

Music genre preference and tempo alter alpha and beta waves in human non-musicians.

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This study examined the effects of music genre and tempo on brain activation patterns in 10 non-musicians. Two genres (rock and jazz) and three tempos (slowed, medium/normal, and quickened) were examined using EEG recording and analyzed through Fast Fourier Transform (FFT) analysis. When participants listened to their preferred genre, an increase in alpha wave amplitude was observed. Alpha waves were not significantly affected by tempo. Beta wave amplitude increased significantly as the tempo increased. Genre had no effect on beta waves. The findings of this study indicate that genre preference and artificially modified tempo do affect alpha and beta wave activation in non-musicians listening to preselected songs.

Abbreviations: BPM – beats per minute; EEG – electroencephalography; FFT – Fast Fourier Transform; ERP – event related potential; N2 – negative peak 200 milliseconds after stimulus; P3 – positive peak 300 milliseconds after stimulus

Keywords: brain waves; EEG; FFT.

Introduction

For many people across cultures, music is a common form of entertainment. Dillman-Carpentier and Potter (2007) suggested that music is an integral form of human communication used to relay emotion, group identity, and even political information. Although the scientific study of music has investigated pitch, harmony, and rhythm, some of the social behavioral factors such as preference have not been given adequate attention (Rentfrow and Gosling, 2003).

A sequence of studies by Rentfrow and Gosling (2003) observed individual differences in music preference. This was one of the first studies that developed a theory of music preference that would research basic questions about why people listen to music. Music preference was found to relate to personality and other behavioral characteristics (Rentfrow and Gosling, 2003). Music preference may interact with other facets to produce significant individual differences in response to music (Rentfrow and Gosling, 2003).

The behavioral relationship between music preference and other personal characteristics, such as those studied by Rentfrow and Gosling (2003), is evident. However, the neurological bases of preference need to be studied more extensively in order to be understood. To assess neurological differences based on genre and tempo, changes in brain waves while listening to music can be measured via electroencephalogram (EEG) or event-related potential (ERP) (Davidson, 1988).

Neurological Measures of ERP and EEG

Both EEG and ERP techniques measure electrical current on the scalp that passes through the meninges of the brain and the skull (Frith and Friston, 2013). These electrical readings are very small in comparison to an electrical signal created by somatic neurons, and the greater the number of neurons in the brain that fire at the same time, the stronger the EEG/ERP signal (Frith and Friston, 2013). The

ERP is best for rapid stimuli, while EEG records over longer durations, and both methods are very temporally accurate and are, therefore, excellent for measuring quick responses to stimuli (Coles and Rugg, 1995). The peaks of brain activity measured by ERP are named for the direction of the peak (i.e., positive or negative) and the latency of the response after the stimulus presentation (Coles and Rugg, 1995). For example, a P2 component would be a positive peak occurring 200 ms after stimulus presentation. EEG measures brain wave activity over longer epochs and activity of certain waves can be averaged over the duration of the recording (Coles and Rugg, 1995). This ability to record over longer periods of time allows participants to process complex stimuli adequately and, therefore, makes EEG the better choice studying reactions to musical stimuli.

Different ERP components indicate different types of mental processing, for example, the presence of an N2 component indicates subconscious processing, while a P3 component indicates conscious cognitive processing of or attention to a stimulus (Caldwell and Riby, 2007). Components that are present in an ERP recording will indicate how the brain processes input. Regarding EEG, average wave amplitude over time will indicate which brain waves were the most synchronous (therefore most prevalent) during stimulus presentation. Each wave occurs within a specific frequency range that can be used to identify the waves. The specific brain wave type indicates the type of brain activity occurring (Davidson, 1988). Alpha waves (8-13 Hz) are more synchronous in the occipital region of the brain when a person is awake but relaxed, with his or her eyes closed, and are indicative of a relaxed mental state (Teplan, 2002; Sammler, et al., 2007). Beta waves (13-30 Hz) are more synchronous during general consciousness and indicate a person is attentive, with his or her eyes open (William and Harry, 1985; Abdou et al., 2006; Teplan, 2002). Beta waves can be observed in the left temporal lobe during a state of wakefulness (Overman et al., 2003). Both alpha and beta waves are most prominent during wakefulness and have been studied well, therefore, these waves will be examined in the current study (Teplan, 2002).

