Hemispheric Responses to Different Musical Selections

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Chapter I

Introduction

The goal of this Senior Honors Thesis was to examine the hemispheric response and cognitive styles of men and women to music of different modalities.\(^1\) This project was selected because of my strong interest in music and how individuals interact and respond to various genres of musical selections. The idea was also stimulated by a curiosity that began in an Honor’s Psychophysiology class. Learning how the brain works and the functional differences between alpha and beta waves piqued my interest. Different types of music evoke different emotions from individuals, and I was interested in examining how these emotions were related to reactions in the brain.

Common views about major, minor, and atonal music

Historically, “modality in music is defined by its pitch-class. It refers to a specific choice of tones relating to a particular tonic.”\(^2\) Music contains many elements, such as tones, intervals, chords, and rhythm. Leaving aside some twentieth-century aleatory works, all of these elements are in sequential order in some way, shape, or form. However, during the Baroque period (1600-1750), two of the established modes, major and minor, became the most widely used by composers. “Tonality is the organized relationship of pitches around a tonic. … We can also speak of tonality in a much broader sense, encompassing the whole body of major and minor scales, the various kinds of

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\(^1\) The term “modality” here includes tonal works composed in major and minor keys, as well as atonal compositions.

harmony based on them, and the music that uses these scales and harmonic types.\textsuperscript{3} This means that there is a central tone that is supported by other tones. Tonality is the process of using other tones in a diatonic scale to create and establish a tonal center. Each note in the scale generates a triad that has a function and serves a purpose in establishing the tonality of the piece. The tonic (1st), subdominant (4th), and dominant (5th) are the most important degrees in the scale, since their triads effectively establish the key. Elements that support tonality are cadences, the use of chord progressions, the use of notes in the major or minor scale, and the avoidance of chords not in the key of the piece.

Atonal music developed through the disappearance of a tonal center. When no tone center can be determined, especially when all of the pitch-classes are treated equally, then the music can be labeled as atonal. Conventional composition techniques, such as chord progressions and traditional harmonies, are abandoned. Composers such as Berg, Webern, and Schönberg began exploring the possibilities of chromaticism in the early 1900s, and this led to stretching compositional guidelines and the lack of a tonal center. Dissonances were not necessarily resolved, which further pushed traditional compositional techniques away. A representative example of early atonal music is one of Schönberg’s \textit{Drei Klavierstücke}, Op. 11, No. 1, m. 40:

\begin{center}
\includegraphics[width=\textwidth]{atonal_music.png}
\end{center}

\textsuperscript{3} Piston, 52.
Dissonance plays a role in most atonal music, and the treatment of this dissonance creates atonality, which bothers some listeners. Atonal music is usually not listened to as often and does not tend to be preferred by listeners, unlike major and minor pieces. Hermann Helmholtz discovered that the human ear reacts negatively to such sounds, and perhaps this is why it is not favored. However, some people do not agree with Helmholtz on this topic, and believe that there are other factors, such as culture that cause these reactions. Atonal music might contain irregular resolutions, mixtures of modes within the piece, tone clusters rather than chords, and avoidance of chord progressions and tone-centers.

The two tonal Western scales, major and minor, are made up of different whole steps and half steps. For the major scale, the half steps are between 3-4 and 7-8 (Appendix A, Figure 1). For example, if a C Major scale is written out, it starts on a C and ends at the next C, an octave higher: C, D, E, F, G, A, B, C. Numerically, it could be written as: 1, 2, 3, 4, 5, 6, 7, 1. Music in a major key is often associated with happy and more uplifting moments, and Helmholtz provides reasoning for this. When children are growing up, the music that they are first introduced to is often of major modality, such as children’s songs, educational songs, and lullabies. “The ABCs,” “Twinkle, Twinkle Little Star,” “Old MacDonald,” and other children’s songs are all in major keys.

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5 Piston, 528-29.
6 Refer to Helmholtz for further discussion on music in major keys and associations with emotions.
For a harmonic minor scale, the half steps are between 2-3, 5-6, and 7-8 (Appendix A, Figure 2). If a C harmonic minor scale is written out, it would start on a C and end at the next C, an octave higher: C, D, E-flat, F, G, A-flat, B, C. Numerically it would be written as: 1, 2, flat-3, 4, 5, flat-6, 7, 1. Minor music is usually associated with sadness and more melancholy moments. There are significantly fewer children’s songs in the minor mode. “We Three Kings” and “Greensleeves” are both associated with the Christmas Season and are in the minor mode. Most people perceive minor keys as sorrowful or perhaps mysterious.

What studies have been conducted with regard to major and minor music?

A functional magnetic resonance imaging (fMRI) study conducted in 2006 investigated the electrophysiological correlates of music and emotion by examining the brain’s response to consonant and dissonant music. This study used consonant (pleasant) and dissonant (unpleasant) music to evoke emotion and functional magnetic resonance imaging (fMRI) to determine neural correlates of emotion processing. There were five females that participated in this study, who ranged from twenty to twenty-nine years old. It was determined that consonant and dissonant musical examples could evoke pleasant and unpleasant emotions respectively. Most studies have shown that the processing of

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7 The natural minor scale corresponds with the key signature, and contains the same notes as the relative major scale. The harmonic minor scale is favored by composers, because it contains a raised seventh degree, which makes the dominant (5th) a major triad. When the dominant (5th) is major then the chord progression can be stronger. The melodic minor scale contains a raised sixth and seventh when ascending and the sixth and seventh are lowered when descending.

8 Refer to Helmholtz for further discussion.


10 Ibid., 239.
emotions in the amygdala is related to visual stimuli and not necessarily auditory recognition.\textsuperscript{11} In another study, Sammler, Grigutsch, Fritz, and Koelsch examined the processing of consonant (pleasant) and dissonant (unpleasant) music, and whether or not emotions influenced the EEG spectrum and heart rate.\textsuperscript{12} There were eighteen students between the ages of twenty to thirty years old who participated in this study.\textsuperscript{13} These participants were non-musicians who had no formal musical training and had never played a musical instrument. The investigators studied dissonant and consonant musical stimuli, which elicited activity changes in the limbic and paralimbic brain structures, such as the amygdalae, the hippocampus, the parahippocampal gyrus, and the temporal lobe (Appendix A, Figure 3). Amygdalae are groups of nuclei that are located within the medial temporal lobes of the brain and process memory and emotional reactions. The hippocampus is also located in the medial temporal lobe of the brain and processes long-term memory and spatial navigation. The amygdalae and the hippocampus are part of the limbic system, which helps with emotions and memory.\textsuperscript{14} The parahippocampal gyrus is grey matter that surrounds the hippocampus. The temporal lobe is part of the cerebral cortex of the brain, and the cerebral cortex facilitates abstract thinking and reasoning.\textsuperscript{15} A t-test is a statistical test that is commonly used to compare two groups (typically two groups’ means), which takes into account the number of units in the sample. Accordingly, a two-tailed $t$ test for paired samples on the mean ratings revealed a significant difference

\textsuperscript{11} Koelsch et al., 244.
\textsuperscript{13} Ibid., 295.
\textsuperscript{15} Ibid., 76-77.
between the ratings following consonant or dissonant musical pieces. Consonant pieces were rated as pleasant, whereas dissonant excerpts were rated as unpleasant. The results showed that emotions induced by consonant pieces were rated more extremely than emotions evoked by dissonance. The EEG findings showed that pleasant music was associated with an increase in frontal midline theta power. These findings were more significant than originally hypothesized.

