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TESTING THE AROUSAL HYPOTHESIS: THE EFFECT OF MUSIC ON AROUSAL AS MEASURED BY ELECTRODERMAL ACTIVITY DURING VERBAL PROCESSING

by

Meghan E. Feeman

A thesis submitted to the Graduate College in partial fulfillment of the requirements for the degree of Master of Music School of Music Western Michigan University December 2017

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TESTING THE AROUSAL HYPOTHESIS: THE EFFECT OF MUSIC ON AROUSAL AS MEASURED BY ELECTRODERMAL ACTIVITY DURING VERBAL PROCESSING

Meghan E. Feeman, M.M.

Western Michigan University, 2017

The purpose of this thesis project is to assess the arousal hypothesis by implementing an auditory stimulus (music) at various times during a task (Verbal Processing section of the GRE) to analyze changes in arousal, as measured by electrodermal activity (EDA). Testing is administered for one hour with music implemented before testing and twice during testing. EDA levels are used to measure physiological response and are collected over the one hour testing period. For analysis, testing material is broken into different time blocks to assess arousal levels through mean slope, mean skin conductance level (SCL), mean skin conductance response ($\overline{x}SCR$), and mean number of peak SCR (nSCR). Results indicate that the beginning of testing display significantly greater means for all EDA measures compared to the end of testing, suggesting a decay effect in arousal during testing. On average, periods of music exposure result in significantly higher SCR means compared to testing periods that occur without music. These results support the arousal hypothesis and have the potential to steer future research in music and cognition and cognitive performance.

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Meghan E. Feeman

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TABLE OF CONTENTS

ACKNOWLEDG	IENTS ii
LIST OF TABLES	vii
LIST OF FIGURE	S viii
CHAPTER	1
I. INTRODU	CTION
Stat	ement of problem1
Rat	onale for research and purpose
Sun	1 mary
II. LITERAT	JRE REVIEW
Arc	usal Hypothesis5
	Arousal Hypothesis and its History5
	Physiological Consideration of the Arousal Hypothesis8
Elec	trodermal Activity9
	Definition, History and Application of Electrodermal Activity9
	The Impact of Music on Electrodermal Activity12
Mu	sic and Arousal14
	The Impact of Music on the Brain14
	The Implementation of Music16
Cur	rent Research Regarding Music and Test Performance19
Sun	1 mary

Table of Contents – Continued

CHAPTER

	Research Questions	23
III.	METHOD	24
	Participants	24
	Design	25
	Apparatus	25
	Music Stimulus	26
	Testing Material	27
	Procedure	28
	Analysis of the Data	30
IV.	RESULTS	35
	Mean Slope	36
	Block Comparisons	36
	Music and Non-Music Block Comparisons	37
	Music Block Comparisons	38
	Block Comparisons Without Music	39
	Mean Slope	40
	Mean Skin Conductance Level (SCL)	41
	Block Comparisons	41
	Music and Non-Music Block Comparisons	43
	Music Block Comparisons	44

Table of Contents - Continued

CHAPTER

Block Comparisons Without Music	45
Mean Skin Conductance Level (SCL)	46
Mean Skin Conductance Response (\overline{x} SCR)	47
Block Comparisons	47
Music and Non-Music Block Comparisons	48
Music Block Comparisons	50
Block Comparisons Without Music	51
Mean Skin Conductance Response (\overline{x} SCR)	52
Mean Number of Peak Skin Conductance Responses (nSCR)	53
Block Comparisons	53
Music and Non-Music Block Comparisons	55
Music Block Comparisons	57
Block Comparisons Without Music	58
Mean Number of Peak Skin Conductance Responses (nSCR)	60
V. DISCUSSION	61
Results of Outcome Measures	61
Mean Slope	62
Mean Skin Conductance Level (SCL)	62
Mean Skin Conductance Response (\overline{x} SCR)	63
Mean Number of Peak Skin Conductance Responses (nSCR).	65

Table of Contents - Continued

CHAPTER

	Summary of Results	66
	Limitations	68
	Musical Choices	70
	Suggestions for Future Research	70
APPEND	ICES	75
А.	Recruitment Flyer	75
B.	Consent Form	76
C.	Music Preference Form	80
D.	Participant Song Choices	81
Е.	HSIRB Approval Letter	82
BIBLIOG	RAPHY	83

LIST OF TABLES

1.	Mean Skin Conductance Level (SCL) -Paired Sample t-test- Block	
	Comparisons with Music4	2

LIST OF FIGURES

1.	Hebb's U-Shape Arousal Hypothesis	6
2.	EDA Signal and Trigger System	26
3.	Flow of Procedure	29
4.	Example of SCR Peak	32
5.	First Analysis Blocks	33
6.	Second Analysis Blocks	33
7.	Mean Slope for Blocks	36
8.	Mean Slope for Music and Non-Music Blocks	37
9.	Mean Slope for Music Blocks	38
10.	Mean Slope for Blocks Without Music	39
11.	Mean SCL for Blocks	41
12.	Mean SCL for Music and Non-Music Blocks	43
13.	Mean SCL for Music Blocks	44
14.	Mean SCL for Blocks Without Music	45
15.	Mean SCR (\overline{x} SCR) for Blocks	47
16.	Mean SCR (\overline{x} SCR) for Music and Non-Music Blocks	49
17.	Mean SCR (\overline{x} SCR) for Music Blocks	50
18.	Mean SCR (\overline{x} SCR) for Blocks Without Music	51
19.	Mean Number of Peak SCRs (nSCR) for Blocks	54

List of Figures – Continued

20. Mean Number of Peak SCRs (nSCR) for Music and Non-Music Blocks	
21. Mean Number of Peak SCRs (nSCR) for Music Blocks	57
22. Mean Number of Peak SCRs (nSCR) for Blocks Without Music	59

CHAPTER I

INTRODUCTION

Statement of the Problem

Society has been fascinated with the effect of music on cognitive performance since the publication of Rauscher, Shaw, & Ky's research in 1993. This study tested spatial reasoning tasks by using three separate conditions: silence, relaxation music and a Mozart sonata. Results showed that participants performed significantly better during the Mozart condition compared to the other two trials. Though Rauscher, Shaw, & Ky's (1993) study only reported an improved performance on spatial reasoning tasks, the results were misconstrued to state that listening to Mozart can increase IQ levels, which coined the phrase "The Mozart Effect."

Soon after the publication of this study, media articles were published stating that 'Mozart makes you smarter' (Rose, 1994) and that listening to Mozart as an infant could increase mental development (Campbell, 1997). This idea intensified in 1998, when the governor of Georgia, Zell Miller, proposed to provide every child born in Georgia with a CD of classical music (Sack, 1998). There are still books, CDs and websites that sell *Mozart Effect* products today ("Mozart Effect," 2017).

The veracity of the *Mozart Effect* has been questioned due to the difficulty in replicating the results of Rauscher, Shaw, & Ky (1993). In a recent meta-analysis, researchers found sixteen articles that tried to replicate the study, but all showed varying results (Pietschnig, Voracek, and Formann, 2010). Though the *Mozart Effect* has proven difficult to replicate, interest in the impact of music on cognitive performance endured.

Numerous research articles have been published investigating a variety of conditions that may impact cognitive performance, such as correlation of music to personality type (Doyle, & Furnham, 2012), the effect of music on musicians compared to non-musicians (Patston, & Tippett, 2010), or analyzing Mozart versus other composers (Thompson, Schellenberg, & Husain, 2012, Verrusio, et al., 2015), but all have shown mixed results.

An alternative theory was developed, arousal-and-mood-hypothesis, as Schellenberg states, "Listening to Mozart is one example of a stimulus that influences the perceiver's arousal level and mood, which can affect performance on a variety of cognitive tasks" (p. 318). This arousal hypothesis suggests that the composer (or even the genre of music) may not be critical, as any stimulus that can elevate arousal will suffice. A recent study examined this concept by analyzing the impact of Mozart, rhythm, traffic sounds and silence during cognitive testing. Roth & Smith (2008) found that all auditory stimuli increased participants' test results, but one stimulus did not show a greater impact compared to the other. Roth & Smith (2008) stated that it may not have been Mozart that improved test performance but rather that adding a stimulus to a person's environment may increase arousal levels and positively impact test performance. Arousal levels were not assessed during this study, but Roth & Smith did recommend further research to assess the arousal hypothesis more directly. The arousal hypothesis considers how physiological changes in the body may affect task performance. It theorizes the idea that if arousal levels are higher, then a person may perform better on a task compared to low levels of arousal.

