Psychophysiological Responses to Isolated Musical Chord Progressions

An Honors Thesis (PSYS 499)

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May 2014

Expected Date of Graduation

May 2014

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Abstract

It is widely accepted that music is capable of inducing emotional responses, but there is a great deal of conflicting evidence among the research concerning the nature of those responses. The present study aimed to begin identifying some specific components of music that contribute to musical emotions by evaluating electrodermal activity and heart rate responses to isolated cadential chord progressions of varying conventionality. The results show a significant main effect of musical ensemble participation on heart rate; participants with any experience in a musical ensemble exhibited significantly greater heart rate responses than participants with no experience in a musical ensemble. This indicates that musical experience modulates physiological responses to isolated chord progressions.

Acknowledgements

I would like to thank Dr. Don Ester, my advisor, for his patient guidance throughout the entire process, and especially for his help with the music-theoretical part of the project. This final product would not be possible without his expertise and encouragement!

I would also like to thank Dr. Stephanie Simon-Dack for inspiring me to pursue this difficult topic and for her help with the physiological measurements and statistical analyses. I could not have asked for a more supportive mentor.

Last but not least, I would like to thank my lab assistants, Gabby, Aaron, and Cady for helping with data acquisition.

Psychophysiological Responses to Isolated Musical Chord Progressions

It is widely accepted that music is capable of inducing emotional responses, but the research concerning the nature of those responses has yielded mixed results. One current view of musical emotion is that it does not occur independently, but rather stems from associations with significant events (Krumhansl, 2002). However, studies show that listeners generally agree with one another when labeling musical emotions, indicating that they are independent of personal experience (Schellenberg, Krysciak, & Campbell, 2000; Vieillard et al., 2008). Another common disagreement concerns whether song lyrics or musical structure contribute more to the emotional experience. Words carry emotion, but we also experience emotions in response to songs in other languages, indicating that the musical structure itself is capable of eliciting an emotional response (Krumhansl, 2002). Miu and Balteş (2012) investigated the effects of empathizing with an opera performer on music-induced emotions, and revealed that participants attributed their emotions more to the music itself than to the lyrics or performer's facial expressions. The present study aims to identify some specific components of music that contribute to musical emotions by evaluating electrodermal activity and heart rate responses to isolated chord progressions.

Dimensions of Emotion

Valence and arousal are the two dimensions of emotion that are typically studied in musical emotion research (Mikutta, Altorfer, Strik, & Koenig, 2012). Valence refers to pleasantness of a stimulus, and is related to the presence of consonant or dissonant chords. Arousal refers to the strength of the stimulus and is primarily related to loudness and musical expectation, but can also be influenced by tempo and dynamics. Musical expectation is a term that describes the natural progression of one chord to the next in Western music. Violations of the expected chord increase arousal, and realizations of the expected chord decrease arousal.

Arousal is in part processed by the right hemisphere of the brain, which receives information from the sympathetic nervous system and is also involved in processing orienting responses and negative affect (Mikutta et al., 2012). Alpha waves are associated with quiet, pre-alert states and can be indicators of reduced activity. Conversely, suppression of alpha waves is a sign of increased activity. As a result, it is normal for arousal to manifest itself in EEG as a suppression of alpha band activity in the right hemisphere, particularly in the frontal region.

Mikutta, Altorfer, Strik, and Koenig (2012) designed a study to observe physiological reactions throughout the entire first movement of Beethoven's 5th Symphony. The researchers hypothesized that perceived arousal throughout the piece would be independent of individual music preference and that there would be reduced alpha band activity in the right frontal region when music-induced arousal was high.

The researchers discovered a correlation between individual arousal ratings and mean arousal ratings across time, implying that all participants experienced the music in similar ways. They also found a correlation between sound pressure and mean arousal, indicating that loudness was an influencing factor in arousal. An additional positive correlation was found between like/dislike of the piece and the mean height of arousal ratings, which points to the conclusion that preferred music is more arousing than other music. After physiological changes due to volume were filtered out, the only EEG activity change independent of loudness was greater alpha activity on the right frontal side during periods of reported high arousal. Because this change was independent of volume, it is likely the result of emotional content in the music.

Perceived Emotion

Emotion perception of music refers to the ability to judge the mood of a piece and objectively determine the emotion being expressed (Sloboda, 1991; Coutinho & Cangelosi, 2011). Perceived emotion is unrelated to physical emotional responses, and is thus independent from subjective emotion (Sloboda, 1991). Although the present study focuses on subjective emotion, studies concerning perceived emotions to music are relevant because they have helped identify musical features that contribute overall emotionality of a piece.

Schellenberg, Krysciak, and Campbell (2000) examined whether perceived emotional context of short melodies was dependent on the pitch and rhythmic structures of the melodies. In general, melodies with complex rhythms tend to be perceived as happy, whereas melodies with more regular rhythms tend to be perceived as sad or boring (Scherer & Oshinsky, 1977). With regards to pitch, upward contours in the melodic line are indicative of fear or surprise, but downward contours are perceived as boring, pleasant, or sad. The effects of pitch and rhythm seem to be additive in some cases, but are interactive in the majority of cases. This fact led the researchers to hypothesize that the interaction of pitch and rhythm would affect objective ratings of musical stimuli more than either pitch or rhythm on their own.

To investigate the interactive effects of pitch and rhythm, participants were presented with a series of short musical examples and instructed to rate the happiness/sadness/scariness of each example by using a 7-point Likert scale (Schellenberg et al., 2000). The musical examples were modified to derive three separate versions: one in which all tones were identical in pitch, one in which all notes were identical in duration, and one in which all tones were identical in pitch and duration. Happiness and scariness ratings were higher for excerpts with changes in pitch and rhythm than for excerpts in which pitch and note durations were held constant.

Sadness ratings were higher for excerpts with pitch changes than for excerpts with static pitch, but the influence of rhythm was not as evident. The researchers concluded that listeners perceive greater emotional meaning from changes in pitch than from rhythmic patterns.