Hevner discovered that the musical background of her subjects did not influence how he or she perceived major and minor music. Two hundred and five subjects were used in her experiment, and in fact, the subjects with the most musical training had a difficult time perceiving major versus minor modes. The subjects voted by an eleven to one majority that ‘stormy’ music is related to the minor mode. In addition, more mournful and gloomy qualities were also strongly connected to the minor mode by those involved in the study. The comparable adjectives were serious, depressing, solemn, and grotesque. In contrast, musical selections reflecting the major mode were strongly compared to a listing of adjectives such as majestic, happy, cheerful, joyous, light, and sprightly.

_What do we know about the left and right sides of the brain?

The two hemispheres are virtually the same in structure. The primary auditory area for processing sounds is located in the superior temporal gyrus of the temporal lobe.
The superior temporal gyrus is one of three gyri in the temporal lobe of the brain, and in ninety percent of humans it is in the left hemisphere. In between the medulla and the midbrain there is an area called the pons. The pons communicates with the cerebellum and motor cortex in coordinating movements and contains a nucleus of the auditory system. Traveling through the core of the pons is the ARAS, the system concerned with sleep and arousal. The medulla is located below the pons, and it is part of the auditory pathway. The pons and the medulla are shown in Appendix A, Figure 5.

Each individual uses both sides of his or her brain; however, there might be a side that is favored more than another. The right and left hemispheres of the brain function in different ways, but ultimately work together. The left side of the brain is more logical, rational, analytical, and deals with reasoning and order. Individuals who favor their left hemisphere are mathematicians or engineers. The right hemisphere is more creative, emotionally inclined, and helps form mental images. Individuals who favor the right hemisphere tend to be artistic and musical. It processes time and space relationships better than the left hemisphere.

*What do we know about men and women?*

According to a study conducted by Christenson and Peterson in 1988, men and women tend to show different emotional responses to music. There were two hundred thirty-nine students from Pennsylvania State University in this study. Females were more likely to show a higher positive response to soft music as opposed to their gender.

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22 Ibid., 56.
23 Loc. cit.
counterparts, who demonstrated a lower response.\textsuperscript{24} In a study conducted by Enrique Flores-Gutiérrez, Díaz, Barrios, Guevara, Río-Portilla & Corsi-Cabrera, there were fourteen students, seven males and seven females, selected to participate. The subjects had no formal or informal musical training. Females showed a greater positive response to music and exhibited higher left-brain predominance.\textsuperscript{25} They also found that men showed less significant differences than women while listening to music, concluding that men and women differ in brain functional organization, and in their emotional response to music.\textsuperscript{26} The results could have been separated by gender; however, the researchers did not do this. If they had, perhaps the results could have been more significant.

\textit{What do we know about left-brained and right-brained people?}

As we already know, the brain has two hemispheres, which are right and left. The left hemisphere is associated with happy or positive emotions, and the right hemisphere is associated with sad emotions.\textsuperscript{27} In the vertebrate nervous system the connections between the body and the brain are linked in an opposite manner. For example, the left hemisphere controls the right hand of an individual.\textsuperscript{28} The left hemisphere is more verbal, and the right hemisphere is more spatial. These two hemispheres of the brain can be considered as ways of thinking and processing, and particular cognitive styles have been ascribed to

\textsuperscript{24} Peter Christenson and Jon Peterson, “Genre and Gender in the Structure of Music Preferences,” \textit{Communication Research} 15, No. 3 (June 1988): 282-301.


\textsuperscript{26} Florez-Gutiérrez et al., 43.

\textsuperscript{27} Wilson, \textit{Biological Foundations of Human Behavior}, (Belmont: Wadsworth Publishing), 385.

each. An individual might be more artistically inclined or more interested in math and logical reasoning depending on his or her hemispheric preference.

The right frontal brain area is where the negative withdrawal-related emotions are found. The frontal regions of the right hemisphere are more active when negative emotions are being experienced by the individual. Sammler’s study found that “in the EEG this is reflected by an asymmetric decrease of alpha power according to the perceived emotion, that is, a decrease of left frontal alpha power during positive emotions and a decrease of right frontal alpha power during negative emotions.” This means that the positive or negative emotions that were perceived corresponded accordingly to the frontal regions of the right or left hemisphere. The understanding and expression of these emotions are processed in different areas of the cerebrum in the right hemisphere.

Wilson cites studies conducted by Riecker (2000) and Zatorre (1999) that demonstrate how musicians and non-musicians process music differently; for non-musicians, music is divided between the left and the right hemispheres. The melody is processed in the right hemisphere and the rhythm is processed in the left hemisphere of non-musicians. Musicians, on the other hand, appear to process music, whether playing or listening, solely in the left hemisphere.

30 Sammler, et al., 294.
31 Loc. cit.
32 Ibid., 233.
34 Wilson, 233.
The Electrocencephalogram (EEG) or “brain wave” was first described by Richard Canton in 1875. Canton discovered the activity while recording data from electrodes placed on the brains of monkeys and rabbits. It was determined that when varying stimuli were presented to the animals they responded differently.

The man who discovered EEG was Hans Berger; he was born in 1873 and lived in Germany. He studied medicine at the University of Jena. Throughout Berger’s career he was an assistant in the university’s psychiatric clinic, a chief doctor, and the director and professor of psychiatry. Berger’s main focus was his quest for correlations between objective activity of the brain and subjective psychic phenomena. In 1902, he began working on brain wave activity in dogs. Eighteen years later he began testing humans. He discovered that fluctuations in electrical potential could be recorded through the skull from the cortex. His first publication on electro-encephalography was in 1929; however, the actual date of discovery was July 6, 1924. Even though the electrical potential measures did not give Berger any further insight into correlation between electrical brain activity and psychic energy, EEG has been constantly improved and continues to be a reliable instrument in the psychological field today.

Through all of Berger’s work, he identified two brain wave patterns, the slow and large waves (alpha) and the fast and small waves (beta). EEG patterns, frequencies, and amplitudes are usually the same for one individual.

Electrodes that are attached to the scalp can measure the different brain waves. Many researchers use the 10-20-system technique to gather data, which is an

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35 Andreassi, 56.
37 Andreassi, 56-57.
international system commonly used for EEG. The placement of the electrodes is correlated with locations on the brain, which are either 10% or 20% of the distance between points used for measuring the head. The locations are labeled as follows: P are over the parietal, which is located above the occipital lobe and behind the frontal lobe; F are over the frontal, which is located at the front of the cerebral hemisphere and in front of the parietal lobes and above the temporal lobes; T are over the temporal, which is beneath the Sylvian fissure (the Sylvian fissure divides the frontal and parietal lobes above from the temporal lobes below) on both sides of the brain; and C are the central areas of the brain. The left side of the head is labeled with odd numbers whereas the right side is labeled with even numbers (Appendix A, Figure 6). This is the electrode-placement system that I utilized in this study.

What do we know about alpha and beta waves?

The EEG power spectrum is usually divided into a minimum of five frequency bands: delta, theta, alpha, beta, and gamma. In this study only alpha and beta waves were monitored during lab testing. An alpha wave occurs at a rate of 8 to 12 times a second (Hz). The magnitude (amount of electrical energy) for an alpha wave is 20 to 60 millionths of a volt. Someone with his or her eyes closed and sitting quietly can produce these waves. When the individual becomes engaged in any mental or physical activity, the alpha waves tend to disappear. There are three different types of alpha rhythms, and each individual type has a different function. The first is the classical posterior alpha rhythm originating from the parieto-occipital cortex, which is strongly dependent on

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39 Andreassi, 58.
other factors such as attention. Second is the Rolandic mu rhythm that is especially
dominant at central electrodes and originates from somatosensory cortex, which is related
to movement and touch. The third is the tau rhythm, which is generated within auditory
cortices and modulated by auditory stimulation. A decrease in alpha waves means an
increase in brain activity.