Genre Preference Measured by ERP and EEG

Caldwell and Riby (2007) studied differences in ERP components in classical and rock musicians when listening to their genre of preference, as well as the other genre. Smaller P3 amplitudes were seen when subjects listened to their specialized genre of music, indicating that fewer “cognitive resources” were applied (Caldwell and Riby, 2007). The P3 components are related to conscious working memory and the maintenance of a mental representation of a stimulus in conscious thought, and a reduction in P3 amplitude may indicate familiarity with a genre. Familiarity is related to preference in that people usually spend the most time listening to the genre they prefer, thus becoming the most familiar with that genre (Caldwell and Riby, 2007). If the P3 component is related to active cognitive processing, it would be expected to have an inverse relationship with alpha wave activity, which is related to relaxation. Preferred genres produced less arousal, indicated by smaller P3 amplitudes; expectedly, alpha waves would increase during decreased arousal experienced while listening to preferred/familiar genres of music (Teplan, 2002).

Höller et al. (2012) looked for any similar effects on alpha and beta brain wave activity for non-musicians when participants selected their own samples of music. EEG recordings were analyzed using FFT to examine the energy of different frequency bands (i.e., alpha and beta). Höller et al. (2012) state that alpha wave activity is inversely related to cognitive activity, so relaxing music can increase alpha wave activity, however alpha wave activity did not discriminate between relaxing and activating music (all music pieces were selected by participants as their favorite pieces to evoke relaxation or arousal), indicating preference, rather than the mental relaxation of the participant produced by the music, has a greater effect on alpha wave activity.

These studies support the effect of genre preference on differences in brain activity. Specifically, EEG measurements indicate the presence of alpha waves during relaxing or familiar music (Berk, 2008). While the literature related to preference involves the use of musicians and non-musicians, both populations

experienced similar brain activation with regard to preferred music. The current study will examine potential relationships between alpha wave activity and a relative preference between two pre-selected genres for non-musicians.

The Effect of Tempo on Brain Activity

In addition to genre, tempo also has the potential to alter brain activity. Because tempo has been shown to affect behavioral measures, such as cognitive performance and arousal (Husain et al., 2002), an effect on the brain waves related to arousal (i.e., beta waves) can be observed. Consistent with this, Steinberg et al.'s (1992) review concluded that music tempo does affect beta waves.

Kornysheva et al. (2010) investigated individual differences in brain activation patterns in response to different tempos and also an individual's preferred tempo. The participants of their study were asked to rate slow and fast tempos as pleasant or unpleasant. Results showed that there was a significant increase in brain activity in the motor areas of the brain in response to tempo (Kornysheva et al., 2010). Larger activation patterns were detected when participants listened to music of a preferred tempo. In Dillman-Carpentier and Potter's study in 2007, faster paced music also elicited greater physiological activation than slower paced music. This increased arousal can be connected to beta wave activation.

In addition to effects of genre mentioned previously, Höller et al.'s (2012) study also applies to the effect of music tempo on brain waves. Participants selected their own preferred samples of relaxing and activating music so the researchers could look for any common response to individually chosen music (Höller et al., 2012). The tempo of the selected relaxing music was generally slow, while the tempo of stimulating music was generally fast. Beta wave activity occurred especially when listening to activating music. Because beta waves are related to arousal, the increase in beta brain waves may have been mediated by increased arousal caused by fast, activating music, as opposed to slower, relaxing music. Since activating music is often directly related to voluntary coordinated movements, such as

dancing, activating music may influence motor regions of the brain, which can result in beta wave activity (Höller et al., 2012).

Current Study

The present study investigates the effects of music genre preference and tempo on brain activation patterns in the alpha and beta frequency band regions. It is predicted that genre on its own will not affect alpha wave activity; however, alpha waves will be more synchronous when participants listen to their preferred genre, as opposed to an unpreferred genre (less cognitive resources are applied while listening to a preferred genre therefore the participants will be more relaxed and have greater alpha wave activation). It is also predicted that faster tempos will produce greater beta wave activation in the left temporal brain region because of the arousing nature of fast-paced music.

