory memory (Bellugi et al., 2000).

Previous research on the auditory processing of WS suggests that they have an abnormal auditory sensitivity, as some participants seemed to be very sensitive to sound while others innately had perfect pitch (Levitin et al., 2003). Interestingly, an affinity for music is eminent in individuals with WS. When compared to typically developing (TD) children, parents of individuals with WS recounted that their children were more engaged with music, especially in their emotional responsiveness to it (Don, Schellenberg, & Rourke, 1999). Other researchers attribute this sensitivity to how extremely receptive they are to emotional communication. Plesa-Skwerer and colleagues (2006) looked at this emotional sensitivity by comparing 3 groups: adults and adolescents with WS, age- and IQ- matched participants with a learning or intellectual disability, and age-matched non-impaired controls. They administered the Faces and Paralanguage subtests of the Diagnostic Analysis of Nonverbal Accuracy Scale (DANVA2) and found that the control group did significantly better, especially on negative emotions. Subjects were assessed with a battery of adult and child faces, voices, and gestures, and then were told to respond as to which emotions were conveyed by happy, sad, angry, or fearful. This finding goes along with behavioral accounts of WS behavior, where individuals are generally happy and naïve to deception, sad, or angry emotions. Intrigued by these results, the same researchers used the same three-group design and looked specifically at affective prosody (Plesa-Skwerer, 2007). The WS group outperformed the learning/intellectual disability group at recognizing the emotional tone of voice, showing a relative sensitivity to affective prosody for conveying emotion, which could be manifested by their hypersociability. In contrast, other studies suggest that prosody perception in language for WS individuals is in fact abnormal and not spared, shedding light as to their differences in emotional processing. A study led by Pinheiro (2010) compared the brain electrical activity of WS to controls through EEG. The test involved two sentences whose context either matched or mismatched, and the participants were asked to say if the sentences made sense together or not. They observed that the WS group had an earlier N100 and P200 component than controls, indicating a quicker response to processing the auditory information. The N400 amplitude difference between matching and mismatching stimuli was also larger in WS individuals than in controls. Finally, the WS group had a P600 that happened later than in controls. This late P600 is thought to reflect problems in multiple stimuli being in agreement or continuity with each other. These findings support the idea that abnormalities early in prosodic processing can have an impact on cognitive language networks. A follow-up study was conducted by the same team, whose aim was to further identify or characterize the electrophysiological responses to happy, sad, and angry prosody (Pinheiro, 2011). Participants were presented with neutral, positive, or negative sentences that had either intelligible or unintelligible semantic and syntactic structure. With intelligible sentences, the WS group was found to have a reduced N100 and an increased P200 compared to the control group. The authors expected the increase of P200, yet they found that their observed N100 was changed from the previous experiment. N100 is traditionally thought of as reflecting the auditory processing of intensity or loudness in a stimulus. The authors suggest that the different effects seen from their last study at the N100 occurred because of difficulty in early parts of prosody processing which interfered with evaluating semantic information. The N300 component was found to be reduced in both sentence conditions in the WS group. The authors mention the N300 is known to involve evaluating what kind of emotion is being presented by how its context is related to the physical properties of sound and its semantic information. These abnormalities in auditory processing are likely to represent deficits in early sensory processing of prosodic speech and music.

The Present Study

A previous study by Lense et al., (2013) examined how music influenced the evaluation of emotion of a face in individuals with WS using an affective priming paradigm. The WS group showed a higher evoked alpha response in the EEG when the emotion displayed by the face was happy. Alpha is known to reflect primary sensory and attentional processes. The authors also found significantly greater gamma activity, thought to reflect cross-modal or multisensory integration, when the emotions of the music and face matched. In addition, the WS group had significantly longer reaction times than the control group, with the longest being when the face and music mismatched. Overall, the results suggested that individuals with WS have an increased sensitivity to the emotional characteristics of music.

The present study is a direct follow-up to Lense et al.'s (2013) experiment, by investigating the potential effect of musical priming on the perception of emotional prosody in language, using spoken pseudowords instead of faces. Brain activity was continuously recorded with EEG to look at the differences in the N400 elicited by the spoken pseudowords when the emotion of the music and prosody match or not. Words whose emotional prosody did not match the emotional valence of the musical prime were expected to elicit a larger N400.

We also compared WS individuals to TD individuals. Since WS individuals are particularly sensitive to language, music, and emotion, their N400 response to mismatching music-word pairs was expected to be greater than in TD individuals. On the behavioral level, longer reaction times and/or a higher error rates were expected when the emotion of the music and word don’t match. A larger effect from the musical prime was predicted in the WS group, as well as an overall difference between both groups in the emotional perception of target music and pseudowords.