Beta waves are irregular; they occur at a frequency of 14 to 30 times a second
(Hz). The amplitude of Beta waves is between 2 and 20 millionths of a volt.\textsuperscript{40} Beta waves
occur when a person is excited or doing a mental or physical task. Studies have found an
increase in beta power following an unspecific increase of emotional arousal. Beta
rhythms are also related to motor functions, such as walking, thinking and various other
activities.

\textit{Music and emotions}

Music processing is a complex set of perceptive and cognitive operations. These
in turn are temporally integrated and linked to previous experiences, which draw upon
extensive memory systems by which emotions emerge.\textsuperscript{41} A melody consists of patterns or
series of pitches. Rhythm is the temporal component that determines how much time can
pass with a specific frequency being heard or not heard. Like language processing, the
perception of music involves processing from different parts of the brain. Music can
arouse thoughts that are either very pleasant or unpleasant. A piece of music can evoke
thoughts from the past, making the listener either happy or unhappy; these emotions can
be relived each time the piece is heard. “The listener brings to music not only specifically

\textsuperscript{40} Andreassi, 58.
\textsuperscript{41} Wilson, 233.
musical experiences, associations, and dispositions but also important beliefs as to the nature and significance of aesthetic experience in general and the expected musical experience in particular.”

Therefore, music that has never been heard before can evoke emotions, too. According to Norretranders, “blood pressure readings and measurements of the electrical conductivity of the skin show that we really are affected by music.”

The composer might have emotions he or she is trying to convey when the piece is written. Meyer quotes C. P. E. Bach, who wrote *Essay on the True Art of Playing Keyboard Instruments* in 1759, “A musician cannot move others unless he too is moved.”

The composer might also be trying to evoke specific emotions from the audience. Both composers and musicians should be able to express and convey emotions through the music that is being written or performed. This in turn will cause the listener to experience emotions, perhaps even similar emotions, as well.

Music affects the human body in many ways, and it is not necessarily only because of the sound waves. When we listen to music there are specific thoughts that might come into our minds, and those thoughts in our imaginations can be completely different than another person’s imaginative pictures. Music can put you into a happy state, not necessarily because you recognize the tune, but because it puts you in a happy mood through the way the music is conveyed. “The main thing in music is not the sound waves. It is that the composer/player converts a number of mental states into a pattern, which evokes the same (or different) mental states in the listener. If we want to

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understand Bach or the Beatles, what we need to look at is not so much the information that is conveyed by the notes but the exformation [explicitly discarded information] that led to them, and thereby the exformation the notes evoke in the listener.\footnote{Norretranders, 112.} You do not need to know any detail or have any knowledge of a piece to enjoy it. The theory that many have is that you need to know yourself and be willing to let your emotions and imagination run wild. These beliefs and concepts connect closely to what Susanne Langer (1895-1985), an American philosopher, wrote about regarding the aesthetics of music.

\textit{Hypothesis}

Because studies have shown that music has affected people’s heart rate and skin conductance level, I wanted to investigate brain waves and hemispheric differences to determine the effect on people who were listening to musical selections. The hypothesis for this experiment was based on previous findings in published literature indicating that the brain tends to respond in specific ways to different musical selections. It was expected that a difference in brain activity would be apparent, depending on what type of music the subject listened to during the experiment. It was also expected that there might be significant correlations between the musical experience and the subject’s response to the different musical selections. Another hypothesis for this study was that men and women would respond differently to major and minor tonalities of music. Emotions were expected to show different brain wave activity, depending on the subject’s gender and whether he or she liked or disliked the musical selection.
Chapter II

Method

Subjects
My subjects were all college-age men and women, ranging from eighteen to twenty-two years old. A total of thirty-one men and women volunteered to participate in this study, twenty-two females and nine males. Data from one participant was thrown out, however, due to loss of electrode response during recording. All subjects were students of Wittenberg University in Springfield, Ohio, and were treated in accordance with the ethical principles of the American Psychological Association. Based on validated measures of cognitive style, nine of the subjects favored the right hemisphere of their brain; eleven of the subjects favored the left hemisphere of their brain; and eleven showed no hemispheric dominance. Twelve subjects had played a musical instrument for over ten years; seventeen subjects played an instrument for less than ten years, and two subjects had not ever played an instrument. Fourteen subjects still play an instrument. Three subjects began studying an instrument at the age of five; three began at the age of six; nine began at the age of seven; two began at the age of eight; two began at the age of nine; five began at the age of ten; three began at the age of eleven; one began at the age of twelve; and one began at the age of fourteen.

Electrode Placement
Six plastic-coated Ag/AgCl electrodes were placed on the subject: one behind each ear, two on the forehead, one on the scalp, and a ground electrode on the wrist to record brain activity. Skin preparation included abrasion with alcohol pads to clean the
area. NuPrep® electrode gel was applied to each electrode site. The electrodes were secured using Grass Instruments AC3 electrode paste and gauze.

Apparatus

The equipment used during the lab testing was a Grass Technologies 79D 4-channel EEG polygraph. During trials, recording was triggered by MATLAB, and the Grass Amplifier filtered the analog signals. It was connected to a National Instruments USB-6009 analog-to-digital converter, which stored the data on a standard personal computer. The program that generated the musical stimuli and recorded the brain data was a program by Mathworks, MATLAB, which was run on a standard personal computer and played through standard speakers.

Procedure

Due to the need for a quiet environment and the duration of the listening portion of the experiment, subjects were scheduled to come into the lab for one-hour increments to avoid distractions. Each individual subject was brought into the lab and given a short-answer survey regarding his or her musical background. The printed musical background survey asked nine questions, which are listed in Appendix B. After completing the first survey, the subject answered a questionnaire with thirty-three questions that measured cognitive style. This survey was made up of two cognitive preference questionnaires that were combined, but scored separately. One questionnaire was taken from The Alert Scale of Cognitive Style,46 and the second was A Refined Neurobehavioral Inventory of

Hemispheric Preference. The questions for The Alert Scale of Cognitive Style are listed in Appendix C. The questions for A Refined Neurobehavioral Inventory of Hemispheric Preference are listed in Appendix D.

After answering all of the questions on the musical background survey and completing the cognitive preference questionnaire, the subject was then asked to sit near the computer that would be monitoring his or her brain activity. Measurements of the subject’s head were taken, in order that the electrodes could be properly placed on each subject. The 10-20-system, as described on page 10, was used to determine the placement of the electrodes. The areas where the electrodes were to be placed were scrubbed with alcohol pads to sanitize the skin and remove any dead skin cells. Electrode gel was used to increase the electrical conduction; this was applied on the cleansed area and then allowed a few minutes for absorption into the skin. Electrode paste was then applied to the electrode and securely placed on the subject. The electrodes were tested to see how much outside electrical activity they were picking up. If the conductance levels were low enough, preferably lower than 5 kMho (Mho is a measure of conductance, the inverse of Ohm, which is a measure of resistance. We measured kiloMhos, or 1,000 times Mho, because of the high level of skin conductance). The subject was then hooked up to the EEG machine, and the experiment was begun.