There is research that supports music altering arousal states (Blood & Zatorre, 2001; Craig, 2005; Guhn, Hamm, & Zentner, 2007; Rickard, 2004; Salimpoor, et al, 2009, 2011; & Zimny & Weidenfeller, 1963) but these often do not assess cognitive performance during testing. Further research must be conducted to assess whether enhanced cognitive performance associated with music exposure is mediated by elevated arousal. Such research should analyze the extent to which music may alter physiological states, decay effects in performance ability, and investigate the impact of the implementation of music during various times to assess cognitive performance.

Rationale for Research and Purpose

The current body of literature focuses either on whether music may affect cognitive performance or whether music impacts arousal, but not both. Articles that analyze music and arousal levels focus primarily on physiological response and not performance ability on tests; however, articles that analyze whether music can enhance test performance often lack analysis of arousal levels. Further research should be conducted to determine if music can impact testing performance through the *arousal hypothesis*. Due to discrepancies in research, it is unknown if it is possible for music to truly improve test performance.

The purpose of this study is to test the relationship between arousal stimulated by participant-preferred music as measured by electrodermal activity (EDA) and its impact on Verbal Processing in the GRE. This study was divided into two master's thesis projects, with one focusing on test performance and the other on arousal. For this thesis project, the analysis will focus on arousal as measured by electrodermal activity (EDA). EDA measures the variations in skin resistance through sweat glands in the skin and is seen as one of the most accessible and successful physiological measures to assess arousal (Boucsein, 2012).

This study has the potential to provide more information on the effect of music on arousal through EDA testing, and whether increases in arousal levels could impact test performance. *Summary*

Since the publication of Rauscher, Shaw, & Ky (1993), there has been a fascination with the benefit of music on cognitive performance. After difficulty replicating the study, further thought has led to the *arousal hypothesis*, but the literature for music and cognitive performance is varied in its methodologies and results. There is research indicating that music alters arousal levels, but it seldom assesses test performance. There is also literature on music and cognitive performance, but arousal levels were not assessed. Research has shown that music can impact physiological response, but it is unknown if it can support test performance by countering decaying attention spans. Through this project, arousal levels were assessed by implementing music during specified times to analyze if music can counterbalance decaying levels of arousal. This study has the potential to provide more information on the extent to which music can alter arousal levels and impact cognitive performance.

CHAPTER II

LITERATURE REVIEW

Arousal Hypothesis

Arousal Hypothesis and its History

The arousal hypothesis theorizes that physiological changes in the body may affect task performance; if arousal levels are higher, a person may perform better on a task compared to low levels of arousal (Yerkes & Dodson, 1908). For years, this concept has been a topic of interest for researchers. The idea that a human's wakefulness or attentiveness could impact performance in motor response, emotional response or cognition left many wondering what purpose physiological arousal could serve (Pfaff, 2006). From this idea, many theories have been developed, analysis of physiological aspects has been examined, and recent research has tested the arousal hypothesis.

One of the first studies to analyze the arousal hypothesis was Yerkes and Dodson in 1908. The behavioral therapists analyzed a mouse's ability to perform a task by providing electrical shocks depending on the number of errors made and the difficulty of the task. The researchers found that the level of stimulation heavily depended on the difficulty of the task. If the mouse found the task to be too easy, the researchers needed to provide more shocks to maintain the mouse's interest. If the task was difficult, the researchers found that shocks needed to be provided at an intermediate level. Finally, if the task was moderately challenging the researchers provided little shock reinforcement. Yerkes and Dodson theorized that this concept could translate to humans as well. If an individual partakes in a tedious or uninteresting task, then arousal levels decrease and require more stimulation; however, if they partake in a difficult task, individuals may become frustrated and lose interest in the task, increasing arousal levels to non-optimal levels. If the task is moderately stimulating, arousal levels maintain with little reinforcement required (Yerkes & Dodson, 1908). This became known as the Yerkes & Dodson Law.

The arousal hypothesis wasn't considered again until the late 1940s to early 1950s, when two researchers, Moruzzi and Magoun, analyzed how arousal levels impacted the brain. Using EEG testing, they found strong activation in the brainstem when participants were aroused by natural stimuli (Moruzzi & Magoun, 1949). More recent research has found that the brainstem, thalamus, and cerebral cortex also play a large part in arousal (Petersen & Posner, 2012). This research showed that arousal levels could be measured both behaviorally, as seen in Yerkes & Dodson (1908), and through brain activation as well.

Later in the 1950s, Hebb (1955) developed the hypothesis that arousal works in an inverted U-shape, see Figure 1 (p. 249).



Figure 1. Hebb's U-Shape Arousal Hypothesis

Within this diagram, the lowest levels of arousal occur during sleeping, then arousal levels increase causing a rise in attentiveness or interest, followed by optimal levels of arousal which relate to optimal levels of learning. Hebb believed that learning was most effective when a person achieved optimal levels of arousal, but he also believed that arousal beyond optimal levels could create a disturbance or provide too much stimulation. Hebb was one of the first to analyze over-stimulating materials and introduced the idea of "optimal arousal levels" (Hebb, 1995; Zuckerman, 2014).

It is believed that at optimal levels of arousal, our mental state can perform at its best (Berlyne, 1971). This is due to "synchronization of biological subsystems," which means the brain's physiological, arousal, motor motivational process, monitoring process and cognition are all synchronized together (Juslin & Västfjäll, 2008). Optimal levels of arousal are difficult to achieve and maintain due to the fact that multiple subsystems are activated. This research would help shape the arousal hypothesis and steer future research.

Soon after the Hebb (1954), Shannon (1958) found that if an individual participated in a task that lacked change, arousal levels decreased, and the individual became less alert. Other sources agreed and added that uncertainty, unpredictability, and high-information tasks promote arousal, but boring and static tasks do not (Pfaff, 2006). Little arousal research was performed in the 1960s, but interest grew in the 1970s when researchers started to test how arousal levels impacted memory and emotions.

Bacon (1974) found that emotions play a significant role in all levels (low, moderate, high) of arousal and that the combination of emotions and arousal levels could improve long-term memory. This work and others has helped the understanding of how memories are

stored. For example, La Bar (2006) found that when considering arousal levels with emotion, the amygdala, frontal and temporal lobes are activated in the brain. These results display similarities to optimal levels of arousal by activating multiple subsystems in the brain.

Soon after Bacon's (1974) study, another article was published that supported Hebb's research in 1954. The research found that human attention levels are greatest in the morning and decrease as the day continues (Posner, 1975). This not only supports Hebb's inverted U-shape theory but Yerkes and Dodson Law as well, showing that arousal levels naturally will decrease unless provided a stimulus to increase arousal. Research on the arousal hypothesis has a long history with researchers analyzing various ways that arousal levels impacts the human body; one of the ways that researchers measure arousal is through physiological response.

Physiological Consideration of the Arousal Hypothesis

Recent research has a strong emphasis on analyzing how heightened physiological arousal activation can be expressed in the human body. Common ways to analyze physiological change include "the autonomic nervous system (heart rate and blood pressure), neuroendocrine system (hormones), the central nervous system (muscles and brain waves), sensory perception channels, and brain regions (attention, executive functioning, and motor control)" (Thaut, 2005, p. 20-21, cited in Berlyne, 1971). With greater insight into the effects of arousal on the human body, researchers have learned that arousal is stimulated in neurotransmitters through the brainstem. The five main neurotransmitters associated with arousal are norepinephrine, acetylcholine, dopamine, serotonin and histamine. When these neurotransmitters are activated, they travel through the brainstem to the corresponding cortex

in the brain. Though each neurotransmitter activates different areas of the brain, they each play a vital role in inducing arousal levels. Norepinephrine, acetylcholine, and histamine all help with wakefulness, vigilance, and arousal; dopamine and serotonin are correlated to mood, arousal, and motor systems (Pfaff, 2006).