CHAPTER II

Method

Participants

Participants included 12 young adults with WS and an age- and sex- matched control group of 12 participants. The groups also were matched for handedness according to the Edinburgh Handedness Inventory (Oldfield, 1971). The participants with WS were recruited from ACM Lifting Lives Music camp hosted by Vanderbilt University, while the control participants were recruited from Middle Tennessee State University. Intellectual functioning was assessed using the Kaufman Brief Intelligence Test, 2nd edition (KBIT-2, Kaufman & Kaufman, 2004). Controls completed a short screening test to eliminate confounds such as current prescribed medications, history of head injuries, concussions, epilepsy, or any other neuropsychological issue in which the participant had to seek medical treatment. Controls and parents/guardians of WS participants were provided with an informed consent document that was authorized by the participant, parent, or guardian before participating in the study (See Table 1 for descriptive statistics).

Table 1: Descriptive Statistics of Samples

Group	Mean Age	Gender (% Female)	Handedness (Right)	KBIT Verbal	KBIT Nonverbal	KBIT Comp. IQ
WS	27.79	41.67	0.53	87.00	74.00	76.5
Control	26.25	50.00	0.54	102.17	110.75	107.5

n = 12 per group

Stimuli

A total of 512 stimuli were used, consisting of a musical prime excerpts followed by target spoken pseudowords. To this end, 182 Pseudowords were initially generated using the pseudoword generator Wuggy (http://crr.ugent.be/programs-data/wuggy). Pseudowords are of particular experimental interest in linguistics as they follow all the rules for making English words and can be pronounced, but they have no semantic meaning. Pseudowords are particularly relevant for the present study in order to avoid confounds between the emotional prosody and the emotional valence of the meaning of the word (e.g., words such as death, accident or burn). All pseudowords were monosyllabic and not English word homophones. A female speaker who had a background in vocal performance recorded Pseudoword stimuli in a soundproof chamber. Two versions of each pseudoword were recorded: one with a happy prosody and one with a sad prosody. A behavioral pilot study was conducted with a group of 5 participants to control for the valence of the emotional prosody. Participants judged the emotional valence of each pseudoword on a 1 – 5 scale. A final set of 128 pseudowords with both the highest and most consistent ratings of emotional valence were selected.

Musical prime excerpts were the same as in Lense et al. (2013). They were adapted from a previous study by Peretz, Gagnon, & Bouchard (1998). A set of 32 musical excerpts was used throughout the experiment, half of which were happy, half of which were sad. Previous research showed that participants evaluated if the music was happy or sad within 250 ms of hearing the target stimuli. All excerpts were instrumental insofar that they were not songs that originally had lyrics. These music pieces were chosen from the catalogue of popular Western music, including styles such as baroque (e.g., Bach), classical (e.g., Mozart), romantic (e.g., Verdi), and contemporary (e.g., Ravel). These selections reflected the importance of using complex and engaging material that has a meaningful arrangement as opposed to a simple scale or sequence of tones.

Two experimental conditions were created by combining the 32 musical excerpts with the 128 pseudoword stimuli: 1) Match (happy music-happy prosody or sad music-sad prosody) and mismatch (happy music-sad prosody or sad music-happy prosody). In addition, using a Latin square design, four different lists of 128 pairs of stimuli (64 in each experimental condition) were created so that each pseudoword would appear in each condition across participants, with no repetition within participants.

Procedure

A session consisted of individually administering a neuropsychological screening form, the Edinburgh Handedness Inventory, the KBIT-2, and the EEG prosody task. Before each session, participants completed an online music background questionnaire through REDCap software (https://redcap.vanderbilt.edu). Each EEG session took place in a sound-attenuated room. Participants were seated at a small desk facing a computer screen. The sets of instruction were presented via headphones using a Toshiba Portege Tablet PC and the software E-prime (PST, Inc., Pittsburgh, PA). Each session began with a block of four practice trials. During the presentation of the stimuli, participants were asked to look at fixation crosses displayed on the computer screen in order to minimize movements of their eyes, head, or other body parts. Between stimuli, subjects attended to a series of x's that count down for five seconds before the stimuli was presented. A short musical excerpt lasting 500 ms was presented through headphones, followed by a spoken pseudoword for 500 ms. Subjects then were asked to attend to only the pseudoword, and respond as to which emotion it was (i.e., happy or sad) by pressing a response key. The subjects had response buttons that were counterbalanced between subjects (See Figure 1).