Each subject completed two trials, one that measured the left hemisphere’s reaction and the other that measured the right hemisphere’s reaction to the predetermined

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musical selections. The order of the two trials was altered at random; it was randomly selected which side of the brain would be measured first and which one second on each particular subject. For each trial, the subject listened to twenty-four musical excerpts, which are described in Chapter III.

Each piece was played once for fifteen seconds followed by a fifteen second pause of silence before the subject marked how he or she felt emotionally and how much he or she liked or disliked the piece. The rating sheet used is found in Appendix E. After the subject completed the rating, he or she continued on to the next musical selection. It was very crucial that the subject stayed as still as possible during the listening portion as well as during the moments of silence. If a subject was moving too much, then the electrodes could have picked up the movement, which would have reflected in poor data retrieval due to the movement artifacts. The entire experiment lasted approximately one hour.
Chapter III

The Music

The twenty-four excerpts of music that were selected for this study were evenly divided from the three different categories as follows: eight pieces were major, eight were minor, and eight pieces were twentieth-century atonal. These pieces were also selected because they were not likely to be familiar to the average, college student music listener. The selections chosen from the compositions were samples lasting only fifteen seconds (Appendix F). Also, by having the computer randomly select the order of the musical excerpts the bias of listening to a specific selection first or last was eliminated. All recordings used are listed in Appendix G.

Major

J. S. Bach’s Prelude in C# Major is from *The Well Tempered Clavier*, Book I. This music was originally composed for the harpsichord, but is commonly performed on the piano, as it was in the selection heard by the participants. The melody in the prelude is easy to follow, but it is not the easiest to sing. Measures 58-75 were chosen for the experiment (Appendix H, Figure 1). Yuri Broze comments that the C-sharp Major Prelude “is almost a taunt, an excited dance which dares to challenge, but never loses its friendly optimism.” The preludes and fugues are so complex in their composition that some have argued they are more intellectually based than the other selections that were chosen for the experiment. In fugues there is usually one subject, which creates multiple melodies that the listener can follow while listening to the music.
The Fugue in C-sharp Major, which follows the prelude, has three voices. The piece sounds more complex than other excerpts selected for the experiment since each voice is brought in at a different time, and each voice carries its own melodic line throughout the composition. Bach’s music is more intellectually stimulating for listeners and performers, which is due to the contrapuntal writing. Sequences, another compositional technique employed by Baroque composers, are used throughout measures 30-34, which were selected for the experiment (Appendix H, Figure 2).

In Johannes Brahms’s Piano Trio No. 1 in B, Op. 8, Movement I, the melody is easy to listen to, and for most people it is easy to follow. All piano trios have the same instrumentation: a piano, a violin, and a cello. The selection chosen for the experiment are measures 35-41 (Appendix H, Figure 3). The strings and piano in this selection follow a similar line that leads to a happy and optimistic listening experience for individuals. The dynamics move along with the use of crescendos, which follow similar rising melodic lines. This part of the Piano Trio is grand and massive, making the selection sound majestic.

Luigi Boccherini (1743-1805) was an Italian composer who primarily composed chamber music. The Minuet was selected from Boccherini’s String Quintet in E Major, Op. 11, No. 5. Many believe that it has a sweet, cheery, and sprightly sounding melody.

Frédéric Chopin’s Polonaise in A, Op. 40, also known as the “Military,” has a meticulous and militaristic type style and tone to it, because of the very precise and rigid

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rhythm. Chopin conveys a military style throughout this musical selection. Measures 1-7 were selected for this experiment (Appendix H, Figure 4). The polonaise is in 3/4 time, and Chopin uses numerous sixteenth notes with a few triplets in this excerpt.

Joseph Haydn’s Symphony No. 6 (“Le Matin”), Hob. 6, Movement I, is *allegro*; and there is a lot of motion. The motion in this piece creates a busy feel, which is caused by the tremolos in the string section and trills in the woodwinds. Measures 72-85 were selected for this experiment (Appendix H, Figure 5). This symphonic work was composed for an orchestra and each instrument is unique in timbre. Therefore, each instrument plays a distinct role in the creation of this piece.

A later work by Haydn is his Symphony No. 104 in D Major, Hob.104, Movement I. It has a very distinct melody in the strings, and the rhythm is supported throughout the piece by other instruments. The brass and the woodwinds provide the background and the strings play the melody. Measures 32-47 were selected for this experiment (Appendix H, Figure 6). The energy of this piece is clearly expressed throughout this excerpt of the composition. Throughout the selection the dynamics stay loud and keep the energy level of this piece high. Haydn’s use of doubling at the octave in this excerpt also helps create this high energy.

Richard Strauss’s Cello Sonata in F, Op. 6, Movement I, is written in 3/4 time. He uses heavy accent markings in the piano and cello in the first two measures. The piano presents an idea that continues throughout the selection, and the cello alternates with the piano for the duration of the selection. Measures 1-12 were selected for the experiment
(Appendix H, Figure 7). With the help of octaves and large chords in the piano, this piece is majestic sounding.

**Minor**

The first four minor pieces selected for this experiment are all solo works for the piano. Béla Bartók’s *Allegro Barbaro* contains a melody buried in the sound of all the other notes; however, the melody is still recognizable. The steady rhythm of this selection makes the piece sound stricter than other selections chosen for the experiment. A mood of tenseness strengthens as the loudness and intensity grow throughout the duration of *Allegro Barbaro*. The energy level is high, and June de Toth performs the musical selection in almost a tense manner. The monstrous chords played throughout the piece give the impression of being somewhat mechanical. Measures 55-76 were selected for the experiment (Appendix H, Figure 8). Although this piece might be more properly categorized as atonal, I included it in the ‘minor’ section, because of the F-sharp minor chords used throughout this excerpt, which create a minor mood.

Ludwig van Beethoven’s Piano Sonata in F minor, Op. 2, No. 1, Movement I, has a melody moving first upward and then downward. The excerpt chosen for this experiment are measures 61-74 (Appendix H, Figure 9). This part of the melodic line gives it the feeling of sadness to some listeners, because it is not climbing, but rather falling. The rhythm is steady; however, the busyness of the piece makes it seem more complicated. With the help of the *sforzando* markings the accents cause the listener to be on edge.
Johannes Brahms’s Ballade in D minor, Op. 10, No. 4, has a fairly simple rhythm and the melody is easy to follow. The melody does not seem to portray the sadness that one would expect in a minor piece; however, it is still somewhat contemplative and reflective. The excerpt that was selected is marked piano and pianissimo, which also helps in conveying a more tender and introspective mood. Measures 1-5 were selected for this experiment (Appendix H, Figure 10).

Frédéric Chopin’s Nocturne in C minor, Op. 48, No. 13 is written in a minor key; however, the portion selected for the experiment contains chords of major tonality. The example selected is heavily chromatic, which creates almost a tense feeling as portrayed by the performer, Vladimir Askenazy. The selection chosen from this nocturne is a quick passage full of sixteenth notes running up the piano to a climax, and then another run going to a different climactic destination. The octaves create a wider-ranged sound, since the lowest note is four octaves below the highest note. Measures 40-46 were selected for the experiment (Appendix H, Figure 11). Each phrase grows as it ascends up the piano.