Arousal levels are activated in the brain, but they can be assessed physiologically as well. Most research studies that analyze arousal levels today examine heart rate, skin temperature, skin response through electrodermal activity (EDA), and respiration rate (Blood & Zatorre, 2001; Craig, 2005; Guhn, Hamm, & Zentner, 2007; Rickard, 2004; Howells, et al, 2010; Salimpoor, et al, 2009, 2011; & Zimny & Weidenfeller, 1963). By analyzing physiological responses, researchers can infer levels of arousal in participants. When assessing arousal, it is important to measure physiological states through either heart rate, skin temperature, electrodermal activity (EDA) or respiration rate, otherwise it is unclear if a stimulus truly impacted arousal levels (Eysenck, 2012). For this thesis project, electrodermal activity (EDA) was assessed.

Electrodermal Activity

Definition, History and Application of Electrodermal Activity

Electrodermal activity (EDA) is an umbrella term used for the measurement of autonomic changes in the electrical response of the skin (Braithwaite, et al., 2013). It is one of the most used physiological measures to assess arousal due to its accessibility and ease of measurement during a wide range of emotive and cognitive states (Braithwaite, et al., 2013). EDA measures the variations in skin resistance through activity of the sweat glands (Boucsein, 2012). "This occurs when neurons from the sympathetic axis of the autonomic nervous system innervate sweat glands and the activity modulates to a current" (Critchley, 2002, p. 132). If the sympathetic nervous system (SNS) is highly aroused, then the sweat glands will increase (Boucsein, 2002), providing researchers a strong physiological test to assess arousal.

Electrodermal Activity (EDA) was first attempted by DuBois-Reymond in Germany in 1849. The experiment aimed to see if an electric current would travel from one contracted limb to the other when subjects' hands or feet were placed in zinc sulfate solution. This study is often not recognized by other articles, as DuBois-Reymond credited the results to muscle action potentials instead of skin electrical response (Neumann & Blanton, 1970). It wasn't until 1878 that researchers Hermann and Luchsinger were able to make the connection between sweat gland activity and current flow in the skin. These two research studies led Herman to analyze voluntary movement three years later and find that certain areas of the skin have stronger sweat glands (palms and fingers) and display greater skin current sites than the previously used wrist and elbow. These findings solidified the importance of human sweat glands in electrodermal activity (Neumann & Blanton, 1970).

The two pioneers for discovery in EDA were a French neurologist Fere and a Russian physiologist Tarchanoff, both of whom discovered the two methods for EDA. Fere supported the exosomatic response, which requires the use of an external current on the skin. Tarchanoff supported the endosomatic method, which records skin response without an external current (Dawson, et al. 2007). Though Fere believed incorrectly that skin response was due to a decrease in blood flow, his analysis of skin response has shaped EDA methodology, and he was first to discover that external stimuli could impact skin response. Tarchanoff was one of the first to believe that EDA was a result of sweat gland activity (not blood as Fere believed) dependent on the response of nerves. This knowledge shaped EDA methodology, as he was the first to measure changes in electrical current by applying two electrodes on the skin without an external current (Boucsein, 2012; Dawson, et al., 2007).

Since these findings, EDA methodology and technologies have greatly expanded. Growth in computer technology has made EDA more accessible and more accurate in collecting signals and triggers. Currently, EDA methodology is considered to be well established with a number of handbooks to support consistent application (Boucsein, 2012). As a result of this growth, EDA is one of the most widely used systems in psychophysiology (Dawson, Schell, & Filion, 2007). EDA analysis not only occurs in psychophysiological research, but engineering psychophysiology, neurology, psychopathology and behavioral sciences as well (Boucsien, 2012).

With further development in technology, researchers have also moved to analyzing how electrical properties in the brain relate to arousal skin response. The hypothalamus and brainstem are active during increases in arousal. These regions of the brain are regulated and modulated based on bodily arousal, which is manipulated by behavioral changes in their environment. When this occurs, a signal is passed through the brain stem and activates EDA response. This can be analyzed through discrete peaks in EDA response (Critchley, 2002). There are other regions of the brain that are associated with arousal and EDA such as the ventromedial prefrontal cortex and amygdala which control motivation, reinforcement and fear conditioning. The anterior cingulate cortex controls behavior, emotion and risk, while the right parietal cortex controls arousal and attention (Critchley, 2002). When considering the use of EDA, it is important to decide which method will be used, as both endosomatic and exosomatic methods are still used today. Endosomatic is the more unobtrusive method, but the results are more complicated (Boucsein, 2012). Exosomatic is the most commonly used and was the method selected for this thesis project. Exosomatic requires that two electrodes be placed on the palmar surface of the skin to access the best reading of the sweat glands due to the hairless surface of the skin. The electrodes are attached to the skin using a wet gel, which allows electrolytes to contact the skin. Each electrode contains a connection point where voltage is applied (Boucsein, 2012). A common source for calculating the appropriate voltage is the *Publication Recommendations for Electrodermal Measurements* (Boucsein, et al., 2012; Fowles, et al., 1981).

The EDA signal presents as a wave of negative and positive response. Skin conductance level (SCL) represents the tonic level of the skin response, which displays general changes in arousal. Skin conductance response (SCR) represents the phasic changes of the skin response, which reflect peaks in the signal (Braithwaite, et al., 2013). The wave will show variations and will increase when arousal or activation occurs. This will be represented by SCR increasing and presenting peaks in a graph. Typically with EDA testing, peak phases occur for a few seconds and then recover (Prokasy, 2012).

The Impact of Music on Electrodermal Activity

As discussed previously, arousal levels can be impacted by external stimuli and measured by EDA; music was the external stimuli chosen for this thesis project. Current research suggests that EDA is an appropriate measurement to use when assessing music's impact on arousal levels due to its accessibility (Braithwaite, et al., 2013), sensitivity and

ability to elicit the sympathetic nervous system (Sequeira, et al., 2009). Numerous research articles analyzing music's impact on physiological response has shown that EDA displays strong SCRs (peak levels in EDA response) when music is implemented (Craig, 2005; Guhn, Hamm, & Zenter, 2007; Grewe, et al, 2007; Rickard, 2004; Salimpoor, et al., 2009; & Zimny & Weidenfeller, 1963). Research has also shown that EDA may be more sensitive in analyzing arousal response compared to other measures; Guhn, Hamm, & Zenter, (2007) found that when music was implemented, EDA levels increased, but heart rate had mixed results.

The majority of research regarding music and physiological response heavily focuses on music's ability to induce an emotion. In the initial stages of research into music and emotional response, researchers would survey subjects to rate their emotion levels for analysis. There arose questions as to whether subjects could accurately measure emotional response, which led to the use of physiological measures for emotion analysis. Research has found that auditory stimuli have a positive effect of EDA response (Bradley & Lang, 2000) and emotional music has a greater response on EDA than non-emotional music (Krumhansi, 1997).

When EDA became a common analysis method for music and emotion, most articles analyzed SCLs (tonic EDA levels). Analysis changed from SCLs to SCRs when researchers grew interested in peak emotional responses during music (Howells, et al., 2010). Some studies have found that certain emotions, such as fear and happiness, display a stronger response in EDA levels than other emotions (Khalfa, et al., 2002). Research has also shown that familiar music had a significantly larger number of peak responses in EDA levels compared to unfamiliar music (Bosch, et al., 2013).

Physiological analysis of emotional response in music has also been applied to clinical purposes. EDA measures have been used to assess whether emotions could be modified through anxiety and stress levels. Through analysis of EDA, researchers found no significance in music's ability to decrease anxiety levels before surgery (Wang, et al., 2002), but EDA did show significant change in a study measuring music's ability to decrease stress levels (Sokhadze, 2007). Studies measuring music's impact on emotion through physiological measures dominate the literature for music's impact on electrodermal activity. These articles provide evidence that music has significant impact on arousal as measured by EDA.