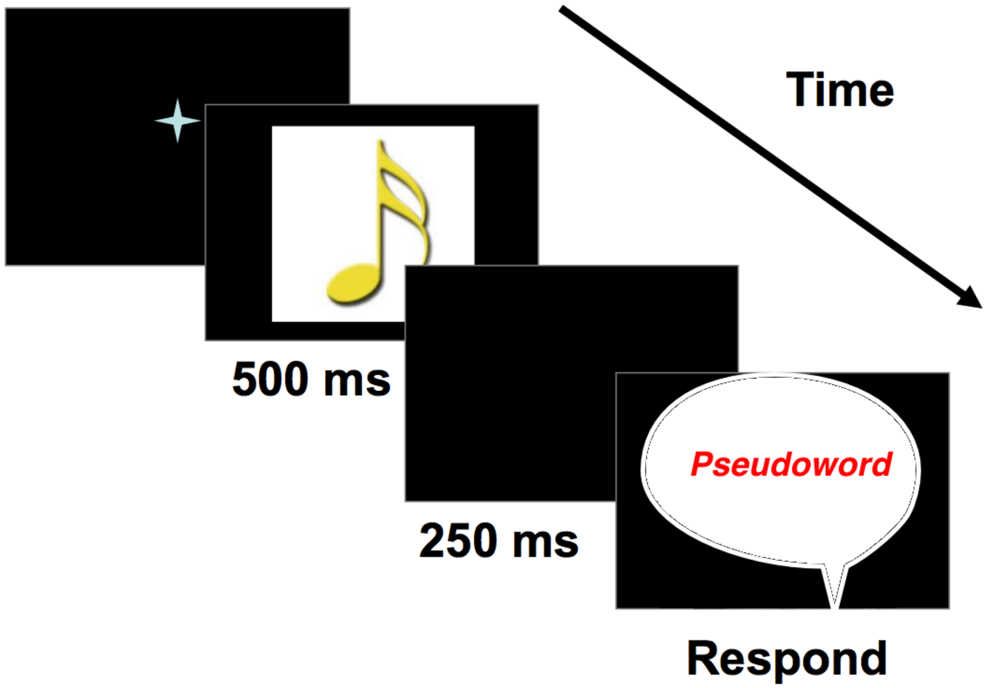

Figure 1: Cross-modal affective priming procedure.

EEG Data Acquisition and Preprocessing

EEG was recorded continuously from 128 Ag/AgCl electrodes embedded in sponges in a Hydrocel Geodesic Sensor Net (EGI, Eugene, OR, USA) placed on the scalp with Cz at the vertex, connected to a NetAmps 300 high-impedance amplifier, using a MacBook Pro computer. The frequency of acquisition was 500Hz, and impedances were kept below 50 kOhm. Data was referenced online to Cz, and later re-referenced offline to the average of the left and right mastoid sensors. The vertical and horizontal electrooculograms (EOG) were also recording in order to detect blinks and eye movements.

EEG preprocessing was carried out with NetStation Viewer and Waveform tools (EGI, Eugene, OR, USA). The EEG was filtered offline with a bandpass of 0.1 to 100 Hz. Epochs lasting 500 ms before and up to 1000 ms after the onset of the target word were extracted from the continuous EEG data. Trials contaminated by artifacts (e.g. eye movements, blinks, amplifier saturation, electrode drifting or muscle activity) were excluded from further analysis. ERPs were computed by averaging the single trial EEG epochs for each participant, condition, and electrode site, relative to a 200 ms pre-stimulus baseline.

CHAPTER III

Results

Behavioral Data

ANOVAs were computed separately for Accuracy rates and Reaction times (RTs0 with Group as the between-subject factor and Match as the within-subject factor. Results of the analysis did not reveal any statistically significant differences, either between conditions or between the two groups (See Figure 2 and Figure 3).

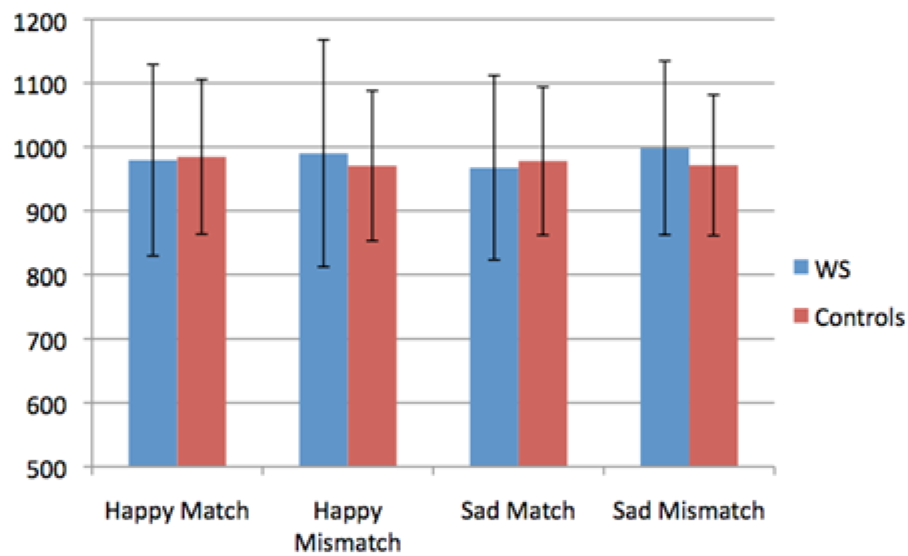

Figure 2: Reaction time to pseudoword targets in WS and Control groups.