Since tempo is often correlated with genre and this could confound the alpha wave recordings related to genre, the researchers sought to separate the two variables by artificially manipulating music tempo within the same set of songs, keeping genre and song constant while tempo varies. By artificially manipulating tempo this study offers new perspectives on the effects of tempo; previous research has focused on the use of naturally fast/slow music rather than artificially modified tempo.

Material and Methods

Participants

Ten participants of ages 20-22 were recruited from the Neuroscience Seminar at Roanoke College in Salem, VA. Students received class credit for participation. Of the ten participants, three were male. Participants had normal audition and no pre-existing neurological conditions. The experiment was conducted in accordance with the guidelines of the Roanoke College Institutional Review Board.

Equipment

EEG signals were recorded using a PowerLab 26T (AD Instruments, Inc., Colorado Springs, CO). The analog input from the electrodes was amplified and converted to digital by the PowerLab 26T then sent to a computer for additional processing by LabChart 7 software (AD Instruments, Inc., Colorado Springs, CO). The time that stimuli were presented was indicated by a signal sent from an external Cedrus StimTracker (Cedrus Corporation, San Pedro, CA) device to the same computer, which was also recorded by the LabChart 7 software. The LabChart 7 software was run on a Dell XPS 15z (Dell, Inc., Round Rock, TX) laptop computer and presented on an external monitor to be viewed by the experimenter but not the participant. The stimuli were presented on the monitor of the laptop using SuperLab 4.5 (Cedrus Corporation, San Pedro, CA).

Stimuli

The stimuli included five different songs for each genre, rock and jazz (Table 1). The songs were selected from the Rentfrow and Gosling (2003) study. The initial set of genre options included electric, country, rock, and jazz. After the participants in the current study completed a survey, rock and jazz were chosen because they were on average rated most often preferred by the participants.

The songs were presented in varying tempo (slow = 100 beats per minute (BPM), medium = 120 BPM, fast = 140 BPM). The songs were all naturally approximately 120 BPM, so the medium speed was not significantly modified

Fifteen second clips from each song were randomly selected from three different sections of the song without vocals. Sections were manipulated using Ableton Live 8 (Ableton, Berlin, Germany) software to achieve a particular tempo, resulting in 15 distinct clips (3 tempos x 5 songs). Participants listened to the music through Coby digital CV-120 over-the-ear headphones at a speaker volume of 30% on the laptop.

Table 1: **Stimulus List**

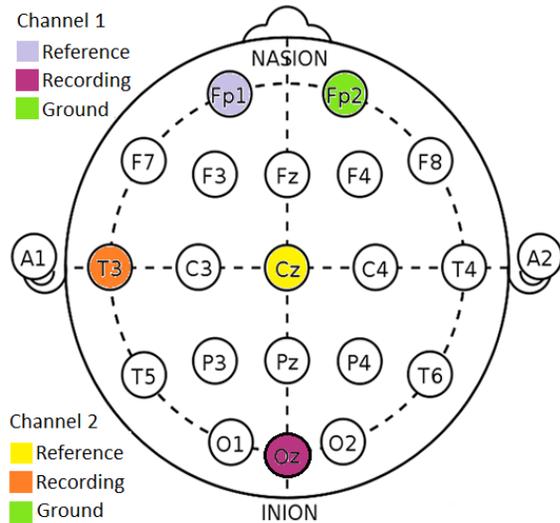
Jazz	
1	All Blues- Miles Davis
2	The Feeling of Jazz- Duke Ellington
3	Stella by Starlight- Charlie Parker
4	Summer in the City- Quincy Jones
5	Giant Steps- John Coltrane
Rock	
1	YYZ- Rush
2	San Berdino- Frank Zappa
3	Brown Sugar- Rolling Stones
4	Money- Pink Floyd
5	Woodoo Child- Jimi Hendrix

Procedures

IRB guidelines were followed during the experiment (approval number: 13PS084)

Five lead shielded electrodes were placed on the participant’s scalp following the guide in Figure 1. The electrodes were held in place using elastic head bands. These positions were chosen because of previous research on successfully recording alpha waves in the occipital lobe region, and beta waves in the left temporal region.