Vieillard et al. (2008) also investigated the interaction of perceived emotion and musical structures, but with the goal of developing a set of musical stimuli for general use in research on emotion. The study consisted of a series of three experiments using computer-generated stimuli with a piano timbre. The proposed happy excerpts were composed in the major mode with an average tempo of 137 Metronome Marking (MM). Sad excerpts were composed in the minor mode with an average tempo of 46 MM. Peaceful excerpts were composed in the major mode with an average tempo of 74 MM and included an arpeggio accompaniment. Scary excerpts included minor chords with many chromatic pitches and had tempos between 44 and 172 MM.

The purpose of the first experiment was to determine whether the musical excerpts conveyed the intended emotion and were easy to discriminate from one another (Vieillard et al., 2008). Happiness was recognized most accurately, but peacefulness was occasionally confused with sadness. Emotions were recognized more accurately when participants were asked to focus on their emotional experience as opposed to mere recognition and labeling. The second experiment consisted of a gating task to determine the number of musical events necessary to accurately recognize an emotion. The researchers discovered that 250 ms from the stimulus onset was sufficient to distinguish happy from sad music, and that happy and sad excerpts required fewer musical events to be recognized than scary and peaceful excerpts. The third experiment investigated how dissimilar the excerpts were from each other, and the excerpts with confidently recognized emotions were published with the study.

Isolated Chord Sequences

In music, chords are defined as the simultaneous presentation of three or more notes (Bigand, Parncutt, & Lerdahl, 1996). The movement from one chord to the next is known as a chord progression, and certain progressions create more tension than others, depending on the harmonic relationship between each chord. Harmonically related chords stem from the same parent key and thus share similar acoustic features (Marmel et al., 2011). Bigand, Parncutt, and Lerdahl (1996) identified three key characteristics that give successive chords a strong harmonic relationship with each other: tones, roots, and scale. Chords are more harmonically related if they have one or more tones in common, if their roots are near each other on the Circle of Fifths, and if their notes all belong to the same major or minor scale.

Harmonic distance contributes to tension in the music, and that perceived tension can be related to emotional response since increased harmonic distance leads to greater tension, which in turn leads to an augmented emotional response (Steinbeis, Koelsch, & Sloboda, 2006). Bigand, Parncutt, and Lerdahl (1996) conducted a study to determine the influence of harmonic function, sensory consonance, and horizontal motion on perceived musical tension in short chord sequences. Stimuli consisted of three-chord sequences, of which the first and last chords were always C major to preserve the feeling of that key. The researchers discovered that chords that were structurally more important to the progression as a whole yielded the smallest amount of perceived musical tension. Greater distance in pitch space (further from each other on the Circle of Fifths) between chords and the presence of minor and seventh chords also contributed to greater perceived musical tension. They also found that diatonic chords (chords belonging to the key) created less perceived tension than nondiatonic chords, and diatonic chords on the first, fourth, or fifth scale degrees created less perceived tension than other diatonic chords.

Lindström (2003) also conducted a study using isolated chord sequences to study music and emotion. He was interested in the effects of immanent (present in the musical score) and performed (loudness, articulation, timing) accents on target notes and how they relate to emotional response. Stimuli consisted of a series of three tones preceded by either a major or minor chord, with the target note being the last high-pitched tone in the series. The stimuli were presented in a lecture hall to a group of participants who were instructed to rate all of the sequences on two bipolar scales: *happy – sad* and *tender – angry*. Minor mode progressions were judged as representing sadness and anger, and major mode progressions were judged as representing happiness and tenderness. Additionally, short-short-long note patterns were judged as the rhythmic pattern most representative of anger. Lindström concluded that certain notes appear to be more important for perceived emotion than other notes, which could be a result of those notes' relation to the implied harmonic function.

Marmel et al. (2011) used isolated chord pairs to determine whether harmonic relatedness enhanced brainstem encoding of the second chord. They hypothesized that when the target chord was preceded by a harmonically related chord, perceptual processing of that chord would be more efficient due to enhanced brainstem encoding. In this study, the target chord was a C major chord and it was presented in three conditions: related (G major), unrelated (F-sharp major), and repeated (C major). Researchers discovered that when the target chord was preceded by the related chord, brainstem responses were stronger than when the target chord was preceded by an unrelated or repeated chord, suggesting that subcortical encoding of music is influenced by basic musical structures.

Musical Structures and Physiological Responses

There are six low level features of music that can help predict listeners' affective responses to music: loudness, pitch level, pitch variation (contour), tempo, texture, and sharpness (Coutinho & Cangelosi, 2011). Sloboda (1991) conducted an exploratory study to determine which specific components of music contributed to emotional response by sending out a questionnaire with a list of physical responses to a large group of British adults. Participants were instructed to rate how often they had experienced each response to music in the past five years, and then to identify up to three pieces in which they had experienced one or more of those responses and where they occurred in each piece.

The most common reported responses were shivers, laughter, lump in the throat, and tears (Sloboda, 1991). Women experienced tears more often than men, and participants in their 30's reported more laughter. After an analysis of the identified musical passages, it was determined that tears were most commonly elicited by melodic appoggiaturas, sequences, and harmonic movements toward the tonic. Shivers were most often elicited by sudden changes in harmony, and racing heart was generally elicited by acceleration and syncopation. Sloboda concluded that different types of musical structures elicit distinct physiological reactions and that the ability to experience physiological responses to music is tempered by practice.