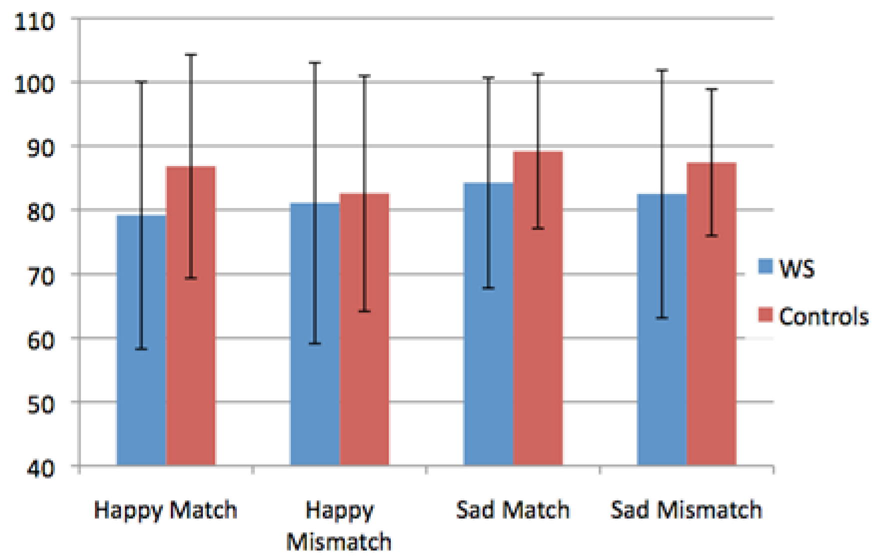

Figure 3: Accuracy rate to pseudoword targets in WS and Control groups.

Electrophysiological data

The grand-average ERPs time-locked to the pseudoword onset for the Williams Syndrome (WS) group are presented for happy prosody on Figure 4 and sad prosody on Figure 5, as well as controls for happy prosody on Figure 6 and sad prosody on Figure 7. A visual inspection of the data suggested that the mismatching conditions (Happy Music – Sad Prosody and Sad Music – Happy Prosody) elicited larger negative ERPs than the matching conditions (Sad Music – Sad Prosody and Happy Music – Happy Prosody) between 300 and 600 ms for the WS group and between 400 and 750 ms for the control group. Analyses of Variance (ANOVAs) were used to compare the mean ERP amplitude in each condition. The mean amplitudes of the ERPs were computed in two successive 250 ms-latency windows between 250 and 750 ms following the onset of the pseudoword

(250-500 ms and 500-750 ms). Emotion (happy vs. sad), Congruency (matching vs. mismatching), Hemisphere (left vs. right), and Region of interest (frontal, central, temporal, parietal) were used as within-subject factors. ANOVAs were computed separately for the TD group and the WS group. All *p* values reported were statistically `significant at the 0.05 alpha level and were adjusted with the Greenhouse-Geisser epsilon correction for non-sphericity when necessary. Pairwise comparisons were used following the ANOVAs to resolve significant interactions involving the factor Congruency.

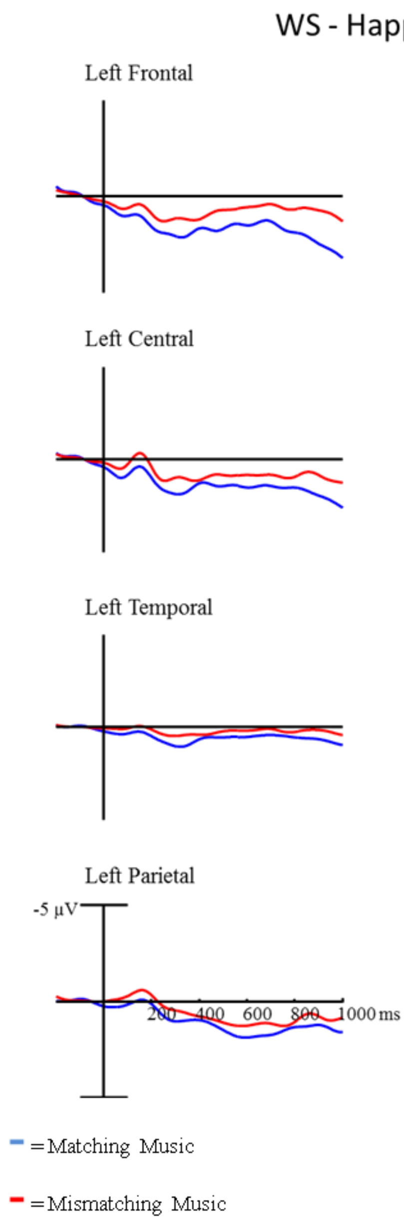

Figure 4: Grand-average ERP time locked to the onset of matching (blue dotted line) or mismatching pseudowords happy (red solid line) for the eight regions of interest considered for statistical analysis. The amplitude (in microvolts) is plotted on the ordinate (negative up) and the time (in milliseconds) is on the abscissa.