Music and Arousal

The Impact of Music on the Brain

As previously stated, there is evidence that arousal levels decrease over time for many reasons: boring tasks (Yerkes & Dodson, 1908), lack of change (Hebb, 1954), and the duration of the day (Posner, 1975). It has also been suggested that humans have the ability to assess arousal levels and seek means to increase them (Berlyne, 1971). Thaut (2005) argues that humans use music in this way and has conducted studies of correlating music elements to physiological, brain and emotional responses.

"Music is unique to the brain because it can create new patterns of perceptual input that the brain could not generate through other means in order to keep sensory functions at optimal levels" (Thuat, 2005, p. 25). As we have learned, optimal levels of arousal appear to benefit the brain. When this occurs, multiple biological subsystems are synchronized, which allows the body to perform at its best (Juslin & Västfjäll, 2008). This is difficult to achieve because not all stimuli can activate multiple areas of the brain nor can they maintain the synchronization required; however, music has this ability because of its cross-hemispheric firing capabilities.

When a person listens to music, they are hearing a variety of complex musical elements that are associated with different cortexes of the brain (Thaut, 2005; Thaut & Hoember, 2014). For example, rhythm is strongly related to the motor system of the brain (Thaut, 2005), whereas music with a strong emotional response can trigger the thalamus, hippocampus and amygdala. All three of these areas represent different capabilities: motor systems (thalamus), memory (hippocampus), and emotional response (amygdala) (Blood, 2001). Research has shown that not only can music activate different neurologic-pathways and cross-hemispheric regions in the brain, but it can also synchronize those mechanics through rhythm (Thaut, 2005).

A key to this network synchronization of neurologic networks is through the ability of rhythm to synchronize oscillatory patterns in the brain through entrainment (Thaut, 2005). The brain processes material through oscillatory patterns by repetitive neural activity due to synchronization of activity patterns (Lewis, et al., 2004). Researchers have assessed rhythmic synchronization through studies that examine a human's ability to synchronize finger tapping with a rhythmic pulse. They found that not only could participants entrain to a rhythmic pulse, but rhythmic pulses also helped synchronize oscillatory patterns in the brain (Lewis, 2004; Stephan, et al., 2002).

Music has the capability to synchronize activity patterns of multiple brain cortexes which may enhance cognitive performance, but to truly assess music's benefit to cognition, the arousal hypothesis poses that analysis of physiological subsystems should be analyzed. Research suggests that music can alter arousal levels through skin response (EDA), heart rate, skin temperature, EEG band power and saliva (Blood & Zatorre, 2001; Craig, 2005; Guhn, Hamm, & Zentner, 2007; Rickard, 2004; Salimpoor, et al, 2009, 2011; & Zimny & Weidenfeller, 1963). Though research supports music's ability to change arousal levels through physiological means, it is important to assess the type of auditory stimulus that is presented.

The Implementation of Music

There are questions as to whether music preferences of the listener impacts arousal levels. Early studies used pre-selected music (Zimny & Weidenfeller, 1963), but more recent research suggests that participant-preferred music is more effective. For example, Salimpoor et al. (2009), found that participant-preferred music significantly changed levels in the autonomic nervous system for arousal through electrodermal activity (EDA), heart rate, respiration rate, skin temperature, and blood volume pulse (BVP) amplitude, whereas preselected music showed a lack of physiological response in arousal. Bosch, et al., (2013) found that familiar music had greater impacts on EDA response than unfamiliar music. Jäncke & Sandmann (2010) found that pre-selected music had no significant effect on arousal. When the researchers referenced feedback from the study, participants had stated that they did not find the music to be stimulating enough. Current research now supports the

use of participant-preferred music over pre-selected (Lingham & Theorell, 2009; Salimpoor, et al, 2009; & Thaut & Davis, 1993).

Research also suggested that specific elements of music may display a greater impact on arousal than others. Sammler, et al. (2007) examined the difference between consonant and dissonant music. They found that consonant music increased heart rate while dissonant music did not; however, after examining theta, alpha, and beta rhythms in the brain, researchers found that dissonance maintained theta rhythmic patterns longer than consonance did. This shows that dissonance affected arousal levels in the brain for longer periods of time, even though consonance displayed stronger physiological responses. Dean, Balles, & Schubert (2011), examined the impact of multiple music pieces on arousal response and found that intensity and loudness had the greatest impact in altering arousal levels (Dean, Balles, & Schubert, 2011). Another article found that fast tempos exerted a greater influence on the activation of the nervous system as measured through EEG testing when comparing genre, slower tempos, and in-tune and out-of-tune music (Dillman, Francesca, & Potter, 2007; Jäncke & Sandmann, 2010).

Emotion has one of the most significant impacts on arousal. Rickard (2004) found significant changes in EDA and chill response, but there were no significant changes in heart rate or skin temperature. Rickard concluded that emotion needs to be considered when testing arousal response because it greatly impacted arousal levels (Rickard, 2004). When individuals are emotionally aroused, the body can activate all areas of cognition, the autonomic nervous system, motor responses, motivation, and can fire them at the same time (Koelsch, 2010; Koelsch & Stefan, 2005). Music can synchronize multiple areas of the brain

and induce optimal emotional and arousing states due to its ability to synchronize oscillatory pattern through rhythm (Lewis, 2004; Stephan, et al, 2002;) and induce emotional response (Blood, 2001; Guhn, Hamm, & Zentner, 2007).

One way to measure how music triggers emotional response through physiological means is chill response. The sensation of chills occurring while listening to music is difficult to explain, but research has shown that it may be the perfect physiological example of how music can achieve optimal levels of arousal (Howells, et al, 2010). For example, Blood (2001) had subjects select a song that they knew induced a chill response. Participants then listened to the song while researchers measured arousal levels. They found that when chills are induced by music, the human body reacts similarly to optimal arousal response. Participants' heart rate, EMG testing and respiration all increased and activated the left ventral striatum, left hippocampus and amygdala. Though this article did not show significance in electrodermal activity (EDA), many other studies claim that chill response is heavily correlated to heart rate and EDA, and that EDA shows a greater response to music (Craig, 2005; Grewe, et al, 2007; Guhn, Hamm, & Zenter, 2007; & Rickard, 2004).

Recent research has tried to examine chill response further by analyzing which components of music may impact chill response the most. For example, Grewe, et al (2007), found that chill response did influence arousal levels, especially when the music was loud and viewed as pleasant, but the optimal peek arousal levels only occurred for a few seconds. This indicated that arousal levels are manipulated throughout musical pieces, but optimal arousal levels only occur at peak times during the piece and only last a few seconds. Similarly, in a studying assess the impact of music during driving performance, researchers 18

found that though music heightened arousal levels at loud volumes, there was a decay effect twenty minutes into testing (Ünal, et al., 2013). This was supported by other research studies stating that arousal levels did increase but only for thirty seconds (Hilz, et al., 2014) or in some cases only a few seconds afterward (Dousty, Deaneshvar, & Haghjoo, 2011). One research article saw similar results when analyzing the onset of music during testing, as participants showed significant arousal effects when music was implemented before testing (Jaušovec, Jaušovec, & Gerlic, 2006). These research articles suggest that the onset of music implementation and the duration of the musical stimuli should be considered when assessing arousal.

In comparison between all articles, it would seem that the duration of music would be important when manipulating test performance. If music is implemented too long, a decay effect could occur (Ünal, et al., 2013), but if the duration of music is not long enough, it may lack the ability to impact arousal response (Jaušovec, Jaušovec, & Gerlic, 2006). Other commonalities include that faster tempos stimulate the brain (Dillman Carpenter, & Potter, 2007; Thompson, Schellenberg, & Letnic, 2011) and music's impact on arousal levels may be individually sensitive (Ünal, et al., 2013, Perham, & Vizard, 2011). It would seem that participant-preferred music, the time of onset, intensity of music and the duration of the music stimulus should all be considered when assessing music's ability to heighten arousal levels and enhance test performance.