Gomez and Danuser (2007) wanted to determine the extent to which musical features and experienced emotions corresponded to musical structure and perceived emotions. Specifically, they wanted to ascertain which structural aspects of music were the most influential on experienced valence and arousal. Since valence and arousal are naturally experienced together, researchers used an analytic strategy that correlated structural features of the music to ratings of both dimensions simultaneously. Participants were first given a questionnaire to assess musical habits, preferences, and training: none reported dislike of classical music (Gomez & Danuser, 2007). While respiration, electrodermal activity (EDA), and heart rate were being monitored, 16 noises and 16 musical passages (excerpts from Western music) of 30 seconds each were presented in a mixed order in a sound-insulated room. After each stimulus, participants were asked to report valence and arousal using the Self-Assessment Manikin (SAM) and then relax for 65 seconds before the next stimulus.

Gomez and Danuser (2007) found that faster tempo, greater accentuation and increased use of staccato contributed to shorter inspiratory (Ti) and expiratory time (Te) and an increase in EDA. Additionally, faster tempo was associated with higher heart rate. Increases in sound intensity led to shorter Te and increased EDA. Wider pitch range was another contributor to increased EDA. Mode, rhythmic articulation, and harmonic complexity contributed the most to distinguishing between negative and positive passages (valence), and accentuation, tempo, and rhythmic articulation contributed the most to distinguishing between low-arousal and high-arousal excerpts.

Psychophysiological Methodology

Music stimulates autonomic brainstem responses that are responsible for the regulation of heart rate, pulse, blood pressure, body temperature, skin conductance, and muscle tension (Chanda & Levitin, 2013). Because of this, measurements of electrodermal activity, heart rate, and respiratory rate are useful ways to observe autonomic responses (Khalfa, Peretz, Blondin, & Manon, 2002). EDA is a measurement of the rapid fluctuation in sweat gland activity, which results from the release of acetylcholine by the sympathetic nervous system. It is ideal for studying emotions since they are brief and event-related.

Khalfa et al. (2002) wanted to determine whether event-related EDA could be elicited by emotions expressed in musical excerpts, and hypothesized that EDA would be able to distinguish between excerpts based on their emotional properties. The researchers evaluated four distinct musical emotions: fear, happiness, sadness, and peacefulness. Stimuli consisted of computer-generated musical clips, each of which was 7 seconds in duration. Fearful and happy stimuli were rated as more stimulating (arousing) than peaceful and sad stimuli, and peaceful and happy stimuli were rated as more pleasant (valence) than sad and fearful stimuli. Researchers found greater EDA for fear and happiness than for sadness and peacefulness, reflecting the greater arousal ratings of the former. It is of interest to note that fearful stimuli elicited the greatest EDA. No significant EDA difference was found between happiness and fear or between sadness and peacefulness, implying that EDA is more indicative of arousal than of valence.

Olsen and Stevens (2013) were also interested in event-related EDA and investigated electrodermal responses to up-ramp (continuously increasing intensity) and down-ramp (continuously decreasing intensity) musical stimuli. Continuous EDA was measured while participants listened to short up-ramp and down-ramp violin excerpts. After the listening task, participants completed emotional arousal and valence rating tasks in order to determine perception of up-ramp and down-ramp stimuli. Ratings of emotional arousal and loudness change were significantly higher for up-ramp stimuli, but ratings of valence did not differ between stimuli (Olsen & Stevens, 2013). Musical down-ramps elicited significantly greater EDA magnitudes than musical up-ramps, indicating that continuously decreasing musical intensity increases physiological arousal.

While EDA is one of the most common methods for studying musical emotions, many studies investigate EDA in conjunction with other measurements, such as heart rate and respiratory rate. Gomez and Danuser (2004) were interested in the differences in physiological reactions to noises and musical fragments. EDA, respiration, and heart rate were measured while participants listened to 16 noises and 16 musical excerpts derived from the canon of Western music. Participants were also asked to make judgments of valence and arousal using the pencil and paper version of the Self-Assessment Manikin (SAM).

Researchers found that negative noises were rated as more arousing than positive noises, and that high-arousal noises were associated with increased heart rate and faster breathing (Gomez & Danuser, 2004). High-arousal music was associated with increased thoracic breathing and increased EDA, but heart rate did not significantly differ: this is consistent with the literature, which states that EDA is more sensitive to arousal and heart rate is more sensitive to valence (Steinbeis, Koelsch, & Sloboda, 2006).

Although heart rate tends to be more sensitive to valence, both EDA and heart rate are generally higher for negative than for positive emotion (Dellacherie et al., 2011). Because the authors state that dissonant music is typically perceived as unpleasant by many people, and is thus indicative of negative valence, Dellacherie et al., (2011) designed a study to investigate perceived and subjective emotional responses to dissonant and consonant musical excerpts. Researchers hypothesized that there would be more negative valence judgments in response to dissonance and that musically-experienced participants would respond more strongly than musically-inexperienced participants. They further predicted greater electrodermal activity and larger heart rate deceleration in response to musical dissonance for all participants.

Dellacherie et al. (2011) discovered that listening to dissonance induced a more negative affect than listening to consonance. However, arousal ratings were the same for both consonant and dissonant excerpts, indicating that dissonance does not modulate arousal. Additionally, participants with greater musical experience judged dissonant excerpts as more negative than those with little musical experience, indicating that experience modulates judgments of valence.

Researchers found no significant difference in heart rate response between the two emotional conditions, but found increased orienting EDA in response to the dissonant excerpts. A more latent EDA response was also found in response to the dissonant excerpts, and this effect was enhanced in musically-experienced participants. These results indicate that musicians and non-musicians respond similarly to the initial unpleasantness of dissonance, but that musical experience enhances the ability to cognitively evaluate dissonance in terms of displeasure.

Present Study

Much of the current research in the field has investigated responses to musical segments, but few have separated those segments into individual components. Of those that have investigated discrete components, even fewer have used chord progressions as stimuli. The present study aimed to bridge that gap by developing and using chord progressions as auditory stimuli. Cadential chord progressions are found at the ends of musical phrases and were used in this study because they are simple to classify in terms of harmonic expectancy.