Before stimulus presentation, the output of the channels was analyzed to ensure that the electrodes were properly placed. The signal should not have exceeded the normal biological range of $\pm 50 \mu V$. Artifacts were minimized by keeping participants’ heads as still as possible while resting on a pillow on a desk. Since alpha waves are synchronous in the occipital region when a person is awake, but relaxed with their eyes closed, participants were encouraged to close their eyes throughout the experiment under the eye mask. This also minimized artifacts created by blinking or other eye movements. These measures reduced the number of peaks in the EEG recording that were related to muscle activity and not brain activity. After the EEG reading was verified, the lights in the room were



turned off and an eye cover and headphones were worn for the duration of the experiment.

Figure 1: Electrode Channel Placement

Two electrodes were placed on the forehead on the prefrontal area (Fp1 and Fp2). The third electrode was placed above the inion on the back of the head in the occipital area (OZ). The fourth electrode was placed on the centro-parietal area (CZ). The fifth electrode was placed on the left temporal area (T3). Fp1 and OZ were included in Channel 1 for anterior/posterior comparison. CZ and T3 were included in Channel 2 for medial/lateral comparison.

Each music clip was presented for 15 seconds so that participants would have enough time to comprehend the tempo and the genre of the clip. SuperLab 4.5 randomized the presentation order of the music clip files for each participant. Two blocks were completed in order to gather as much data as possible while still keeping the experiment length within 30 minutes. Thus, for each block in the experiment, 30 music clips played with varying tempos and genres, meaning that each block lasted approximately 7.5 minutes. The length of breaks between each music clip (i.e., 1.25s, 1.50s, or 1.75s) was randomized by SuperLab 4.5. Breaks were randomized so that brain activity did not mimic a constant pattern of 15 second music clips separated by a standard break time.

To encourage paying attention to the stimuli, participants were asked to count the number of songs in which a guitar (i.e., bass, acoustic, or electric) was played in the first

block of clips, and then the number of songs in which a brass instrument was played in the second block. There were 13 clips with guitars in the first block and 12 clips with a brass instrument in the second block. Participants noted whether or not they heard the instrument in question at any point during the entire music clip, so faster clip tempos would not make it more difficult to count instruments. The task was implemented so that participants would not fall asleep while listening to the music in a comfortable position with their eyes closed. Because the study is not about the behavioral enjoyment of the music, the task's effect on the participant's pleasure was not considered.

Survey

Following all of the music presentation, participants then completed a survey on demographic information, preference for rock or jazz music, preference for slow, medium, or fast paced music, and the nature of any prior musical training. Participants rated their preference for rock and jazz independently on a 7-point Likert scale (1=least preferred; 7=most preferred). The genre with the higher of the two ratings was taken as the most preferred. Five participants preferred Rock, four preferred Jazz, and one was neutral in that they rated each genre equally. The data was removed for the neutral participant when analyzed with respect to preference because the survey results indicated no genre preference. Tempo preference was not used in the analysis due to a lack of variability in responses; all participants responded that they preferred "medium-paced music."

Statistical Analysis

Since the duration of the clips exceeded the time range needed for ERP analysis, the results were analyzed using FFT. The ERP measures brain activity on the order of seconds before and after stimulus presentation and, because the current study uses 15 second clips, FFT analysis is more appropriate.

FFT analysis calculates average amplitude at particular frequencies over time and creates a curve of amplitude (in microvolts) on the y-axis and frequency (in hertz) on the x-

axis. The standard curve for an FFT has a 1/F shape because there are higher amplitudes at lower frequencies than at higher frequencies due to biological noise, such as head and body movements. The activity recorded by the EEG appears as peaks jutting out from the standard 1/F curve, and the peaks' areas can be calculated by subtracting the 1/F curve from the line created by the peaks. The peak areas or magnitudes are then averaged across participants based on genre, tempo, or the independent variable in question.

Figure 2 shows FFT output for a single participant. MatLab (The MathWorks, Inc., Natick, MA) was used to take individual FFTs for each clip and overlay them for the corresponding clips based on genre and tempo. Six FFTs were created for each participant (2 genre x 3 tempo) averaging across ten repetitions (5 songs x 2 blocks of clips) per condition. The conditions represent the possible combinations of tempo and genre. Within the six averaged FFTs, the alpha and beta frequency bands were analyzed separately. For the alpha wave analysis, the peak amplitude was taken from data within the range of 8-13 Hz; beta wave data was taken from 13-30 Hz (Sammler et al., 2007).