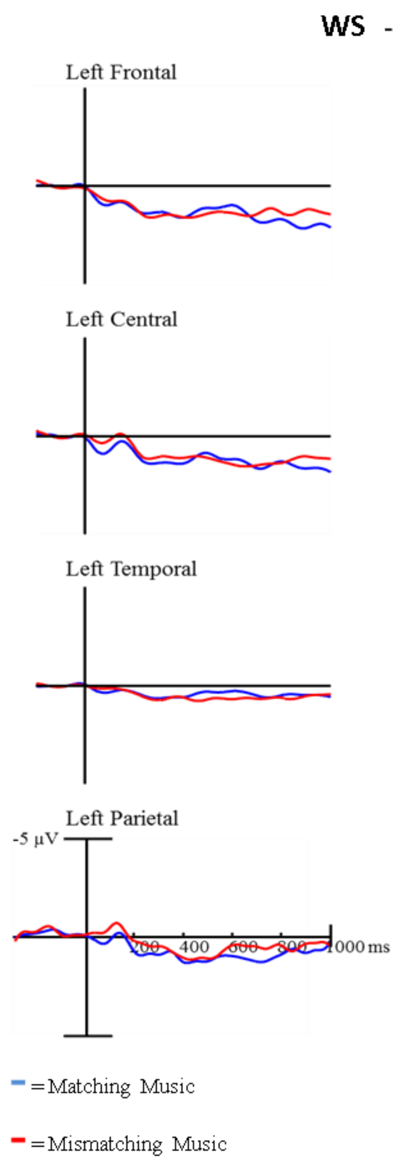

Figure 5: Grand-average ERP time locked to the onset of matching (blue dotted line) or mismatching pseudowords happy (red solid line) for the eight regions of interest considered for statistical analysis. The amplitude (in microvolts) is plotted on the ordinate (negative up) and the time (in milliseconds) is on the abscissa.

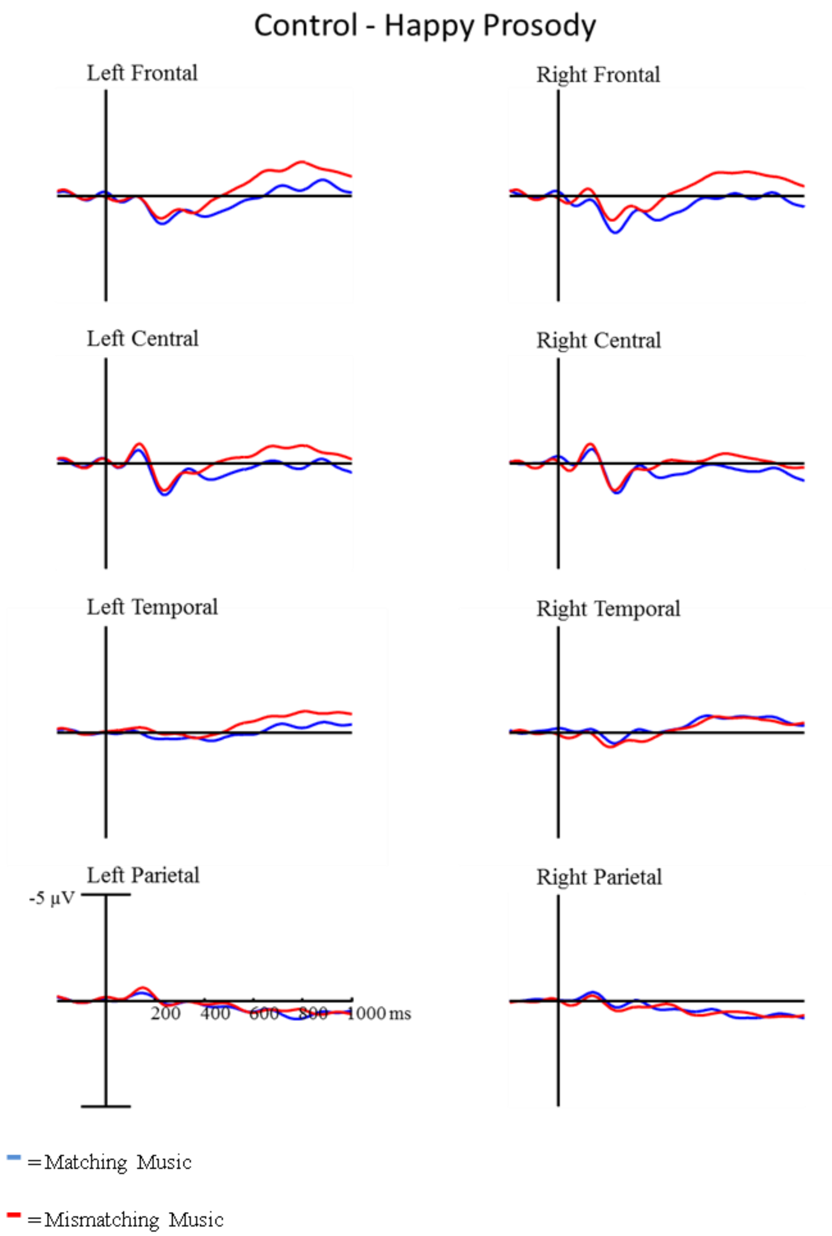

Figure 6: Grand-average ERP time locked to the onset of matching (blue dotted line) or mismatching pseudowords happy (red solid line) for the eight regions of interest considered for statistical analysis. The amplitude (in microvolts) is plotted on the ordinate (negative up) and the time (in milliseconds) is on the abscissa.