Many of the previously cited studies focused on objective emotion as opposed to subjective emotion, especially when a structural approach was taken. Because of this, the present study only considered subjective emotion in terms of its physiological manifestations (EDA and heart rate).

Hypotheses

Since electrodermal activity increases with arousal, and arousal is related to musical expectancy, it was hypothesized that electrodermal activity will be the highest for very unconventional chords, such as the chord built on a tritone. It was further hypothesized that heart rate will increase with increasing unconventionality of the progressions.

Method

Participants

Participants were 19 undergraduate students (4 male) aged 18 to 42 years with no previously diagnosed hearing problems. Eight participants reported some degree of experience in a musical ensemble, ten reported no experience, and one failed to respond. Eight participants also reported some degree of experience with private music lessons and eleven reported no experience. Participants were recruited from the Ball State University Psychological Science department subject pool, which allows introductory psychology students to complete experiments for partial course credit. Participants received one hour of research credit for their participation. Additional participants were recruited from the Ball State University School of Music, and they received ten points of class credit for their participation.

Materials

Materials consisted of a set of cadential chord progressions, a musical background survey, the PANAS mood questionnaire, and the iWorx 214 Psychophysiology Teaching Kit for physiological data acquisition.

Stimuli. Auditory stimuli consisted of six different musical chord progressions presented in piano timbre (see musical notation of progressions in Appendix). The progressions used in the present study were selected from an original set of 16 progressions assessed in a pilot study, and were chosen based on the strength of observed physiological responses. Each chord progression was presented a total of six times throughout the experimental session. Stimuli were generated using the music software GarageBand and were presented at a uniform tempo (100 MM) and level of loudness. Chord progressions were composed in C-major or C-minor and consisted of five chords each. Stimuli ranged on a continuum from very conventional (perfect authentic cadence) to very unconventional (#iv – i cadence) in order to elicit a range of psychophysiological responses. Conventional progressions sounded more consonant, and unconventional progressions featured more dissonant chords. Progressions included a perfect authentic cadence, a deceptive cadence, and a #IV – I cadence, each presented in both major and minor modes.

The musical stimuli were presented from iTunes playlists via Bose ® QuietComfort ® 3 Acoustic Noise Cancelling ® on-ear headphones. Order of the 6 chord progressions was block-randomized across 3 different playlists, and playlists were assigned to participants in a counterbalanced order.

Musical background survey. Participants were asked to complete a brief survey consisting of questions assessing demographic information, hearing impairments, prior music experience, frequency of music listening, and music listening preference.

PANAS mood questionnaire. The Positive and Negative Affect Schedule (PANAS) is a mood questionnaire designed to efficiently measure the two primary dimensions of mood: positive and negative affect (Watson, Clark, & Tellegen, 1988). The questionnaire consists of two 10-item mood scales that are internally consistent and have demonstrated convergent and discriminant validity. Each scale consists of a number of words that describe different feelings and emotions, and participants will be asked to rate to what extent they feel the given feeling and emotion at that moment on a 5-point Likert scale (1 = *very slightly or not at all* to 5 = *extremely*). The PANAS was included in this study because there is speculation that music cannot generate true emotions, but rather functions to modulate mood (Krumhansl, 2002). Rather than creating original emotions, there is a chance that music merely enhances whatever emotion is presently being experienced.

Physiological response measurements. Participants' heart rate and electrodermal activity (EDA) were recorded with the iWorx 214 Psychophysiology Teaching Kit (iWorx Systems, Inc.). The system is designed for simple data acquisition to be accomplished by undergraduate students in a classroom or laboratory setting and for simple experimental design. For heart rate acquisition, disposable electrodes were attached using hypoallergenic adhesive to the inside of each participant's wrist and to their lower right ankle. For acquisition of electrodermal activity, reusable electrodes were attached to participants' left index and middle fingers with velcro collars. The software used to collect and analyze the psychophysiological data was LabScribe2 (iWorx Systems, Inc.).

Procedure

Participants first read and signed the consent form then completed the musical background survey and PANAS questionnaire before preparing for data collection. Participants were then asked to wash their hands with soap and water before electrodermal data was collected, and their wrists and right ankle were lightly swabbed with alcohol before heart rate data was collected. Electrodermal activity and heart rate were acquired continuously throughout the duration of the experiment, which took place in a sound-shielded room. After the electrodes were attached, participants were instructed to place the headphones over their ears and sit as still as possible for the remainder of the experiment.

The experiment began with three minutes of silence to allow for habituation and acquire a baseline prior to presentation of the chord progressions. After the baseline was recorded, each chord progression was presented in a block-randomized order. Each progression was six seconds in duration and was followed by 30 seconds of silence to allow physiology to return to resting levels. Each chord progression was presented six times throughout the experiment. A resting period of two minutes followed the final progression to collect a post-experiment baseline.

Results

Statistical differences were assessed by 3 x 2 x 2 mixed repeated measures analyses of variance (ANOVAs) with expectancy (authentic/deceptive/tritone) and mode (major/minor) as within-participant factors, and participation in a musical ensemble (none/any) as a between-participant factor. Partial Eta squared values are reported as a measure of effect size. Statistical analyses revealed a main effect of ensemble participation on heart rate; participants with any experience in a musical ensemble (*M* = 1.90, *SD* = 0.65) exhibited significantly greater heart rate responses than participants with no experience in a musical ensemble (*M* = -0.90, *SD* = 0.58), $F(1, 16) = 10.464$, $p = .005$; $\eta_p^2 = 0.395$. ANOVAs also revealed an interaction between mode and ensemble for heart rate, $F(1, 16) = 4.792$, $p = .044$; $\eta_p^2 = .230$. Participants with ensemble experience exhibited significantly greater heart rate responses to minor progressions (*M* = 2.16, *SD* = 0.70) than to major progressions (*M* = 1.65, *SD* = 0.60), as seen in Figure 1.