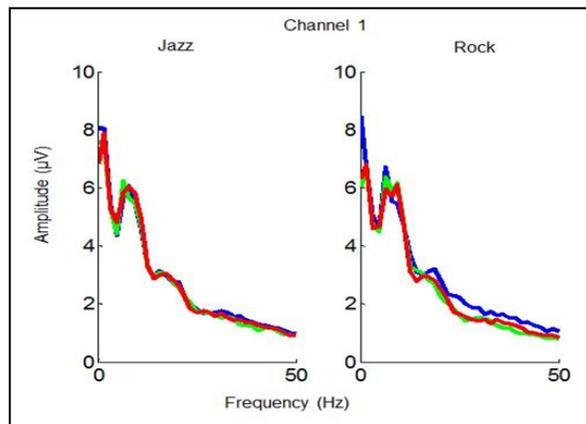


Figure 2: Single Participant's FFT Output Showing the 1/F Curve with Peaks.

FFT analysis of a single participant's alpha and beta peaks for both genres in channel 1. The blue (fast), green (medium), and red (slow) lines correspond to the three tempos of the song stimuli. The first and sharpest peak represents average alpha wave amplitude while the second smaller peak represents beta amplitude.

An analysis of variance (ANOVA) is used to analyze the means of two or more groups and state whether or not the differences between the means are statistically significant. The null hypothesis is that all means are equal, while the alternate hypothesis is that at least one mean is different from the others.

Paired *t*-tests were used to analyze whether or not two particular means were significantly different.

Results

Alpha Waves on Channels 1 and 2

When data (not coded for preference) were analyzed using a repeated measures ANOVA, the main effect of genre on alpha waves in the prefrontal and centro-occipital comparison region (Channel 1) was not significant ($F(1,8) = 1.242, p = 0.298, \alpha = 0.05$). The main effect of tempo on alpha waves and the interaction effect between tempo and genre were also not significant (tempo $F(2,16) = 0.972, p = 0.4$, interaction $F(2,16) = 0.627, p = 0.547, \alpha = 0.05$).

When data were organized based on genre preference and analyzed again using a repeated measures ANOVA, a significant main effect of genre on alpha waves was seen ($F(1,7) = 6.616, p = 0.037, \alpha = 0.05$ (Figure 3)). Analysis of the recoded data showed tempo still had no effect on alpha waves in Channel 1 ($F(2,14) = 0.723, p = 0.502, \alpha = 0.05$), and there was no interaction between tempo and genre ($F(2,14) = 1.838, p = 0.195, \alpha = 0.05$). Eight out of 10 participants were used in the preference analysis, as one was eliminated due to excessive familiarity with the stimuli and the other due to no preference to either rock or jazz music.

Figure 4 shows confidence interval bars that indicate using genre alone (i.e., Rock - Jazz) to calculate amplitude differences did not produce differences in amplitude by genre significantly different from zero. The data were recoded for preference and the calculation of alpha amplitude difference was based on individual genre preference. Participants' unpreferred genre amplitudes were subtracted from the preferred genre amplitudes, whether that

preference was for rock or jazz music. Confidence interval bars indicate a significant positive difference between alpha amplitudes based on preferred genre when data were reorganized.

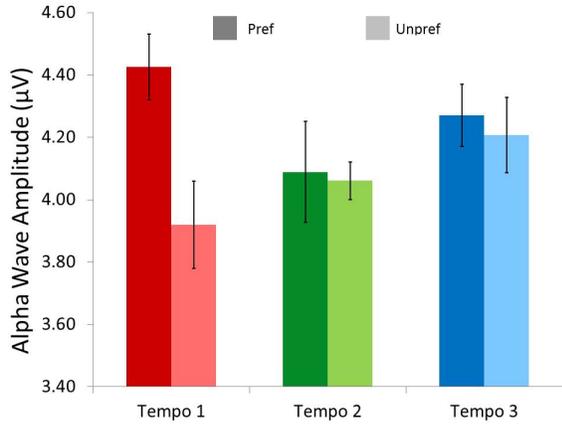


Figure 3: Alpha Amplitudes Significantly Larger During Preferred Genre Presentation.