Antonín Dvořák’s Cello Concerto in B minor, Op. 104, Movement II, has a prominent melody. The strings are very heavy, and the lines in the lower instruments are brought out quite loudly as a counter-melody. Measures 63-68 were selected for the experiment (Appendix H, Figure 12). The two rhythms are not extremely difficult to follow. The modality of this piece is minor, and Dvořák is able to convey darkness and sadness by the heavy chords he selected for this piece. It is the complete opposite of uplifting and joyous.
Sergei Rachmaninoff’s Piano Prelude in G-sharp minor is in 12/8 time. The phrases in this selection are almost identical. The modality of the piece is minor; however, one might not consider this composition to be sad. This could be because of the D-sharp major chords in measure 19 or the ascending melodic line in the left hand in measures 20-21. The way that the chords are played in an almost quick and sprightly manner makes it harder for this piece to evoke a sad emotion. Although the melody is often easy to follow, there are times where there is so much going on with other notes that it might be difficult to detect. Measures 17-21 were selected for the experiment (Appendix H, Figure 13).

Richard Strauss’s Also sprach Zarathustra, Op. 30, Part VI. Von der Wissenschaft is loosely based on a prose poem by Friedrich Nietzsche. The part chosen, Von der Wissenschaft, translates to Of Science. Strauss wrote numerous tone poems (symphonic poems), and Also sprach Zarathustra is one of these tone poems.49 A tone poem is an orchestral work, which is “a piece of orchestral music, usually in one movement, based on a literary, poetic, or other extra-musical idea.”50 This section of Zarathustra is one of the few orchestral pieces that has a double bass line that reaches the lowest B-flat. It could be considered an intellectual composition since it contains a twelve-tone fugue in the beginning of the piece; however, this was not played for the participants. Measures 20-23 were selected for this experiment (Appendix H, Figure 14). This selection is rhythmically written in a slow and somber manner; it feels like the listener is being

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dragged along. The strings carry the tune in this selection and the bassoon melodic line is very prominent. When the rhythm and modality are combined in this piece, the overall feeling and emotion that is evoked could be considered to be glum or somber. Strauss employs numerous instruments in this piece, and these instruments work together to convey the subdued feeling of this piece.

Scene 10 from Act II of Pyotr Ilich Tchaikovsky’s ballet, *Swan Lake*, Op. 20, is rhythmically easy to follow. This piece was written for an orchestra, and all of the instruments play a part in creating a grim and eerie moment in this piece. Measures 16-23 were selected for the experiment (Appendix H, Figure 15). The effect of tremolos in the string section contrasts drastically with the dynamically loud brass section and creates an eerie atmosphere. It is likely that many individuals may have heard this piece, so perhaps the familiarity of the selection evoked emotions that were not necessarily brought on by the mode of the music.

*Atonal*

Samuel Barber’s first piano *Excursion*, Op. 20 is rhythmically complex. Although the piece is in C minor, I placed it in the atonal section, because the excerpt chosen demonstrates bitonality. Bitonality is when two tonal centers are played simultaneously. In this instance, the right hand tonality is different from the left hand, creating two different keys. The piece is quick and energetic; the melody is often chaotic in the selection chosen. Measures 72-81 were selected for the experiment (Appendix H, Figure 16).
Henry Cowell’s *The Banshee* contains a melody that is difficult to sing. The rhythm is difficult to decipher because of the different techniques that are used during the playing of this piece. There is not a tonal center, and it is played both in the inside of the piano (on the strings) and on the actual keyboard. The performer is instructed to scrape his or her fingernails and scratch other strings inside the instrument. In this excerpt there are markings that indicate that the performer must sweep with the flesh of the finger from the lowest string to the note given and also sweep lengthwise along the string of the note given with flesh of the finger. Measures 1-5 were selected for the experiment (Appendix H, Figure 17). Chords are struck with the keys and the other hand will simultaneously run over strings inside the instrument. It is an interesting technique that Cowell devised in the process of composing this piece. The way that the sounds are produced creates a disorienting effect, and distinct tones cannot be discerned.

Charles Ives’s *Waltz-Rondo*, for piano, often sounds somewhat tonal, but does not contain a tonal center that is easily recognizable. The melody jumps from different registers on the piano so quickly and drastically that the listener may have trouble deciphering melodic phrases. The rhythm of this piece has rather irregular patterns. The crescendos in this selection are slight, and overall the piece tends to stay at the same dynamic level for the duration of the fifteen-second excerpt. Measures 1-8 were selected for the experiment (Appendix H, Figure 18).

Charles Ives’s *Three-Page Sonata* was composed for solo piano. It is a difficult piece to follow, since there is no conventional melodic line. Measures 72-79 were used for the experiment (Appendix H, Figure 19). The melodic line seems recognizable in the
score; however, it might be difficult for some to follow the melody while listening to the excerpt. The rhythm is very chaotic and eclectic.

The fourth piece from Arnold Schönberg’s *Five Piano Pieces*, Op. 23, contains numerous quarter notes that are played as triplets. Schönberg’s experimentation with chromaticism and other unconventional composition techniques helped him branch out into composing atonal music. This piece has a rhythm that is so chaotic that the selection seems as if it is merely floating through space. There is a sense of melody, but one would not attempt to sing it. Measures 19-23 were selected for the experiment (Appendix H, Figure 20). The dynamics in the piece grow and soften at anticlimactic moments. There are portions where the phrases seem to be falling down the piano in a tumbling sort of manner.

Anton Webern’s Symphony, Op. 21, is another composition that some might deem a very chaotic piece. The rhythm is difficult to follow and the modality is unrecognizable. The pattern of intervals is not what one would expect to hear. Webern uses serialism in this piece, which is a technique that was introduced by Schönberg in the twentieth-century.\(^{51}\) Serialism or tone row is the term used to describe the ordering of the twelve pitch classes.\(^{52}\) Some might consider serialism to be eclectic sounding; however, Webern would not agree, because he would consider the piece to be organized and mathematically correct. Measures 3-14 were used in the experiment (Appendix H, Figure 21). The selection from this piece slowly gathers momentum, while the sound level

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grows. The instruments drop out and enter suddenly at various times. With the pizzicato markings in the strings, a lighter and free sound is created.

Eric Whitacre’s *Ghost Train* was written for a concert band. The melody is heard throughout this excerpt and it moves throughout different instruments. The rhythm is very quick and fast paced. It is interesting that Whitacre shifts from 3/4 to 4/4 time during the excerpt that was selected. Measures 106-13 were selected for the experiment (Appendix H, Figure 22). The beginning of the selection grows in sound level through the use of dynamics, but once the runs descend in the bassoons, trombones, and euphoniums in measures 110-11 then the decrescendo occurs simultaneously. There are portions where straight eighth notes are being played against triplet eighth notes, creating an unsteady feeling.

Giacinto Scelsi’s title, *Anahit*, derives from Armenian mythology and translates as “the goddess of fertility and birth.” Scelsi (1905-1988) was an Italian composer who explored different mediums to use in his compositions, such as electronic instruments. In the words of scholars Christopher Fox and David Osmond-Smith, “In his most wholly characteristic works pitch, timbre, register and dynamics are heard as the inherent expressive potentialities of each sound, rather than as separate parameters to be controlled more or less independently.” With no apparent melody, *Anahit* seems to be an ongoing pitch that tends to fluctuate ever so slightly. This piece, scored for violinists and eighteen other instrumentalists, is very tense and sharp sounding with weird and bizarre noises that sound almost like the instruments are tuning for a concert. It is hard to

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determine the rhythm of this piece, because of the ambiguity of the instruments and the lack of tonality in this selection.
Chapter IV

Results

Based on the hypotheses of my investigation, statistical analyses were conducted to examine the effect of the musical selections on brain activity, hemispheric activation, and emotional response. In addition, I analyzed the data to determine the effect of gender and musical training on brain activity and response to the music excerpts. The results of these analyses are summarized in this section. Only significant and nearly significant findings are reported.