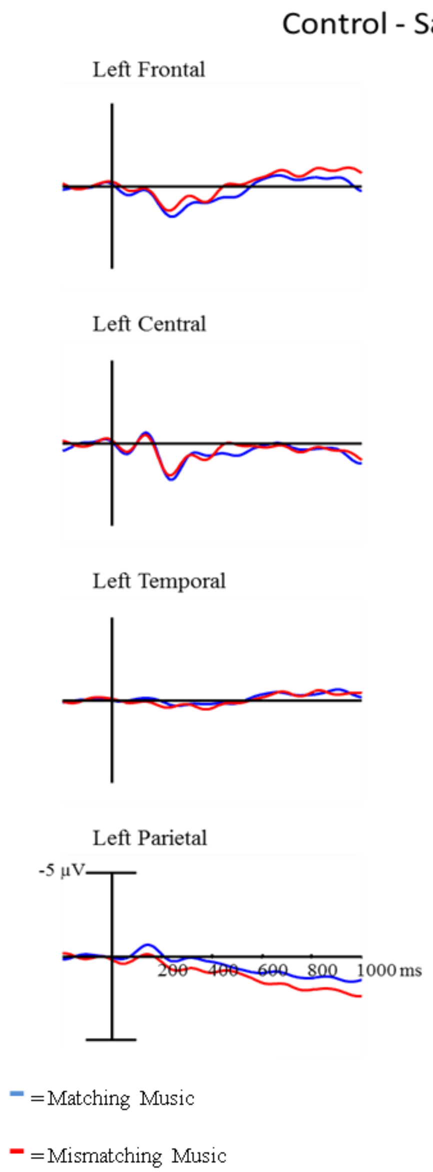

Figure 7: Grand-average ERP time locked to the onset of matching (blue dotted line) or mismatching pseudowords happy (red solid line) for the eight regions of interest considered for statistical analysis. The amplitude (in microvolts) is plotted on the ordinate (negative up) and the time (in milliseconds) is on the abscissa.

TD Group:

In the 250-500 ms range, there was a significant Match by Region interaction [F (3, 33) = 4.84, p = 0.024]. Post-hoc analysis revealed mismatching music-pseudoword pairs elicited larger negative ERPs than matching music-pseudoword pairs in the frontal region (difference: Match vs. Mismatch [d] = -0.86 µV), p < 0.01, and central region (d = -0.53 µV), p = 0.01, while no significance was found in the temporal or parietal regions. No main effect of Match or Match by Emotion interaction was found to be significant.

In the 500-750 ms range, the Match by Region interaction was significant [F (3, 33) = 4.90, p = 0.016]. Post-hoc analysis again showed mismatching music-pseudoword pairs eliciting larger negativity than matching conditions in the frontal region (d = -1.08 µV), p < 0.01, and central region (d = -0.52 µV), p = 0.03, while no statistical significance was found in the temporal or parietal regions. There was no significant main effect of Match or Match by Emotion interaction.

Williams Syndrome Group:

In the 250-500 ms latency window, there was a significant main effect of Match [F (1, 11) = 4.89, p = 0.049]: Mismatching conditions elicited larger negative ERP than matching conditions. In contrast, no significant Match by Region or Match by Emotion interaction was found. In the 500-750 ms latency window, there was no main effect of Match, but a Match by Emotion interaction [F (1, 11) = 4.86, p = 0.049]: there was a significant difference between mismatching and matching conditions for pseudowords with a happy prosody (d = -0.90 µV), p = 0.036, but not for pseudowords with a sad prosody.

CHAPTER IV

Discussion

The present study sought to examine how the emotions of musical excerpts influence the subsequent processing of prosody in spoken pseudowords. In summary, analysis of the electrophysiological data revealed an increased negative ERP for mismatching conditions in both groups. Interesting differences were also found between the two groups, both in terms of latency of the mismatch effect and sensitivity to different types of emotion. In contrast, the behavioral data for accuracy rate and RT did not show any statistical significance across the four experimental conditions, or between the WS and TD groups.

Effect of Cross-Modal Music Priming

In the present experiment, the negativity elicited by target pseudowords with emotional prosody that did not match the emotional valence of the musical prime shared a similar time window and scalp distribution as the classic N400 component. In previous studies using ERP methodology, the N400 has been interpreted as reflecting lexico-semantic processing, and its amplitude increases when two stimuli appear to be semantically incongruent with each other. In addition, the N400 effect has been reported for written and spoken language, and both words and pseudowords (Kutas & Federmeier, 2011).