Alpha wave amplitudes for both genres on channel 1. After recoding the Channel 1 data for preference, the data showed that participants' preferred genre elicited greater alpha wave amplitudes than the unpreferred genre. Tempo 1 indicates 100 BPM, Tempo 2, 120 BPM, and Tempo 3, 140 BPM. The darker bars refer to amplitudes measured when participants listened to their preferred genre. The lighter bars refer to amplitudes measured when participants listened to their unpreferred genre.

No significant results were found regarding alpha waves measured in the left temporal and centro-parietal region comparison (Channel 2).

Beta Waves on Channels 1 and 2

Though the main effect of tempo on beta waves in Channel 1 was not significant ($F(2,16) = 2.278, p = 0.15, \alpha = 0.05$), there was a significant linear trend in the data not coded for genre preference ($F(1,8) = 7.742, p = 0.024, \alpha = 0.05$ (Figure 5)). Increasing song tempo corresponded with increasing beta wave amplitudes. The trend was verified with a paired t-test that revealed a significant difference between the fast tempo beta data (averaged across genre) and the slow tempo beta data (averaged across genre) ($t(8) = 2.717, p = 0.026, \alpha = 0.05$).

After recoding the data for genre preference, the effect of tempo was also reanalyzed on the coded data. Since the main effect of tempo

essentially averages the beta activation across the genres, the recoding based on genre preference did not influence the tempo main effect.

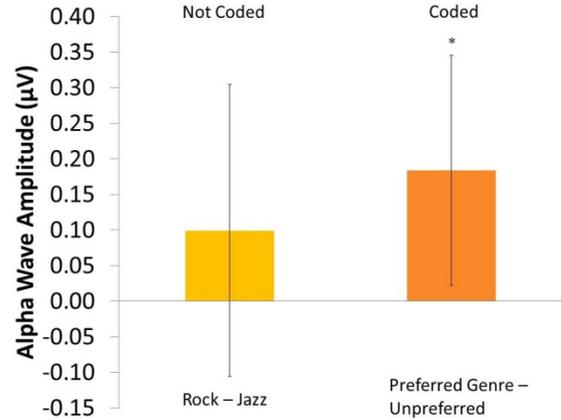


Figure 4: Significant Difference between Alpha Amplitudes When Data Coded For Genre Preference.

Differences between preferred genre amplitudes and unpreferred amplitudes were significantly positive after recoding the data for preference, indicating higher alpha amplitudes were elicited during preferred genre stimulus presentation. Ninety five percent confidence interval bars show differences in alpha amplitudes elicited by Rock and Jazz music that are significantly different from zero, suggesting that alpha waves are affected by music genre preference. The Not Coded bar refers to the raw data that were not organized by preference. The Coded bar refers to the data that was reorganized based on participant's preference for rock or jazz music. The asterisk indicates the coded difference is significant at the $p < .05$ level.

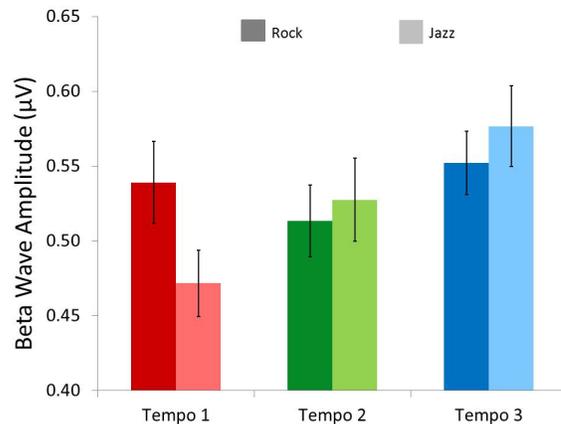


Figure 5: Beta Amplitudes Increase as Tempo Increases.

There is a linear trend of increasing beta amplitudes across both genres with regard to increasing tempo. The greater the music clips' BPM, the greater the amplitude of the beta waves produced. Tempo 1 indicates 100 BPM, Tempo 2: 120 BPM, and Tempo 3: 140 BPM.