Does the type (modality) of music make a difference?

A multivariate ANOVA compared brain activity in the left and right hemispheres with the three types of music in men and women. For all types of music, beta waves (mean = 1.475) were significantly more active than alpha waves (mean = 0.666), indicating arousal to the music, $F = 38.16, p < 0.001$. The type (modality) of the music had no significant effect overall, although a nearly significant interaction was found between type of music, brain-wave frequency, and musical experience, $F = 2.165, p = 0.095$. This interaction is shown in Appendix I, Figure 1. No differences between hemispheres were noted for the three types of music, and no gender differences were found in responses to the three types of music.

Does brain dominance make a difference?

When the effects of gender and brain dominance as measured by The Alert Scale of Cognitive Style (Crane, 1989) were analyzed, an interesting pattern emerged for all three types of music for beta frequencies. For music selections with major tones, right-
brained women and left-brained men showed the highest levels of beta activity, $F = 2.60$, $p = .096$ (Appendix I, Figure 2). The same trend was seen for beta activity in response to minor and atonal musical excerpts on the left side of the brain, with right-brained women and left-brained men showing the highest levels of beta activity (Appendix I, Figures 3 and 4). These findings were not obtained when the other measures of brain dominance were analyzed together with gender.

Overall, beta wave activity in response to all three types of music was highest in the left hemisphere for right-brained individuals, but this was probably due to the fact that women outnumbered men by 2:1. It is true, as indicated by other studies, that right-brained women show the greatest beta activity in the left hemisphere; however, this is not found in right-brained men. No significant differences were found for responses in the alpha frequencies or right brain activation.

*Does musical training make a difference?*

Two measures of musical experiences were analyzed: the age at which musical training began, and the years of musical training. For the age at which musical training began, participants were grouped into three cohorts for the purposes of the analysis: 1) training began before the age of 7 years ($n = 15$), 2) training began between the ages of 8 and 14 ($n = 12$), and 3) training began after the age of 15 ($n = 2$). No effects of age at which training began were found for alpha or beta activity in response to any type of music.

For the years of musical training, participants were grouped into four cohorts: 1) no training ($n = 2$), 2) 1 – 3 years of musical training ($n = 6$), 3) 4 – 9 years ($n = 10$), and
4) 10 or more years ($n = 11$). Beta activity was higher on both sides of the brain to all types of music in people who had more years of musical training, although this trend was not significant. The same effect was not seen for alpha activity.

**Correlational analyses**

Correlational analyses were conducted to determine significant relationships between the participants’ liking for types of music, the emotions evoked by the music, musical experience, hemispheric dominance (cognitive style), and brain wave frequencies. Participants who liked major music also liked minor music, $r = .528, p = .003$. Those who liked major music had the greatest emotional response to major music, $r = .815, p < .001$. Those who liked minor music showed a large alpha wave response in the right hemisphere when minor music was played, $r = .400, p = .032$. If the subjects showed an alpha response in the right hemisphere, then they also showed an alpha response in the left hemisphere, $r = .735, p < .001$. If the subjects showed a beta response to major music in the right hemisphere then they showed a beta response in the left hemisphere, $r = .521, p = .004$. Those who showed an alpha response to minor music in the left hemisphere showed an alpha response to minor music in the right hemisphere, $r = .756, p < .001$. Those who showed a beta response to minor music in the left hemisphere also showed a beta response to minor music in the right hemisphere, $r = .528, p = .003$. Those who showed an alpha response to new age music in the left hemisphere showed an alpha response to new age music in the right hemisphere, $r = .779, p < .001$. Those who showed a beta response to new age music in the left hemisphere showed a beta response to new age music in the right hemisphere, $r = .597, p = .001$. 
Chapter V

Discussion

In summary, this study showed no significant differences in responses to the different types of music. In addition, no differences between hemispheres and no gender differences were seen. Beta waves activation to all types of music was significantly greater than alpha wave activation. Also, musical experience (defined only by number of years of training, not type of training), age at onset of training, or number of years of training, showed no significant results. The significant findings were in right-brained women and left-brained men, who showed the highest beta activity to all types of music. An alpha wave finding that was significant was this: the more the subject liked the minor-key music the more significant alpha activation occurred on the right side of the brain.

About major and minor modes in music:

In 1935, Kate Hevner investigated the affective quality of the major and minor modes in music. Even though this experiment was conducted over seventy years ago and the number of subjects was a small sample of the population (205 subjects) many of Hevner’s findings are still of interest. According to Hevner and the results of her experiment, “musicians also recognize that in producing its effect in the listener, the mode (major or minor) is never the sole factor; it is only a part of the total effect.” Over the centuries, the science of musical aesthetics has yet to determine the cause of aesthetic response, and such discussions necessarily breed more ambiguity than those that analyze other art forms. Hevner makes a good point, “For example, the soothing affect of a

54 Hevner, 104.
certain composition may be due to any one of a number of different factors or to a combination of them; to the slow tempo, or low intensity, or smooth and simple harmony, or the even unaccented rhythm, or to the contrast with a preceding animated and excited section.” Each category of music had different types of harmonic structure, rhythms, and tempos. Rhythms, harmonies, and tempos all affect the emotions that an individual experiences while listening to music. I could have factored this into my study, because some pieces were simpler rhythmically or more complex harmonically; however, other studies have used complex compositions, too. For example, I selected a Bach Prelude and Fugue, whereas Hevner selected a Bach Minuet. Perhaps if the simpler and less complicated pieces were played, other complications with the study could have arisen. One might think that individuals will not care for minor music over major music, but perhaps the different rhythms, harmonic structures, and tempos cause some individuals to prefer and respond that they liked a few of the minor modality pieces. It is possible that subjects felt peaceful and not necessarily sad and mournful.

Other psychologists who have experimented with mood effects have observed subjects listening to varying compositions. As noted musicologist and aesthetician Leonard Meyer has observed, “In some cases the response must have been made to those elements of the musical organization which tend to be constant, e.g., tempo, general range, dynamic level, instrumentation, and texture.” If there are inconsistent results with how subjects respond to musical selections, then perhaps one can deduce that

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55 Hevner, 104.
56 Meyer, 7.
individuals are each so unique that one does not respond the same way emotionally as another individual.

While listening to music, a listener might be affected differently from what one might expect. For example, one will assume that a song in a major key is always happy and uplifting or if a song is in a minor key it is sad and gloomy. However, Hevner observes, “Naturally the effect on the listeners of a sprightly minuet is cheerful and stirring, even though it is written for the most part in the minor mode, and the effect of a funeral march, with ponderous chords is slow in tempo, is heavy and depressing even though it is written in the major key.” The idea that music that is fundamentally major or minor centered could evoke the opposite emotion than expected is intriguing. The music that was selected for my senior thesis project has some selections that had the opposite effect on people than expected, because of this concept. Some subjects responded that he or she liked and/or felt happy when he or she heard a piece, and others felt sad when they listened to the same musical selection. The atonal pieces could have made it difficult for listeners to determine an emotion, possibly because of the chromatics or different types of triads that were in the compositions. Meyer writes that, “Because chromatic and whole-tone scales and augmented and diminished triads all involve intervallic equidistance, they create uniformity and produce ambiguity.”