Current Research Regarding Music and Test Performance

Current research does not provide much evidence on how music could be beneficial to test performance through the arousal hypothesis. As stated in the previous section, many

articles support the arousal hypothesis in comparison to *The Mozart Effect* (Roth & Smith, 2008; Schellenberg, 2005). Both Roth & Smith (2008) and Schellenberg (2005) stated a need for further analysis on how music impacts test performance through the arousal hypothesis, and once this information is assessed there will be greater insight into the potential benefits.

Many articles that attempt to assess music's impact on test performance often implement background music that occurs for the full duration of testing. Unfortunately, research shows varied results, which may be due to a lack of an arousal assessment. For example, in a study analyzing how background music affected work performance, Lesiuk (2005) found that environments implementing background music during the entire duration of a workday increased work performance as well as worker's mood. Moreno, et al. (2011) tested music's impact on IO tests in children and found that the group receiving music training (compared to art training) improved test performance by 90%. Further analysis of test performance in math and reading comprehension showed that music neither hindered nor increased test performance when compared to the control group (Hallam, Price, Katsarou, 2002; Pool, Koolstra, & Voort, 2003). Another article testing reading comprehension found that music significantly decreased test performance compared to the silent condition (Anderson & Fuller, 2010). Though most of these examples show that music does not hinder test performance, they highlight the lack of arousal assessment as well as inconsistencies in results, methodology and implementation of music.

Another inconsistency that should be assessed is the selection of music. Several articles tested quiet, relaxing music compared to exciting or aggressive music when completing a cognitive task. For example, one article found significant improvement in test

performance with relaxing music while aggressive music decreased test performance (Hallam, Price, & Katsarou, 2002). Cassidy & MacDonald (2007) found that all music conditions negatively impacted test performance; relaxing music displayed better test performance compared to aggressive music, but it was not significant. These results contradict the arousal hypothesis, stating that relaxing music is better for test performance, though the results were not significant; the arousal hypothesis implies that excitable music could increase arousal levels, which may result in an increase in test performance. Neither article assessed arousal levels, so it is hard to say if these articles disprove the arousal hypothesis or not.

Schellenberg & Hallam (2005) tested pop music compared to Mozart and talk radio during cognitive testing, and they found that only pop music positively impacted test performance. These results support the idea that excitable music elevated arousal, but it was not explicitly measured. Jäncke & Sandmann (2010) did analyze arousal and tested how fast, slow, in-tune, and out-of-tune music implemented throughout testing impacted verbal learning through EEG testing. They found that all music conditions neither increased nor hindered test performance, but researchers did state that only fast music conditions elicited an EEG response. This supports the idea of the arousal hypothesis and other articles stating that fast music stimulates a stronger arousal response (Dean, Balles, & Schubert, 2011; Grewe, et al, 2007; Jäncke & Sandmann, 2010), but may demonstrate that music will not benefit testing performance if implemented throughout testing. Because of the varied methodologies and lack of arousal assessment, it is hard to determine whether music has the potential to enhance test performance.

Summary

Through research that supports the arousal hypothesis we have learned that the tasks in which we partake affect our arousal levels, and arousal can be altered with varying stimuli, such as music. When considering the use of music to manipulate arousal levels, there are many factors to consider; arousal levels are individually sensitive, they increase more successfully when the music stimulus is upbeat, and arousal levels are manipulated for only a few seconds.

The duration of arousal response to music is important to consider because it poses the question as to when the music stimulus should be implemented and for how long. Most research testing music's impact on test performance either implements music before testing or as background music. Music before testing may help stimulate arousal levels at the beginning of testing, but arousal levels may already be heightened and they may decrease as the task continues. Background music conflicts with the arousal hypothesis because the music stimulus loses its stimulating nature and may result in stagnant arousal levels.

While the arousal hypothesis is an established concept, the consideration of music's impact as a stimulus enhancement for test performance has little research support. Further research must be conducted to learn more about music's ability to manipulate arousal levels, decay effects in attention spans, and the time of onset of music during testing. With this knowledge, researchers will gain a greater understanding of the benefits to the arousal hypothesis through the implementation of music during testing. This research can expand to other disciplines as well, as music is not the only stimulus that can increase arousal. This

study has the potential to not only increase awareness regarding music's ability to impact test performance but to test the arousal hypothesis as a whole.

Research Questions

Research Question 1

Will time have a main effect on arousal as measured by electrodermal activity

(EDA)?

Research Question 2

Will there be a difference in arousal, as measured by electrodermal activity (EDA),

between music blocks and testing blocks?

Research Sub-Question 2a

Will there be a difference in arousal, as measured by electrodermal

activity (EDA), between different music blocks?

Research Sub-Question 2b

Will there be a difference in arousal, as measured by electrodermal activity

(EDA), between different testing blocks without music samples?

CHAPTER III

METHOD

Participants

The subjects in this experiment were recruited through advertisements posted in Western Michigan University's College of Health and Human Services building, Sangren Hall and Wood Hall (See Appendix A). Recruitment was also achieved through email to specific departments and classrooms such as Psychology, Occupational Therapy and Speech Pathology. The sample size of the study was determined by using the G*Power program (version 3.1) with an effect size of 0.25, an alpha level of 0.05, a beta level 0.8 and conditions set at 4. The results displayed that 24 subjects were needed for the study to be fully powered. A total of twenty-nine subjects were recruited, but only twenty-four subjects' data were analyzed; technical error in EDA data collection resulted in the removal of five subjects' data. All subjects enrolled in this study had an age range of 18-65 years with 8 males and 16 females.

All subjects were required to be between the ages of 18-65, speak English as their first language, have no visual or hearing impairments, and no deficits in cognition or reading abilities. Subjects could not have received more than one year of musical training, or have received any training within the last three years. The age range was chosen to reflect the articles reviewed for this thesis project (Roth, & Smith, 2008) and to avoid discrimination against the non-traditional college aged students. A maximum of 65 years of age was selected due to research suggesting cognitive decline occurring past this age (Au, et al., 2006). Specifications of English as the native language and no impairments in visual, hearing
or cognitive abilities were specified due to the potential impact on the participant's ability to successfully accomplish the online verbal processing GRE test. The musical training specifications were chosen to mirror specifications used by Roth & Smith (2008), and it's been demonstrated that non-musicians perform significantly better on language processing tests when music is implemented in the background compared to musicians (Patston, & Tippett, 2011). The presence of one or more of these conditions disqualified any potential subject from participating in the study.

Design

The study used a repeated measures within-subjects design. This design was chosen to test the individual difference in cognitive performance as a result of the time-of-onset of music. By having all subjects individually participate in each test condition, all music was participant-preferred and each subject acted as his or her own control.

Apparatus

Instrumentation used to administer this thesis project included a 27 inch 2012 iMac computer, laptop computer, MATLAB R2016a Version 9.0 which was used to administer the GRE practice Exam and data analysis, and AcqKnowledge Version 4.3 was used to run the EDA analysis. All music selections were played through Koss UR-20 home headphones Model T55959. In order to synchronize the EDA signal and testing material together to support accuracy for analysis, MATLAB and AcqKnowledge were linked through a trigger system. The EDA signal was collected throughout the 63-minutes of testing and a trigger was sent to AcqKnowledge alongside the EDA signal (Figure 2) both at the onset of each new question presentation and when each question was answered.



Footnote: The figure above is an example of data output in AcqKnowledge. The top portion represents triggers generated by MATLAB with blue lines marking each time a question is either presented or answered. The bottom portion represents the subject's EDA signal during testing.

Figure 2. EDA Signal and Trigger System

The EDA testing was administered through the BioNomadix MP150 Model number 507 data acquisition and analysis system. This system contains a wireless transponder and a Velcro strap that attaches to the wrist of the subject. The BioNomadix also contains disposable electrodes (model EL-658) that were placed on the subject's distal pad of the third and fourth digit of the non-dominant hand with the use of electrode conductivity gel, disposable adhesive discs (model ADD 208) and medical tape.