Other ERP studies using emotional priming paradigms have found increased N400 activity. A study by Kamiyama et al. (2013) looked at processing of facial expression and musical excerpts using an affective priming paradigm in TD population.

Participants were presented with happy or sad images of faces then happy or sad musical excerpts, and were asked to judge the congruency of the stimuli pairs. Results found a larger N400 component was elicited when the two stimuli were emotionally incongruent than congruent.

In line with the previous aforementioned literature, the N400 effect elicited in the present study suggests that mismatching emotional valence of the musical primes increased the load on the lexical search initiated by the pseudowords.

Difference in Emotional Sensitivity between WS and TD Individuals

An important aspect that should be considered for ERP interpretation is that WS individuals have an atypical course of brain development compared to the TD population. To be able to compare the N400 effect between groups, the differences that exist in earlier processing should be recognized. Researchers have recently looked at what differences in brain processing WS may have compared to TD, specifically with their apparent strengths in face and language processing. An ERP study by Mills (et al., 2013) looked at this question by attempting to find a neural marker for face and language processing across two experiments. The first experiment concerned facial processing, where participants were shown pairs of faces and then asked to judge if the two pictures had the same or different person's face. When the faces didn't match, WS showed a small N1 and large N2 while TD had the opposite results (i.e., larger N1 and smaller N2). In the context of this study, the N1 reflects sensory and perceptual processing of visual stimuli while N2 was related to an index of increased attention to faces. Similar differences were found in experiment 2, which focused on language processing. Participants listened to spoken sentences that ended with either an anomalous word, which did not relate semantically, or a word that best completed the sentence. In the anomalous sentence condition, WS had a small N1 and large P1 and P2 markers, while the TD showed N1 amplitudes greater or equal to the mean of P1 and P2 amplitudes. In the auditory domain, N1 reflects the initial processing of sound, P1 represents selective attention to sound, and P2 is elicited in early stimulus encoding. The results of these two experiments suggest that the atypical brain development of WS individuals influences the ways in which they process faces and language.

Similar to Mills et al. (2013), a study by Pinheiro (et al., 2010) presented participants with sentences that ended with words that were either anomalous to the previous context of the sentence or fit the sentence for best completion. N1 and P2 amplitudes in the WS group were atypical, which support the later findings by Mills (et al., 2013). Pinheiro and colleagues also found that N400 markers were preserved insofar as latency, with WS having larger negative N400 than TD. While the apparent differences between WS and TD individuals exist in early processing, results showed the elicitation of the N400 seems to be preserved in WS despite N1 and P2 amplitudes being widely different than TD.

In the present study, the effect of cross-modal music priming was present in both groups. However, the N400 elicited by the WS group was broadly distributed while the TD group had a N400 component more localized over the frontal and central scalp regions. Interestingly, Lense et al. (2013) found similar differences in scalp distribution of brain activity between TD and WS groups, regarding alpha and gamma oscillation. It is important to note, though, that the relationship between oscillatory activities (alpha, gamma) and ERP components (e.g., N400) remain to be better understood.

In contrast to the ERP data, reaction times and accuracy were not different across conditions in either group, though the WS group had somewhat longer RTs than the TD group. This is a different result than Lense et al.'s study that found overall longer RTs in the WS compared to the TD groups, especially in the mismatching conditions. This difference of findings between the two studies could be explained by the difference in the type of target stimuli used (pseudowords in the presents study, and faces in Lense et al.). Musical and spoken word processing have been found to have overlapping cerebral networks, such as Broca's area, the middle and superior temporal gyri, and the inferior and middle frontal gyri (e.g., Maess et. al, 2001; Schon et al., 2010), whereas processing of faces lie in a separate brain area, the fusiform gyrus (Plesa-Skwerer et al., 2006). Thus, in WS, the atypical processing of emotional prosody may be facilitated by their heightened sensitivity to auditory stimuli as well as the shared neural substrate involved in music and speech processing.

Asymmetrical Cross-Modal Priming in WS Individuals

In the WS group, the mismatching happy condition had a longer-lasting N400 (250-700 ms) than the mismatching sad condition (250-500 ms). This is in line with previous literature on emotional processing which showed that WS individuals are more sensitive to happy than sad emotions. A study by Pinheiro (et al., 2011) looked at the perception of neutral, happy, and angry emotions across semantically neutral sentences that were spoken with either pure prosody (i.e., only emotional quality) or prosody with semantic content. Participants were asked to judge whether the sentences were emotionally positive, negative, or neutral. Results showed that WS individuals had the highest accuracy rate in the happy conditions only, and the lowest for the angry condition.