To determine whether this significant main effect could also be observed for participants with experience in private lessons, an additional 3 x 2 x 2 mixed repeated measures ANOVA with expectancy (authentic/deceptive/tritone) and mode (major/minor) as within-participant factors, and participation in private music lessons (some/any) as a between-participant factor. No significant main effect of lesson participation was found for heart rate, $F(1, 17) = 2.970$, $p = .103$, $\eta_p^2 = .149$.

Additional differences were assessed by a 3 x 2 repeated measures ANOVA with expectancy (authentic/deceptive/tritone) and mode (major/minor) as within-participant factors. No significant main effects of expectancy, $F(2, 32) = .288$, $p = .751$; $\eta_p^2 = .018$, or mode, *F*(1,

16) = 1.742, $p = .205$; $\eta_p^2 = .098$ were found for heart rate. The ANOVA also revealed no significant interaction between expectancy and mode for heart rate, $F(2, 32) = .680$, $p = .514$; $\eta_p^2 = .041$.

Significant positive correlations were found between years of ensemble participation and heart rate in response to all chord progressions, $r(18) = .621$, $p < .01$, as seen in Figure 2. A positive correlation was found for ensemble and heart rate response to authentic progressions, $r(18) = .561$, $p < .05$. Another positive correlation was found for ensemble and heart rate response to authentic minor progressions, $r(18) = .532$, $p < .05$. A strong positive correlation was found for ensemble and heart rate response to deceptive progressions, $r(18) = .610$, $p < .01$. An additional strong positive correlation was found for ensemble and heart rate response to deceptive minor progressions, $r(18) = .718$, $p < .01$. A positive correlation was found for ensemble and heart rate response to tritone progressions, $r(18) = .488$, $p < .05$. An additional positive correlation was found for ensemble and heart rate response to tritone minor progressions, $r(18) = .589$, $p < .05$. These correlations indicate that heart rate responses to all chord progressions increased with years of participation in a musical ensemble.

Because EDA steadily habituated throughout the duration of the experiment and did not change in response to the stimuli, it was concluded that the stimuli used in the present study were not salient enough to evoke a response capable of being measured by the available equipment. Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(2, N = 19) = 19.997$, $p = .000$. As a result, the EDA data acquired was considered unreliable, and was not considered in statistical analyses.

Discussion

The purpose of this experiment was to determine whether isolated cadential chord progressions are capable of eliciting universal physiological responses from participants. It was hypothesized that electrodermal activity and heart rate responses would increase with increasing unconventionality of the chord progressions.

The present study found that participants who had participated in a musical ensemble to any degree exhibited increased heart rate responses to the chord progressions. This mirrors the effects seen in the study by Dellacherie et al. (2011) where researchers observed enhanced physiological responses for individuals with musical experience. While that study only reported greater responses for dissonant music, the present study saw greater responses for all progressions in general. Because individuals are normally only exposed to isolated chord progressions through musical training, it makes sense that participants with experience in a musical ensemble would exhibit increased heart rate responses when compared with participants without ensemble experience.

The present study also found significant correlations between years of musical ensemble experience and heart rate responses to all chord progressions. This is interesting because it suggests that the more experience one has had in a musical ensemble, the greater their heart rate response will be to isolated cadential chord progressions.

Participants with musical ensemble experience exhibited significantly greater heart rate responses for minor progressions than for major progressions. As discussed in the study by Lindström (2003), minor mode progressions are typically judged as representing sadness or anger, which are negative emotions. Dellacherie et al. (2011) reported that heart rate is generally higher for negative emotions, which could explain this trend for participants with ensemble experience.

It is interesting to note that these effects were only observed for participants with experience in a musical ensemble, and not for musicians in general, as demonstrated by the nonsignificant main effect for participants with experience in private music lessons. This could indicate that the active listening required by participation in an ensemble influences responses to minute elements of music, such as chord progressions, later on in life.

Limitations

A potential limitation of the present study was the quality of the equipment used to acquire physiological data. The iWorx 214 Psychophysiology Teaching Kit (iWorx Systems, Inc.) is designed to be used primarily as a tool to teach students the basics of physiological data acquisition, and as such is not as sensitive as equipment used in other studies in the field. It is possible that this lack of sensitivity contributed to the poor EDA data acquired in the present study. Future studies should attempt to replicate this procedure with more sophisticated equipment in order to assess EDA responses to isolated cadential chord progressions.

Conclusions

The present study concludes that any amount of experience in a musical ensemble modulates heart rate responses to isolated chord progressions, with the greatest responses for minor progressions. Because there were no discernable trends in heart rate responses for participants with no ensemble experience, it is further concluded that isolated chord progressions are not sufficient to yield similar physiological responses across all participants.

References

Bigand, E., Parncutt, R., & Lerdahl, F. (1996). Perception of musical tension in short chord sequences: The influence of harmonic function, sensory dissonance, horizontal motion, and musical training. *Perception and Psychophysics, 58*(1), 125-141.

Chanda, M. L., & Levitin, D. J. (2013). The neurochemistry of music. *Trends in Cognitive Science, 17*(4), 179-193.

Dellacherie, D., Roy, M., Hugueville, L., Peretz, I., & Samson, S. (2011). The effect of musical experience on emotional self-reports and psychophysiological responses to dissonance. *Psychophysiology, 48,* 337-349.

Gomez, P., & Danuser, B. (2004). Affective and physiological responses to environmental noises and music. *International Journal of Psychophysiology, 53,* 91-103.

Gomez, P., & Danuser, B. (2007). Relationships between musical structure and psychophysiological measures of emotion. *Emotion, 7*(2), 377-387.

Khalfa, S., Peretz, I., Blondin, J., & Manon, R. (2002). Event-related skin conductance responses to musical emotions in humans. *Neuroscience Letters, 328,* 145-149.

Krumhansl, C. L. (2002). Music: A link between cognition and emotion. *Current Directions in Psychological Science, 11*(2), 45-50.