However, because the data for one participant was dropped when the recoding was done, this did weaken the statistics and the linear contrast was no longer significant. Still, a paired t-test between the beta activation for the slow tempo and the fast tempo was significant with a one-tailed test ($t(7) = 1.97, p = 0.045, \alpha = 0.05$), consistent with the previously observed tempo effect.

No data regarding beta waves in Channel 2 were significant.

Discussion/Conclusion

The data support the hypothesis that listening to a preferred genre of music produces greater alpha wave amplitudes than listening to an unpreferred genre. Because significant results for genre were found only when recoding the data for preference, it is suggested that it is the preference in music that mediates the change in brain activity, not the genre or the nature of the music itself. It is possible that the observed changes are due to the cognitive resources being applied when listening to preferred and unpreferred genres (Höller et al., 2012). Here, the term “cognitive resources” refers to the attention and focus devoted to the music (Höller et al., 2012; Kellaris and Kent, 1992). When participants listen to their preferred genre, they are more likely to be relaxed and therefore apply less attention while listening, resulting in increased alpha wave amplitude. When participants listen to an unpreferred genre, more attention is applied because the participant is less familiar with that type of music, thus the alpha wave amplitude is smaller (Caldwell and Riby, 2007). The relationship between the P3 amplitudes measured in Caldwell and Riby’s (2007) study and alpha wave measured by the current study is inverse. Because P3 ERP components are associated with working memory and active processing of a stimulus, a smaller P3 amplitude would indicate less arousal. Alpha wave activity in the occipital region of the brain is associated with a relaxed

mental state, therefore greater alpha wave amplitudes indicate greater relaxation and less arousal.

The predictions for the effects of tempo were also supported by analysis; faster paced songs with higher BPM produced greater beta brain wave amplitudes. These results are consistent with Höller et al.’s (2012) findings that activating music increases beta wave activity. Beta waves are associated with arousal and wakefulness, and so it makes sense that faster and more upbeat music would increase brain arousal. It is true that some individuals may find faster tempos more relaxing, which would affect beta wave activity; it would be interesting to research beta wave activity in relation to tempo preference in the same way the current study analyzed alpha wave amplitude in terms of genre preference.

Little research has investigated the relationship between tempo and preference and its effect on brain activity. This study attempted to assess that relationship, but lack of variability in tempo preference among participants prevented those responses from being considered in analysis. Because the current study recoded the data based on participants’ genre preference and found differences in alpha wave activation in relation to preference, it can be said that the amplitude differences were due to the psychological construct of preference rather than simple physiological fluctuation. However, because the beta wave amplitudes were not recoded based on preference, it is possible that the differences in beta wave activation were simply due to natural beta wave fluctuation over time. This is unlikely, however, because the stimulus presentation order was random within each participant and between participants, so consistencies across tempos likely indicate a true neural response to different physical stimulations. However, the natural tempos for Rock and Jazz music may be similar enough to not see an interaction with genre or relative genre preference. It is because of this that more research is needed to understand the relationship between beta waves and tempo preference.

The slow and fast songs in this study were not originally 100 BPM and 140 BPM respectively, rather songs that were normally

120 BPM were digitally modified to become slower or faster. Höller et al. (2012) had participants choose their own activating and relaxing music samples, and these personal choices were naturally faster for activating and slower for relaxing, rather than modified. In this study, there was no need to use multiple songs (and possibly multiple genres) with naturally different tempos because the differing tempos were artificially created. This was helpful to avoid confounds caused by differing music types co-varying with tempo. Some genres, such as punk, are naturally faster paced than other genres, such as reggae. While a fast or slow pace cannot be applied to genres as a whole, there are tempo patterns that occur within genres. While Höller et al.'s (2012) study produced differing beta waves with songs naturally differing in tempo, the current study shows that beta waves are also affected by artificially modified tempos. Although genre confounds on tempo were avoided, there were still some differences in the magnitude of effect that faster tempos had in conjunction with Rock and Jazz genres. Higher BPM music seemed to have a larger effect on beta wave amplitudes in Jazz music than in Rock music, and vice versa for slow tempos, therefore certain genres may produce greater effects on beta waves when paired with changing tempos. More research is needed to explore the potential interaction effect between genre and tempo on beta waves.