Music Stimulus

The researcher requested that each participant select one song that they found most arousing; this was defined as a song that was personally motivating, upbeat (above 90 bpm) (Dillman Carpenter, & Potter, 2007), caused the subjects to feel relaxed and alert, and did not over-stimulate. Subjects could not participate in the study until they had provided the researcher with the song title, artist and defined which three minutes were most preferred in the song, as each song was only played for three minutes. Subjects could not choose a song which was shorter than 3-minutes in duration. The 3-minute specification was used to keep music samples consistent between subjects, and to provide enough time to measure EDA SCR peak and decay. Participant-preferred music was selected due to the corresponding research stating that arousal levels are highly individualized (Eysenck, 2012), and that participant-preferred music shows stronger reactions to arousal response than pre-selected music (Blood & Zatorre, 2001; Craig, 2005).

Testing Material

The GRE practice exam material was taken from the four Verbal Processing practice exams in the 2012 *Official Guide to the GRE revised General Tests*. The GRE testing material focused on the Verbal Reasoning section; questions included reading comprehension and discrete questions which consist of selecting the appropriate word to complete the corresponding sentence. Verbal Reasoning was selected due to the estimated time required to answer each question, in order to assess attention decay. Pilot testing was used to preselect questions that took no less than thirty seconds and no longer than three minutes to answer; a total of sixty-nine questions were used. GRE testing material was also selected to reflect supporting literature (Roth, & Smith, 2008).

Procedure

Upon arrival, the subjects were asked to review and sign the WMU Human Subjects Institutional Review Board consent form (Appendix B). After the subjects agreed to participate in the study, the researcher provided each subject with a music preference form explaining what type of song should be selected (Appendix C). Subjects were scheduled to participate in the study once the researcher received an email with the subject's song selection. The music was downloaded from iTunes, edited into a 3-minute section and input into MatLab before the subjects returned for data collection.

Subjects were instructed to sit in front of a computer and listen to testing instructions. The instructions provided information on the nature of the testing material and what will be expected of the subject; the instructions also reminded the subjects to focus on test accuracy instead of overall completion, to wear the headphones at all times and to keep the nondominant hand as still as possible. Once the instructions were completed, the BRAIN Lab manager or BRAIN Lab assistant connected the subjects to the BioNomadix, biophysiological feedback equipment, by instructing them to place the non-dominant hand in a supine position on the table where the electrodes would be placed on the distal pad of the third and fourth digits of the non-dominant hand. This was used for monitoring EDA to measure arousal response. The subjects were instructed to leave the non-dominant hand on the table in a supine position for the duration of testing and asked to avoid moving the hand as much as possible once the testing began. EDA data collection was administered for the full duration of testing. Once the EDA application was completed, the participants were reminded of the testing instructions and asked to place the headphones on their head. A 30-second baseline of EDA was recorded, following the sample of music before testing. Once the 3minute participant-preferred music was complete, the testing material began.

Each participant was asked to complete sixty-minutes of testing material taken from the GRE Verbal Reasoning practice exam. Four testing blocks occurred during testing with music implemented before testing and twice during testing at separate intervals. All testing blocks occurred in 15-minute intervals to allow a potential decay effect in arousal levels and to provide enough questions for analysis of each condition. Subjects were instructed to continue testing without stopping when music was implemented during testing. Below is a flow chart of the procedure (Figure 3).



Figure 3. Flow of Procedure

Subjects participated in testing individually so that all exposure to music was preferred. Upon completion of the testing material, all subjects were given a gift card in exchange for their participation in the study.

Analysis of Data

Before the EDA data was analyzed, the signal was filtered using a low pass filter at 1 Hz and smoothed to remove any artifacts or noise. The preferences for Electrodermal Activity were modified to 0.01μ S (mircrosiemens) SCR threshold, and the 10% SCR detection rejection rate was maintained. SCR thresholds are commonly set at 0.05 μ S, but 0.04 to 0.01 μ S are sometimes used (Braithwaite, et al., 2013). An SCR threshold of 0.01μ S was used instead of 0.05 μ S as some subjects' peak responses were too small causing no SCRs to be detected when the "Locate SCRs" measurement was set at 0.05 μ S. The 10% SCR detection rejection rate was maintained, as recommended in Kim et al. (2004), to allow outside stimuli or events that may have affected the EDA signal to be excluded.

Mean slope, mean skin conductance level (SCL), mean skin conductance response $(\bar{x}SCR)$ and the number of peak responses (nSCR) were extracted from the EDA signal and used for statistical analysis for all research questions and sub-questions. The mean slope was used to assess whether there was a decay effect in arousal levels during testing blocks. This was achieved by calculating a mean slope in the tonic EDA signal through the AcqKnowledge software. If a positively sloped mean occurs, a starting data value will be lower than the data value at the end of the testing block. The mean slope is either a positive or negative number.

Next, skin conductance level (SCL) was measured and is the overall tonic level for the EDA signal. To measure the mean SCL for each testing block, it is first important to account for inter-individual differences. EDA signals can vary greatly among individuals, as some may have an average tonic level of 2 μ S and another individual may have an average of $9 \ \mu$ S (Cacioppo, et al., 2007). To account for inter-individual difference of variance, it is recommended that the subject's range be calculated by finding their minimum and maximum SCL. To achieve this, the formula (SCL-SCLmin)/(SCLmax-SCLmin) was used. This reduces error variance and increases power for the statistical tests run (Braithwaite, et al., 2013; Bosch, et al., 2013; & Lykken & Venables, 1971).

Also, the mean SCR was calculated by taking the peak height of the tonic SCL and subtracting it to the value of the tonic SCL at the time that the SCR began (How Can I Obtain the Mean, n.d.). For the specific equation used see Equation 1.



A visual example of where the peak and onset SCL are located in a typical SCR signal can be seen in the figure below (Figure 4).



Footnote: This figure represents a single SCR peak taken from a subject's EDA signal. The decaying line before the peak response represents the skin conductance level (SCL) or tonic EDA signal and the peak in the EDA signal represents the skin conductance response (SCR).

Figure 4. Example of SCR Peak

Finally, the number of peak SCRs (nSCR) for each block was extracted from the data. This is a common measurement used to assess whether a given stimulus impacted arousal levels by displaying more peaks in the SCR signal compared to another stimulus (Braithwaite, et al., 2013; Craig, 2005; Bosch, et al., 2013; Grewe, et al, 2007; Guhn, Hamm, & Zentner, 2007; Howells, et al, 2010; Salimpoor, et al., 2009; & Sokhadze, 2007). In order to account for varying block durations, the mean number of SCRs was divided by the duration of the block to normalize the data across blocks. All preparation of EDA signal and selection of measurements for EDA analysis was advised by the expertise of technical support from Biopac.

Multiple outcome measures were used for this student thesis project, with the other student researcher analyzing the number of questions attempted versus the number of questions answered correctly. For this thesis project, the intervallic (the numerical difference between two events) difference between the changes in amplitude of the wave recorded during the EDA testing (through mean slope, mean SCL, mean SCR and number of peak SCRs) throughout the 63-minute testing period was analyzed using paired sample *t*-test. All significance testing used an alpha level set at p<0.05. The statistical test chosen was advised through a consultation with the Director of Statistical Consulting Center at Western Michigan University.

The data was analyzed twice to answer the two corresponding research questions and two sub-questions for research question 2. The first analysis ran a paired sample *t*-test between blocks. The EDA signal was divided into four 15-minute blocks, with music implemented during the first 3-minutes for Blocks 2 and 3 (Figure 5).



Figure 5. First Analysis Blocks

The second analysis divided the EDA signal into the three 3-minute music samples and four testing blocks (Figure 6).



Figure 6. Second Analysis Blocks

For research question 2, a paired sample *t*-test was run between the music blocks and nonmusic blocks. For research sub-question 2a, a paired sample *t*-test was run between all music blocks. Finally, for research sub-question 2b, a paired sample *t*-test was run between all blocks without the music. For this analysis, Block 1 and 4 were 15-minutes long because music was not implemented during these blocks. Block 2 and 3 were 12-minutes long because music was taken out of the analysis.