Lindström, E. (2003). The contribution of immanent and performed accents to emotional expression in short tone sequences. *Journal of New Music Research, 32*(3), 269-280.

Marmel, F., Parbery-Clark, A., Skoe, E., Nicol, T., & Kraus, N. (2011). Harmonic relationships influence auditory brainstem encoding of chords. *Neuroreport, 22*(10), 504-508.

Mikutta, C., Altorfer, A., Strik, W., & Koenig, T. (2012). Emotions, arousal, and frontal alpha rhythm asymmetry during Beethoven's 5th Symphony. *Brain Topography, 25,* 423-430.

Miu, A. C., & Balteş, F. R. (2012). Empathy manipulation impacts music-induced emotions: A psychophysiological study on opera. *PLoS ONE 7*(1): e30618. doi:10.1371/journal.pone.0030618

Olsen, K. N., & Stevens, C. J. (2013). Psychophysiological response to acoustic intensity change in a musical chord. *Journal of Psychophysiology, 27*(1), 16-26.

Sammler, D., Grigutsch, M., Fritz, T., & Koelsch, S. (2007). Music and emotion: Electrophysiological correlates of the processing of pleasant and unpleasant music. *Psychophysiology, 44,* 293-304.

Schellenberg, E. G., Krysciak, A. M., & Campbell, R. J. (2000). Perceiving emotion in melody: Interactive effects of pitch and rhythm. *Music Perception: An Interdisciplinary Journal, 18*(2), 155-171.

Scherer, K. R., & Oshinsky, J. S. (1977). Cue utilization in emotional attribution from auditory stimuli. *Motivation and Emotion, 1,* 331-346.

Sloboda, J. A. (1991). Music structure and emotional response: Some empirical findings. *Psychology of Music, 19,* 110-120.

Steinbeis, N., Koelsch, S., & Sloboda, J. A. (2006). The role of harmonic expectancy violations in musical emotions: Evidence from subjective, physiological, and neural responses. *Journal of Cognitive Neuroscience, 18*(8), 1380-1393.

Vieillard, S., Peretz, I., Gosselin, N., Khalfa, S., Gagnon, L., & Bouchard, B. (2008). Happy, sad, scary and peaceful musical excerpts for research on emotions. *Cognition and Emotion, 22*(4), 720-752.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070.

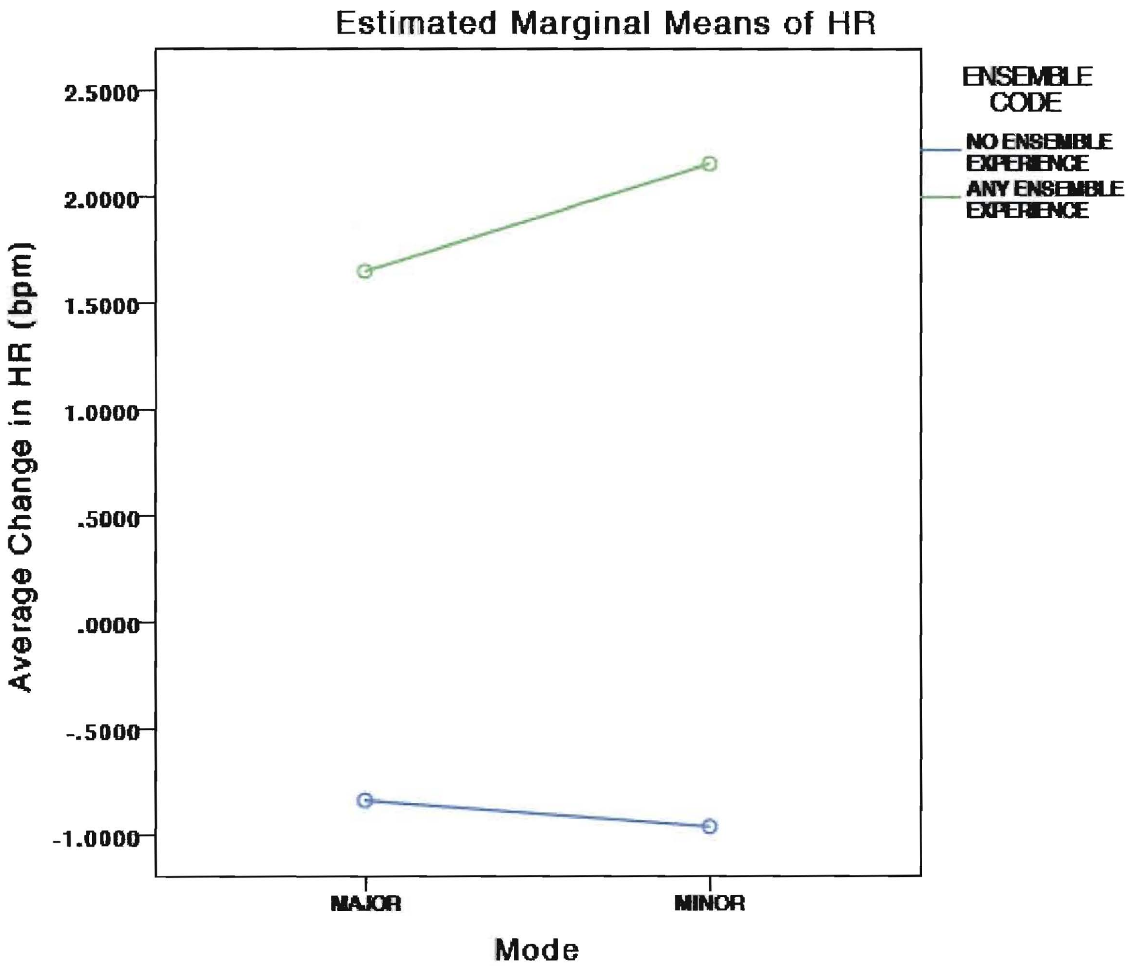


Figure 1. Comparison of heart rate responses for participants with experience in a musical ensemble versus participants without experience in a musical ensemble