Hevner also found that the musical background of her subjects did not influence how they perceived major and minor compositions. This finding, by Hevner and similar

57 Hevner, 104.  
58 Meyer, 164.  
59 Hevner, 103-18.
to my own findings, could also explain why sometimes it was difficult for subjects to think of an emotion that they were experiencing within the music.

There are many different ways that one could improve this study. The number of subjects was limited, and perhaps a larger sample would have shown more significant results. Perhaps the reason there was a lack of significant findings was due to the selections that were chosen. The pieces could have been shorter and played more than twice, or an entire piece played once. The room that the individuals were seated in was not the quietest, and results could possibly be improved if the room had fewer noise distractions, for example, if the lab had not been located next to the utility closet. If the seating arrangements had been more comfortable than a plain desk-chair, then the subjects would have been more relaxed and not so tense and uptight; this could have influenced the readings from the electrodes. If this study had been conducted where subjects could have been selected who had not had any musical training, then the results could have been more conclusive. On the contrary, there would have possibly been different issues that would have been discovered with subjects that had no musical training; for example, they might not enjoy listening to any type of music. Perhaps if the musical background survey was more specific with regard to the type of musical training, for example what skills, level, and so forth, then the musical experience would have been defined in a better manner.

This study was disappointing, because the hypotheses were not supported. There are a number of reasons why the hypotheses could not have been met. If this study were to be conducted again there could be many improvements made to the current model. For example, the musical selections might need to be popular pieces and not pieces that are
unfamiliar. Perhaps if the pieces were selected based on previous studies (for example if I had used Hevner’s pieces, such as a Bach Minuet or a folk song from Schumann) that specifically found results based on emotional differences then the findings might have been more significant. Perhaps scales or even shorter passages should have been used, rather than excerpts of music. Also, if this study were conducted again, putting the subjects in a different environment would have been better for determining results. If the periods of silence had been longer, then the electrodes would have had a better chance of picking up information that was not relevant to the study.

My study attempted to determine if different types of music affected the brain differentially. Although the brain’s response to the three types of music do not differ in my experiment, I found that right-brained women and left-brained men were more aroused by the musical selections in comparison to the results found in left-brained women and right-brained men. Further research should examine why right-brained women and left-brained men respond so strongly to music. A possible explanation for this finding could be that men in the United States often exhibit a greater degree of emotional repression and are less encouraged to show emotions, whereas women often have a tendency to display more emotions. Since the left side of the brain is more analytical, this might explain why men showed more activity in this hemisphere while listening to music. This also might explain why women showed more activity in the right side of the brain, since the right hemisphere is more emotional and creative; however, this still should be seen in the context of a very limited sample of college students.
Appendix A:

Figure 1: Major

\[ \text{Figure 2: Harmonic Minor} \]

\[ \text{Figure 3: Limbic System} \]

Taken from Gerrig and Zimbardo, 78.
Figure 4: Lateral Surface of the Brain

Taken from Andreassi, 54

Figure 5: Pons and Medulla

Taken from Gerrig and Zimbardo, 78
Figure 6: 10-20-System

FIG. 3.7. Top view of scalp locations used by researchers studying relations between brain activity and performance. The locations are the active, or EEG-producing, areas. The reference area may be the earlobes, singly or in combination as “linked ears,” or the tip of the nose. The numbering system is a portion of that used in the International EEG 10-20 system. The nasion refers to the bridge of the nose, and the inion is the occipital protuberance.

FIG. 3.8. In this diagram the 10-20 system locations are shown for the left side of the scalp. Note that left-side locations have odd-numbered designations, whereas the right-side locations are indicated by even numbers. (F, frontal; C, central; P, parietal; O, occipital; T, temporal.) From Callaway (1975). Copyright 1975 by Grune & Stratton. Adapted by permission.

Taken from Andreassi, 61
Appendix B: Musical Background Survey

1) How old are you?

2) Have you ever played an instrument (if no, skip to question 7)?

3) What did you play?

4) What age did you start playing and for how many years did you play?

5) Do you still play regularly?

6) Are you involved in any ensembles on campus?

7) What kind of music do you listen to on a regular basis?

8) Do you listen to a lot of classical music?

9) Do you like to listen to music while you work?
Appendix C: The Alert Scale of Cognitive Style

For questions 1-21 please circle the sentence that is truer.

1. A) It's fun to take risks.
   B) I have fun without taking risks.

2. A) I look for new ways to do old jobs.
   B) When one way works well, I don't change it.

3. A) I begin many jobs that I never finish.
   B) I finish a job before starting a new one.

4. A) I'm not very imaginative in my work.
   B) I use my imagination in everything I do.

5. A) I can analyze what is going to happen next.
   B) I can sense what is going to happen next.

6. A) I try to find the one best way to solve a problem.
   B) I try to find different answers to problems.

7. A) My thinking is like pictures going through my head.
   B) My thinking is like words going through my head.

8. A) I agree with new ideas before other people do.
   B) I question new ideas more than other people do.

9. A) Other people don't understand how I organize things.
   B) Other people think I organize well.

10. A) I have good self-discipline.
    B) I usually act on my feelings.

11. A) I plan time for doing my work.
    B) I don't think about the time when I work.

12. A) With a hard decision, I choose what I know is right.
    B) With a hard decision, I choose what I feel is right.

13. A) I do easy things first and important things later.
    B) I do the important things first and the easy things later.

14. A) Sometimes in a new situation, I have too many ideas.
    B) Sometimes in a new situation, I don't have any ideas.

15. A) I have to have a lot of change and variety in my life.
    B) I have to have an orderly and well-planned life.

16. A) I know I'm right, because I have good reasons.
    B) I know I'm right, even without good reasons.
17. A) I spread my work evenly over the time I have.  
    B) I prefer to do my work at the last minute.

18. A) I keep everything in a particular place.  
    B) Where I keep things depends on what I'm doing.

19. A) I have to make my own plans.  
    B) I can follow anyone's plans.

20. A) I am a very flexible and unpredictable person.  
    B) I am a consistent and stable person.

21. A) With a new task, I want to find my own way of doing it.  
    B) With a new task, I want to be told the best way to it.
Appendix D: A Refined Neurobehavioral Inventory of Hemispheric Preference

For questions 22-33 please circle the activity you prefer.

22. a) Major in logic  
    b) Write a letter  
    c) Fix things at home  
    d) Major in art  

23. a) Be a movie critic  
    b) Learn new words  
    c) Improve your skills in a game  
    d) Create a new toy  

24. a) Improve your strategy in a game  
    b) Remember people’s names  
    c) Engage in sports  
    d) Play an instrument by ear  

25. a) Review a book  
    b) Write for a magazine  
    c) Build new shelves at home  
    d) Draw a landscape or seascape  

26. a) Analyze market trends  
    b) Write a movie script  
    c) Do carpentry work  
    d) Imagine a new play  

27. a) Analyze management practices  
    b) Locate words in a dictionary  
    c) Put jigsaw puzzles together  
    d) Paint in oil  

28. a) Be in charge of computer programming  
    b) Study word origins and meaning  
    c) Putter in the yard  
    d) Invent a new gadget  

29. a) Analyze production cost  
    b) Describe a new product in words  
    c) Sell a new product on the market  
    d) Draw a picture of a new product  

30. a) Explain the logic of a theory  
    b) Be a copy writer for ads  
    c) Work with wood and clay  
    d) Invent a story  

31. a) Be a comparison shopper  
    b) Read about famous men and women  
    c) Run a traffic control tower
d) Mold with clay and putty

32.  
  a) Analyze your budget 
  b) Study literature 
  c) Visualize and re-arrange furniture 
  d) Be an artist 

33.  
  a) Plan a trip and make a budget 
  b) Write a novel 
  c) Build a house or shack 
  d) Make crafts your hobby
Appendix E\textsuperscript{60}: Rating Sheet

On the first scale please place a vertical mark to rate how much you liked or disliked the music selection. On the second scale please place a vertical mark to rate how sad or happy the piece made you feel.