Because the significance of the tempo effect on beta did not change when the data were recoded based on genre preference, and neither analysis resulted in an interaction effect, this study does not support a relationship between tempo and preference for rock or jazz genre. In order to generalize that statement to other genres, other genres should be explored in the same method. It is possible that rock and jazz are too similar to produce significant interaction effects between tempo and genre. Tempo and genre preference may be related in that some genres are naturally faster or slower than others, however this study used artificially modified tempos and so different songs/genres were not necessary to assess different tempos. Artificial tempo manipulation avoided confounding brain activation due to tempo with that due to genre,

but this methodology may have prevented interaction effects from surfacing.

Because of the similar effect of artificial tempos and natural tempos on beta brain waves, it would be interesting to explore further the differences between these types of tempo manipulations, in addition to the effects of tempo on different types of brain waves. Yuan et al. (2009) measured alpha wave amplitude in response to three tempos; original tempo (52 BPM); middle bias tempo (26-78 BPM); and ultimate tempo (138 BPM). Their results show that alpha wave amplitude decreased with increasing BPM, or the further a song's tempo got from its original tempo. The current study found that increasing tempo increased beta wave amplitudes and this finding compliments Yuan et al.'s (2009) study, which found that increasing tempo decreased alpha wave amplitude. More research on all types of brain waves with regard to music tempo would add to the understanding of how musical aspects affect the brain.

There were many limitations of this study. One of the participants created the stimuli, thus he was more familiar with the experiment than the other participants, and his data was excluded for much of the analysis. While this decrease in the number of subjects did not prevent the finding of significant results, some of the significance values may have been stronger with a larger subject pool. In addition, the sensitive nature of the EEG recordings meant that slight head or eye movements when participants were listening to stimuli may have contributed to "noisy" data with less clear results. A larger sample size would counteract the "noisy" data, however, the small n did not prevent significant results. A larger n in this case would be a luxury not a necessity. There was also a lack of control measurement during which participants did not listen to music. A baseline measurement before stimulus presentation would have allowed us to eliminate brain activation changes due to individual differences and to only look at the changes due to music processing. While studies like Höller et al. (2012) found individual differences between experimental conditions and baseline, this study was more concerned with the finer effects based on differences of tempo and preference, which

are still valid measurements in and of themselves.

Results from the left temporal and centro-parietal region (Channel 2) were possibly not significant because of the location of the electrodes. Location CZ is near the motor strip in the frontal lobe, and listening to activating music may have stimulated this area as if the listener was moving along with the music. EEG electrode channels must have at least two electrodes in order to compare activity recorded by one electrode to the activity on the other. Because of the likelihood of beta activity in both electrodes, it is possible that the lack of significant results for this channel was due to the lack of amplitude difference between electrodes, because both were recording similar beta wave amplitudes. Beta waves were recorded from location T3 because Overman et al. (2003) concluded that tempo was processed on the left side of the brain; however the CZ electrode location was simply for comparison to the temporally placed electrode. In the future, studies examining beta waves might use different placement for the comparison electrode in order to gather a cleaner recording of these waves with less interference.

Preference cannot be completely separated from familiarity during experimentation because preference is a multifaceted construct, which includes familiarity, complexity, and other variables regarding music. The relationship between familiarity and preference is unclear; preference may lead to familiarity or familiarity may lead to preference (North and Hargreaves, 1995; Demorest and Shultz, 2004). The current study did not control for familiarity because the songs used have been released to the public for many years and there was no practical way to ensure participants had the same level of familiarity with each song. Using songs from other cultures and removing data of participants who are familiar with them could control for familiarity confounds. However, because familiarity is closely related to preference, it may not be a confounding variable but simply an intervening variable needing to be acknowledged, but not eliminated (North and Hargreaves, 1995). In follow-up studies it would be useful to assess participant's familiarity with the songs. This

would allow genre preference to be separated from familiarity during analysis.

Despite these limitations, this study contributes to the field of neuroscience and offers new perspectives on brain activity through EEG rather than ERP, which has been the preferred analysis method of previous brain activation research. Genre preference and musical tempo affect the brain's activity, which in turn may be the underlying cause of the behavioral and cognitive effects of music.

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