CHAPTER IV

RESULTS

Mean slope, mean skin conductance level (SCL), mean skin conductance response (\overline{x} SCR) and the number of peak SCRs (nSCR) were analyzed using paired sample *t*-test for all data reported. All significance testing used an alpha level set at p<0.05. Statistical test choices were advised through a consultation with the Director of Statistical Consulting Center at Western Michigan University, and all data was reported through the suggested format in Discovering Statistics Using SPSS (Field, 2009), which follows the requirements of the British Psychological Society and American Psychological Association. In order to answer each of the research questions, the analysis focused on the effect of time on arousal for block comparisons, music and non-music block comparisons, music comparisons, and block comparisons without music for each analysis measurement (mean slope, mean skin conductance level (SCL), mean skin conductance response (\overline{x} SCR) and the number of peak SCRs (nSCR).

Mean Slope

Block Comparisons

When comparing Block slope means using a paired sample *t*-test, participant EDA signals displayed a significantly greater slope mean for Block 1 (M= 0.0008, SE= 0.0003) compared to Block 2 (M=-0.0003, SE= 0.0002), t(23)= 3.822, p<.05, r=0.6, Block 3 (M=-0.0004, SE= 0.0001), t(23)= 3.548, p<.05, r=0.6, and Block 4 (M=-0.0003, SE= 0.0001), t(23)= 3.134, p<.05, r=0.6 (Figure 7). There were no further significantly different pairwise comparisons.



Footnote: This figure represents the mean slope, measured in microsiemens, of the tonic EDA signal for blocks with music. Blocks 1 and 4 were 15-minutes long with no music and Blocks 2 and 3 were 15-minute long with 3-minutes of music at the beginning of testing. Block 1 had the only positively sloped mean, which is represented above zero. All other blocks had a negatively sloped mean represented below zero.

Figure 7. Mean Slope for Blocks

Music and Non-Music Block Comparisons

When comparing Music Blocks to their corresponding Testing Blocks, using a paired sample *t*-test, participant EDA signals displayed significantly greater slope mean for Music for Block 2 (M=-0.0020, SE= 0.0009), t(23)= -2.135, p<.05, r=0.4 compared to Block 2 (M= -0.0001, SE= 0.0001) (Figure 8). There were no further significantly different pairwise comparisons.



Mean Slope for Music and Non-Music Blocks

Error Bars: 95% CI

Footnote: This figure represents the mean slope, measured in microsiemens, of the tonic EDA signal for music and non-music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. Non-music blocks represent the testing blocks that occurred during Blocks 1, 2, 3 and 4. For this analysis the music samples were compared to the corresponding testing blocks; Music Before Testing vs. Block 1, Music during Block 2 vs. Block 2, Music for Block 3 vs. Block 3. Block 1 had the only positively sloped mean, which is represented above zero. All other blocks had a negatively sloped mean represented below zero.

Figure 8. Mean Slope for Music and Non-Music Blocks

Music Block Comparisons

When comparing all Music Blocks, using a paired sample *t*-test, no significant difference in slope mean was found (Figure 9).



Mean Slope for Music Blocks

Error Bars: 95% CI

Footnote: This figure represents the mean slope, measured in microsiemens, of the tonic EDA signal for music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. All music samples were for 3-minutes.



Block Comparisons Without Music

When comparing Testing Blocks without music, using a paired sample *t*-test, participant EDA signals displayed significantly greater slope mean for Block 1 (M= 0.0009, SE=0.0003, compared to Block 2 (M=-0.0001, SE=0.0001), t(23)= 3.124, p<.05, r=0.5, Block 3 (M=-0.0005, SE= 0.0003), t(23)= 3.009, p<.05, r=0.5, and Block 4 (M=-0.0003, SE= 0.0001), t(23)=3.182, p<.05, r=0.6 (Figure 10). There were no further significantly different pairwise comparisons.



Mean Slope for Blocks Without Music

Footnote: This figure represents the mean slope, measured in microsiemens, of the tonic EDA signal for blocks without music. Music was not implemented during Blocks 1 and 4, but was implemented during Blocks 2 and 3. The 3-minute music sample was removed during the analysis resulting in a duration of 12-minutes for Blocks 2 and 3. Block 1 had the only positively sloped mean, which is represented above zero. All other blocks had a negatively closed mean removed block zero. sloped mean represented below zero.

Figure 10. Mean Slope for Blocks Without Music

- *Block Comparisons*: EDA signals for mean slope displayed significant difference between Block 2, 3, and 4 compared to Block 1. Blocks 2, 3, and 4 presented decreasing EDA tonic slope while Block 1 had an increasing tonic slope.
- Music and Non-Music Block Comparisons: EDA signals for mean slope displayed a significantly higher slope mean for Music for Block 2 compared to Block 2.
 Block 1 had a positively sloped mean, with all other music and testing blocks having a negatively sloped mean. These results are the same for block comparisons with music, with Block 1 having the only positively sloped mean.
- *Music Block Comparisons*: The data displayed no significant difference in sloped mean between music samples.
- *Block Comparisons Without Music*: The data displayed that Block 1 had a significantly higher mean slope compared to all other blocks. Block 1 was also the only block with a positive slope, which is consistent with the results for block comparison with music.

Mean Skin Conductance Level (SCL)

Block Comparisons

When comparing Block means using a paired sample *t*-test, participant EDA signals displayed significantly greater mean SCLs for the Baseline (M= 0.4540, SE= 0.0285) compared to Blocks 1 (M=0.3825, SE= 0.0211), t(23)= 2.289, p<.05, r=0.4, Block 2 (M=0.3825, SE= 0.0160), t(23)= 6.038, p<.05, r=0.8, Block 3 (M=0.2916, SE= 0.0181), t(23)= 6.117, p<.05, r=0.8, and Block 4 (M=0.3080, SE= 0.0289), t(23)= 3.653, p<.05, r=0.6 (Figure 11).



Footnote: This figure represents the mean SCL, measured in microsiemens. All blocks are 15minutes in duration, with Blocks 2 and 3 having music for the first 3-minutes of testing. Baseline occurred for 30 seconds before testing and the first music sample.

Also, on average, participant EDA signals displayed significantly greater mean SCLs for Block 1 (M= 0.3825, SE= 0.0211) compared to Blocks 2 (M=0.3825, SE= 0.0160), t(23)= 3.439, p<.05, r=0.7, and Block 3 (M=0.2916, SE= 0.0181), t(23)= 3.856, p<.05, r=0.7 (Table

1). There were no further significantly different pairwise comparisons.

Table 1

Mean Skin Conductance Level (SCL) -Paired Sample t-test-Block Comparisons with Music

		t	df	Sig. (2-tailed)
Pair 1	Block 1 - Block 2	3.439	23	.002
Pair 2	Block 1 - Block 3	3.856	23	.001
Pair 3	Block 1 - Block 4	2.059	23	.051

Music and Non-Music Block Comparisons

When comparing Music Blocks to their corresponding Testing Blocks, using a paired sample *t*-test, no significant difference in mean SCLs were found between the music samples and their corresponding Blocks (Figure 12).



Error Bars: 95% CI

Footnote: This figure represents the mean SCL, measured in microsiemens, music and nonmusic blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. Non-music blocks represent the testing blocks that occurred during Blocks 1, 2, 3, and 4. For this analysis the music samples were compared to the corresponding testing blocks; Music Before Testing vs. Block 1, Music during Block 2 vs. Block 2, Music for Block 3 vs. Block 3. Data was normalized to represent the average number of peak SCRs (nSCR) per minute, with music samples occurring for 3-minutes, Block 1 occurring for 15-minutes, and Blocks 2 and 3 occurring for 12-minutes.

Figure 12. Mean SCL for Music and Non-Music Blocks

Music Block Comparisons

When comparing Music Blocks, using a paired sample *t*-test, participant EDA signals displayed significantly greater mean SCLs for the Music Before Testing (M= 0.3865, SE= 0.0226) compared to Music for Block 3 (M=0.3117, SE= 0.0135), t(23)= 2.868, p<.05, r=0.5. (Figure 13). There were no further significantly different pairwise comparisons.



Mean SCL for Music Blocks

Error Bars: 95% CI

Footnote: This figure represents the mean SCL, measured in microsiemens, for music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. All music samples were for 3-minutes.