Selection 1)

\begin{center}
\begin{tabular}{c}
\hline

\textbf{strongly dislike} & \textbf{strongly like} \\
\hline

\textbf{extremely sad} & \textbf{extremely happy} \\
\hline
\end{tabular}
\end{center}

\textsuperscript{60} This was the rating sheet for each selection and each round.
## Appendix F: Times for Musical Examples

<table>
<thead>
<tr>
<th>Title</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anton Webern’s Symphony No. 21</td>
<td>0:10-0:25</td>
</tr>
<tr>
<td>Antonín Dvořák’s Cello Concerto in B minor, Op. 104, Movement II</td>
<td>4:15-4:30</td>
</tr>
<tr>
<td>Arnold Schönberg’s Five Piano Pieces, Op. 23, No. 5</td>
<td>1:05-1:20</td>
</tr>
<tr>
<td>Béla Bartók’s Allegro Barbaro</td>
<td>1:20-1:35</td>
</tr>
<tr>
<td>Charles Ives’s Three-Page Sonata</td>
<td>4:45-5:00</td>
</tr>
<tr>
<td>Charles Ives’s Waltz-Rondo</td>
<td>0:00-0:15</td>
</tr>
<tr>
<td>Eric Whitacre’s Ghost Train</td>
<td>3:40-3:55</td>
</tr>
<tr>
<td>Frédéric Chopin’s Military Polonaise in A</td>
<td>0:17-0:32</td>
</tr>
<tr>
<td>Frédéric Chopin’s Nocturne in C minor, Op. 48, No. 13</td>
<td>3:50-4:05</td>
</tr>
<tr>
<td>Giacinto Scelsi’s Anahit</td>
<td>3:00-3:15</td>
</tr>
<tr>
<td>Henry Cowell’s The Banshee</td>
<td>0:00-0:15</td>
</tr>
<tr>
<td>J. S. Bach’s Fugue in C# Major</td>
<td>2:40-2:55</td>
</tr>
<tr>
<td>J. S. Bach’s Prelude in C# Major</td>
<td>0:45-1:00</td>
</tr>
<tr>
<td>Johannes Brahms’s Ballade in D minor, Op. 10, No. 1</td>
<td>0:00-0:15</td>
</tr>
<tr>
<td>Johannes Brahms’s Piano Trio No. 1 in B, Op. 8, Movement I,</td>
<td>1:20-1:35</td>
</tr>
<tr>
<td>Joseph Haydn’s Le Matin Symphony No. 6, Movement I</td>
<td>3:25-3:40</td>
</tr>
<tr>
<td>Ludwig van Beethoven’s Sonata in F minor, Op. 2, No. 1, Movement I</td>
<td>1:40-1:55</td>
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<tr>
<td>Luigi Boccherini’s String Quintet in E, Op. 11, No. 5, Movement III Minuet</td>
<td>0:18-0:33</td>
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<tr>
<td>Pyotr Ilich Tchaikovsky’s Swan Lake, Op. 20, Act 2: Scene 10</td>
<td>0:55-1:20</td>
</tr>
<tr>
<td>Richard Strauss’s Also sprach Zarathustra, Op. 30, Part VI. Von der Wissenschaft</td>
<td>1:35-1:50</td>
</tr>
<tr>
<td>Richard Strauss’s Cello Sonata in F, Op. 6, Movement I</td>
<td>0:00-0:15</td>
</tr>
<tr>
<td>Samuel Barber’s First Excursion Op. 20, No. 1, un Poco Allegro</td>
<td>2:00-2:15</td>
</tr>
<tr>
<td>Sergei Rachmaninoff’s Prelude in G-sharp minor, Op. 32, No. 12</td>
<td>1:00-1:15</td>
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</table>
## Appendix G: CD Recording Information

<table>
<thead>
<tr>
<th>Title</th>
<th>CD Title</th>
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<tbody>
<tr>
<td>Webern’s Symphony No. 21</td>
<td>Wien: Philharmonia, The Development of Western Music.</td>
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<tr>
<td>Ives’s <em>Three-Page Sonata</em></td>
<td>Alan Mandel. Charles Ives: Works for Piano</td>
</tr>
<tr>
<td>Ives’s <em>Waltz-Rondo</em></td>
<td>Alan Mandel. Charles Ives: Works for Piano</td>
</tr>
<tr>
<td>Chopin’s Military Polonaise in A</td>
<td>Vladimir Askenazy. Ultimate Piano Classics.</td>
</tr>
<tr>
<td>Cowell’s <em>The Banshee</em></td>
<td>Steffen Schleiermacher. The Bad Boys!.</td>
</tr>
<tr>
<td>Bach’s Fugue in C# Major</td>
<td>András Schiff. J.S. Bach: The Well-Tempered Clavier, Book I.</td>
</tr>
<tr>
<td>Brahms’s Ballade in D minor, Op. 10, No. 1</td>
<td>Artur Rubinstein. The Rubinstein Collection, Vol. 63</td>
</tr>
<tr>
<td>Haydn’s <em>Le Matin</em> Symphony No. 6, Movement I</td>
<td>Trevor Pinnock: The English Concert. Haydn: Symphonies</td>
</tr>
<tr>
<td>Strauss’s <em>Also sprach Zarathustra</em>, Op. 30, Part VI. <em>Von der Wissenschaft</em></td>
<td>Boston Pops Orchestra.</td>
</tr>
<tr>
<td>Haydn's London Symphony No. 104, H 1/104, Movement I</td>
<td>Christopher Hogwood: Development of Western Music II</td>
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</tbody>
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Figure 1, Bach: Prelude in C-sharp Major, mm. 54-75

Figure 2, Bach: Fugue in C-sharp Major, mm. 30-35
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Figure 22, Whitacre: Ghost Train, mm. 104-107
Figure 23, Whitacre: Ghost Train, mm. 108-111
Appendix I: Figures for Results

Figure 1:

“Major” Music

“Minor” Music
Figure 2:
Figure 3:

“Minor” Music – Left Beta

Figure 4:

“Twentieth-Century” Music – Left Beta
Bibliography


Christenson, Peter, and Jon Peterson. “Genre and Gender in the Structure of Music Preferences.” *Communication Research* 15, No. 3 (June 1988): 282-301.


Abstract

The aim of this study was to detect, using electroencephalography, whether or not individuals respond differently to modalities within Western tonal music. Specifically I investigated whether or not hemispheric dominance had any effect on the participants’ responses to specific musical selections, and if men and women respond differently. Electroencephalography records neurons firing throughout the brain and picks up this electrical activity on the scalp. In this experiment two electrodes were placed behind the subject’s ears, two on the subject’s forehead, one on the scalp, and a ground electrode on the forearm. The results indicated that there was no effect of music on a particular hemisphere or brainwaves, although right-brained females and left-brained males showed the greatest response to all types of music.