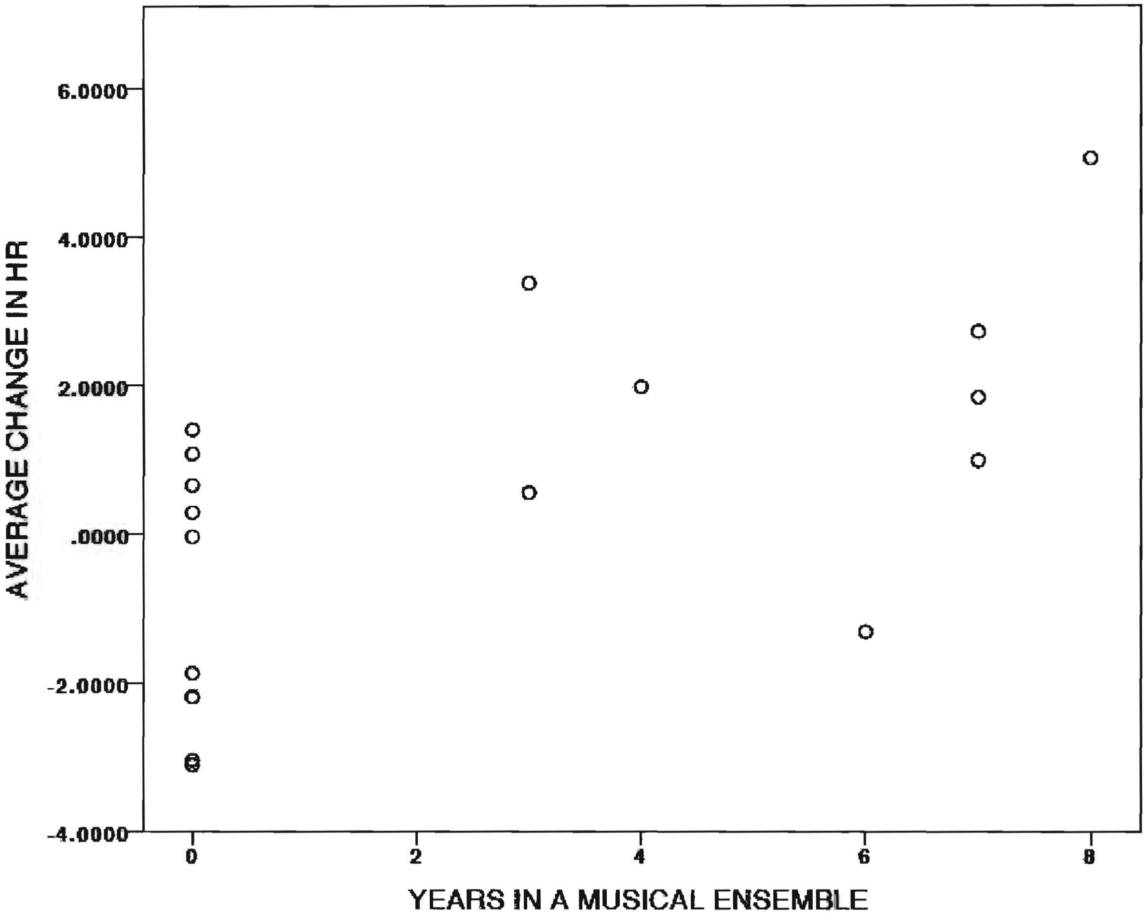
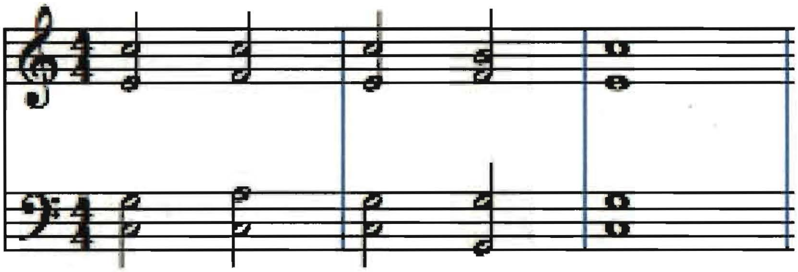


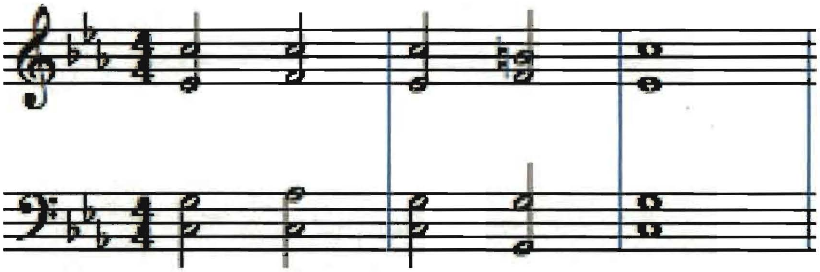
Figure 2. Correlation between years of experience in a musical ensemble and average change in heart rate in response to all chord progressions