Limitations and Implications for Future Research

Existing limitations in this study should be addressed for further research. First, the control group should be better matched in terms of age, gender and musical experience. Secondly, the EEG system and stimulus presentation equipment varied between the EEG labs at Vanderbilt University and Middle Tennessee State University. Both EEG systems had 128 channels and are from the same company (EGI), but use slightly different electrode coordinates. This factor was controlled for by using only electrodes that shared similar coordinates in the two systems. However, it remains to be determined to what extent the systems are different in terms of calibration and sensitivity. Stimuli were presented to the WS group from a small speaker that was placed above their head, whereas headphones were used for the TD group. Finally, the present study only used happy and sad emotions, thus the effect of musical priming in the context of this experiment is not yet known to be replicable in other emotional domains such as anger or neutral emotions.

For future directions of research, it would be interesting to alter the presentation of stimuli to tease apart the impact emotional music has on the processing of prosody in words. For example, one avenue is to make the instructions for the participant an explicit task, where participants would be asked to pay attention to both the emotions in the music and pseudoword and then rate the pairs as matching or mismatching by emotion. Another route would be to switch the order of music and pseudoword stimuli to see if processing the emotional prosody of the pseudoword subsequently interferes with the task of judging the emotional quality of the music. Future studies could also use real words with emotional content instead of pseudowords with emotional prosody. This may increase the integration aspect of the N400 as the real emotional word puts constraints on semantic processing, whereas before the pseudoword only constrained lexical access.

Conclusion

The primary aim of this study was to find what differences might exist in the processing of emotions in music and language contexts among WS and TD individuals. This study also sought to extend the findings presented by Lense (et al., 2013) on facial processing in WS and how affective auditory priming can influence the processing of emotional prosody in spoken pseudowords. Our present findings support previous literature that sought to understand the relationship between the different modalities of affective priming in auditory processing. The study also highlights the differences that exist between WS and TD individuals for emotional processes in music and spoken language. Finally, the results are consistent with previous studies on the cross-modal processing of auditory stimuli in WS and TD individuals. Implications for therapeutic and educational interventions are abundant as affective priming could be used as a tool for motivation, stress relief, and behavioral modification in both WS and TD populations.

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Appendices

APPENDIX A
Pseudoword List

bloam
claft
corld
drair
drewn
falp
firsh
flipe
frice
garch
glast
grood
jeve
learm
nunge
paith
phic
plesh
plour
preet
quaz
ryke
scrog
slerk
sluce
splum
strob
thaid
thide
treme
trood
wrast
blumb
clearn
crylt
drarp
drin
fauze
flear
floag
froad
gelle
glorn
gures
joype
murm
nunts
pauve
pidge
plich
prall
prepe
quilp
saist
septh
sless
smins
spoan
swong
thark
thike
tremp
tumph
yasht
barsh
burve
cloop
delsh
dreet
drock
felce
fleft
frath
froll
glaim
gloud
gwarf
knort
mynch
nyst
pebe
pizz
plin
prang
pumph
realp
salph
shish
sloup
smows
spump
tarce
theck
thirp
trome
twear
bley
chull
clyke
dempt
drell
fadge
filbe
flide
fraws
frool
glamp
graim
hilms
knove
nipes
oorph
phafe
pleck
plorn
praph
puzz
reash
scaid
shrow
slour
speen
strit
tearl
thept
thirt
tront
weith

APPENDIX B
IRB Approval Letter for WS data

October 24, 2012
Michael Pridmore, Dr. Cyrille Magne
Department of Psychology
Mdp3k@mtmail.mtsu.edu, Cyrille.Magne@mtsu.edu
Protocol Title: "Emotional Perception of Music and Words in Williams Syndrome"
Protocol Number: 13-111

Dear Investigator(s),

The exemption is pursuant to 45 CFR 46.101(b) (2). This is because the research being conducted involves the collection or study of existing data that is being recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished your research within the three (3) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Your study expired on October 24, 2015.

Any change to the protocol must be submitted to the IRB before implementing this change. According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance before they begin to work on the project. Once your research is complete, please send us a copy of the final report questionnaire to the Office of Compliance. This form can be located at www.mtsu.edu/irb on the forms page.

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,
Andrew W. Jones
Graduate Assisstant to:
Emily Born
Compliance Officer
615-494-8918
Emily.Born@mtsu.edu

APPENDIX C

IRB Approval Letter for control data

November 8, 2012
Cyrille Magne, Michael Pridmore
Protocol Title: Neural Markers of Emotional Processing in Music and Language
Protocol Number: 13-117
Cyrille.Magne@mtsu.edu

Dear Investigators,
The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 and 21 CFR 56.110. Should you be using a written consent and/or assent form, please use the version with the IRB stamp of approval.

Approval is granted for one (1) year from the date of this letter for **60** participants.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting and analyzing data. Should you not finish your thesis within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Failure to submit a Progress Report and request for continuation will automatically result in cancellation of your research study. Therefore, you will NOT be able to use any data and/or collect any data.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Emily Born, Box 134) before they begin to work on the project.

All research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after the study completion and then destroyed in a manner that maintains confidentiality and anonymity.

Sincerely,
Mark T. Banks
MTSU Institutional Review Board