Appendix

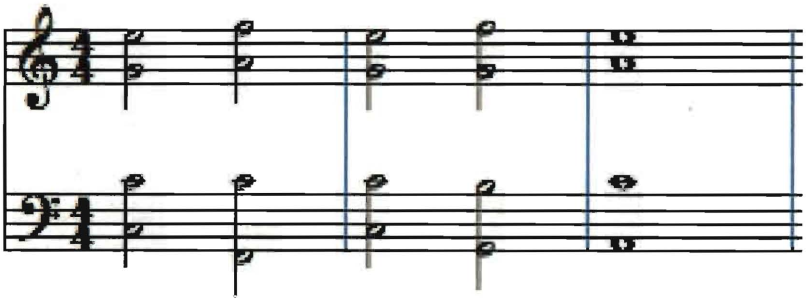
Musical Notation of Chord Progressions



Perfect Authentic Cadence

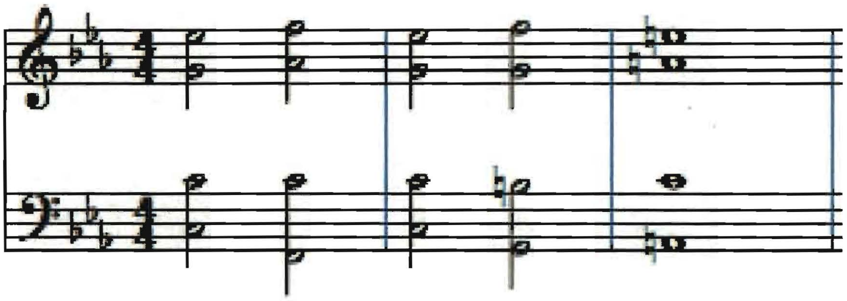


Perfect Authentic Minor Cadence

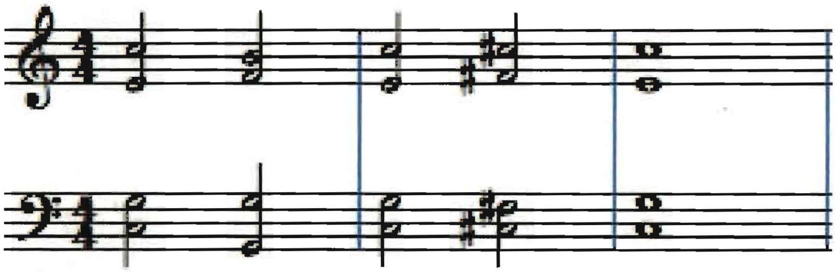


Deceptive Cadence

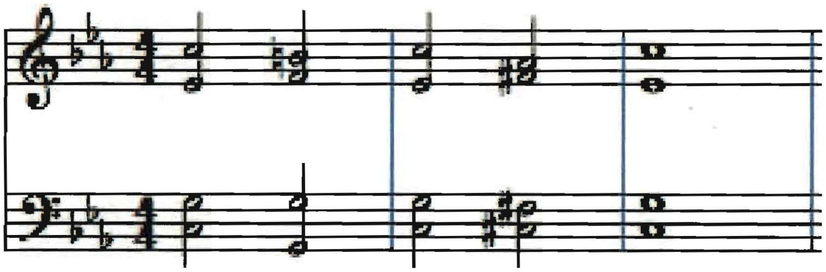
Appendix (continued)



Deceptive Minor Cadence



#IV – I Cadence



#iv – i Cadence

BALL STATE
UNIVERSITY

Office of Research Integrity
Institutional Review Board (IRB)
2000 University Avenue
Muncie, IN 47306-0155
Phone: 765-285-5070

DATE: December 17, 2013

TO: Heather Daly

FROM: Ball State University IRB

RE: IRB protocol # 547956-1
TITLE: Psychophysiological responses to isolated musical chord progressions
SUBMISSION TYPE: New Project

ACTION: APPROVED
DECISION DATE: December 17, 2013
EXPIRATION DATE: December 16, 2014
REVIEW TYPE: **Expedited:** This protocol had been determined by the board to meet the definition of minimal risk.

The Institutional Review Board has approved your New Project for the above protocol, effective December 17, 2013 through December 16, 2014. All research under this protocol must be conducted in accordance with the approved submission and in accordance with the principles of the Belmont Report.

Review Type:

	Category 1: Clinical studies of drugs and medical devices
	Category 2: Collection of blood samples by Finger stick, Heel stick, Ear stick, or Venipuncture
	Category 3: Prospective collection of biological specimens for research purposes by noninvasive means
	Category 4: Collection of data through Non-Invasive Procedures Routinely Employed in Clinical Practice, excluding procedures involving Material (Data, Documents, Records, or Specimens) that have been collected, or will be collected solely for non-research purposes (such as medical treatment or diagnosis)
	Category 5: Research involving materials that have been collected or will be collected solely for non-research purposes.
	Category 6: Collection of Data from Voice, Video, Digital, or Image Recordings Made for Research Purposes

x	**Category 7:** Research on Individual or Group Characteristics or Behavior or Research Employing Survey, Interview Oral History, Focus Group, Program Evaluation, Human Factors, Evaluation, or Quality Assurance Methodologies
	Category 8: Continuing review of research previously approved by the convened IRB
	Category 9: Continuing review of research, not conducted under an investigational new drug application or investigational device exemption where categories 2-8 do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and not additional risks have been identified.

Editorial Notes:

1. Approved.

As a reminder, it is the responsibility of the P.I. and/or faculty sponsor to inform the IRB in a timely manner:

- when the project is completed,
- if the project is to be continued beyond the approved end date,
- if the project is to be modified,
- if the project encounters problems, or
- if the project is discontinued.

Any of the above notifications must be addressed in writing and submitted electronically to the IRB (http://www.bsu.edu/irb). Please reference the IRB protocol number given above in any communication to the IRB regarding this project. Be sure to allow sufficient time for review and approval of requests for modification or continuation. If you have questions, please contact Sarah Ryle at (765) 285-5052 or sgryle@bsu.edu.

In the case of an adverse event and/or unanticipated problem, you will need to submit written documentation of the event to IRBNet under this protocol number and you will need to directly notify the Office of Research Integrity (http://www.bsu.edu/irb) **within 5 business days**. If you have questions, please contact (ORI Staff).

Please note that all research records must be retained for a minimum of three years after the completion of the project or as required under Federal and/or State regulations (ex. HIPAA, FERPA, etc.). Additional requirements may apply.

Christopher M. Mangelli

Bryan Byers, PhD/Chair
Institutional Review Board

Christopher Mangelli, JD, MS, MEd, CIP/Director
Office of Research Integrity