Figure 13. Mean SCL for Music Blocks

Block Comparisons Without Music

When comparing Testing Blocks without music, using a paired sample *t*-test, participant EDA signals displayed significantly greater mean skin conductance level (SCL) for Block 1 (M= 0. 3825, SE= 0.1036), compared to Block 2 (M=0.3020, SE= 0.0653), t(23)= 3.380, p<.05, r=0.6, and Block 3 (M=0.3057, SE= 0.1129), t(23)= 2.440, p<.05, r=0.5. (Figure 14). There were no further significantly different pairwise comparisons.



Mean SCL for Blocks Without Music

Error Bars: 95% CI

Footnote: This figure represents the mean SCL, measured in microsiemens, for blocks without music. Music was not implemented during Blocks 1 and 4, but was implemented during Blocks 2 and 3. The 3-minute music sample was removed during the analysis resulting in duration of 12-minutes for Blocks 2 and 3.

Figure 14. Mean SCL for Blocks Without Music

Mean Skin Conductance Level (SCL)

- *Block Comparisons*: EDA mean SCLs were significantly higher during the baseline compared to all other Blocks (1, 2, 3, and 4). Also, mean SCL for Block 1 was significantly higher compared to Blocks 2 and Block 3, but Block 4 lacked significance (p<.051).
- *Music and Non-Music Block Comparisons*: The data displayed no significant difference in mean SCLs between music samples and their corresponding Blocks.
- *Music Block Comparisons*: The data displayed a significant difference between the mean SCL for Music Before Testing compared to Music for Block 3.
- Block Comparisons Without Music: The results showed that Block 1 had a significantly higher SCL mean compared to Blocks 2 and Block 3, but Block 4 lacked significance (p<.051). This is consistent with the analysis for block comparisons with music.

Mean Skin Conductance Response (\overline{x} SCR)

Block Comparisons

When comparing Block means using a paired sample *t*-test, participant EDA signals displayed significantly greater mean SCR (\bar{x} SCR) for Block 1 (M= 0.1161, SE= 0.0270) compared to Blocks 4 (M=0.0852, SE= 0.0245), t(23)= 2.142, p<.05, r=0.4 (Figure 15). There were no further significantly different pairwise comparisons.



Mean SCR (x SCR) for Blocks

Error Bars: 95% CI

Footnote: This figure represents the mean SCR (\overline{x} SCR), measured in microsiemens. Blocks 1 and 4 were 15-minutes long with no music and Blocks 2 and 3 were 15-minute long with 3-minutes of music at the beginning of testing.

Figure 15. Mean SCR (\overline{x} SCR) for Blocks

Music and Non-Music Block Comparisons

When comparing Music Blocks to their corresponding Testing Blocks, using a paired sample *t*-test, participant EDA signals displayed significantly greater \overline{x} SCR for music samples compared to their corresponding blocks, except for Block 1 (Figure 16):

Participant EDA signals displayed significantly greater mean SCR (\overline{x} SCR) for Music for Block 2 (M= 0.1325, SE= 0.0332) compared to Block 2 (M=0.0976, SE= 0.0236), t(23)= 2.487, p<.05, r=0.5.

Participant EDA signals displayed significantly greater mean SCR (\overline{x} SCR) for Music for Block 3 (M= 0.1091, SE= 0.0288) compared to Block 3 (M=0.0932, SE= 0.0239), t(23)= 2.225, p<.05, r=0.4.

Participant EDA signals displayed significantly greater mean SCR (\overline{x} SCR) for Block 1 (M= 0.1161, SE= 0.1324), compared to Music Before Testing (M= 0.0700, SE= 0.0185), t(23)= -2.216, p<.05, r=0.4.



Mean SCR (x SCR) for Music and Non-Music Blocks

Footnote: This figure represents the mean SCR (x SCR), measured in microsiemens, for music and non-music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. Non-music blocks represent the testing blocks that occurred during Blocks 1, 2, 3 and 4. For this analysis the music samples were compared to the corresponding testing blocks; Music Before Testing vs. Block 1, Music during Block 2 vs. Block 2, Music for Block 3 vs. Block 3.

Figure 16. Mean SCR (\overline{x} SCR) for Music and Non-Music Blocks

Music Block Comparisons

When comparing Music Blocks, using a paired sample *t*-test, participant EDA signals displayed significantly greater mean SCR (\bar{x} SCR) for Music for Block 2 (M= .1325, SE= .0332) compared to Music Before Testing (M=.0700, SE=.0185), t(23)=-2.367, p<.05, r=0.4, and Music for Block 3 (M=.1091, SE=.0288), t(23)=3.190, p<.05, r=0.6 (Figure 17). There were no further significantly different pairwise comparisons.



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Error Bars: 95% CI

Footnote: This figure represents the mean SCR (\overline{x} SCR), measured in microsiemens, for music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. All music samples were for 3-minutes.

Figure 17. Mean SCR (\overline{x} SCR) for Music Blocks

Block Comparisons Without Music

When comparing Testing Blocks without music, using a paired sample *t*-test, participant EDA signals displayed a significantly higher mean SCR (\bar{x} SCR) for Block 1 (M= 0.1161, SE= 0.1161), compared to Block 2 (M=0.0976, SE= 0.1157), t(23)= 2.591, p<.05, r=0.5, Block 3 (M=0.0932, SE= 0.1172), t(23)= 2.868, p<.05, r=0.5, and Block 4 (M=0.0854, SE=0.1203, t(23)=2.129, p<.05, r=0.4 (Figure 18). There were no further significantly different pairwise comparisons.



Footnote: This figure represents the mean SCR (\overline{x} SCR), measured in microsiemens, for blocks without music. Music was not implemented during Blocks 1 and 4, but was implemented during Blocks 2 and 3. The 3-minute music sample was removed during the analysis resulting in duration of 12-minutes for Blocks 2 and 3.

Figure 18. Mean SCR (\overline{x} SCR) for Blocks Without Music

Mean Skin Conductance Response ($\overline{x}SCR$)

- *Block Comparisons:* The data displayed similar mean SCRs for all blocks, including baseline, with the only statistically significant comparison occurring between Block 1 and Block 4.
- *Music and Non-Music Block Comparisons*: The data state that the two music samples that occurred during testing had significantly higher SCR means compared to their corresponding blocks, whereas, when music occurred before testing it had a significantly lower SCR mean compared to Block 1.
- *Music Comparisons*: The data shows that Music for Block 2 had significantly higher mean SCRs compared to Music Before Testing and Music for Block 3.
- *Block Comparisons Without Music*: The data displayed a significantly higher mean SCR for Block 1 compared to all other Blocks. This is inconsistent with the analysis for block comparisons with music, as Block 1 only had a significant difference compared to Block 4.

Mean Number of Peak Skin Conductance Responses (nSCR)

Block Comparisons

When comparing Block means using a paired sample *t*-test, participant EDA signals displayed significantly greater numbers of peak SCRs (nSCR) for Block 1 (M= 44.0000, SE= 6.7540), t(23)= 2.796, p<.05, r=0.5, Block 2 (M= 47.5417, SE= 6.1187), t(23)= 3.729, p<.05, r=0.6, and Block 3 (M= 38.9167, SE= 5.0855), t(23)= 2.685, p<.05, r=0.5, compared to Block 4 (M= 26.7917, SE= 4.6776).

Also, on average, participant EDA signals displayed significantly greater number of peak SCRs (nSCR) for Block 2 (M= 47.5417, SE= 6.1187), t(23)= 3.296, p<.05, r=0.6, compared to Block 3 (M= 38.9167, SE= 5.0855) (Figure 19). There were no further significantly different pairwise comparisons.



Mean Number of Peak SCRs (nSCR) for Blocks



Footnote: This figure represents the mean number of SCRs (nSCR), measured in microsiemens. Blocks 1 and 4 were 15-minutes long with no music and Blocks 2 and 3 were 15-minutes long with 3-minutes of music at the beginning of testing.

Figure 19. Mean Number of Peak SCRs (nSCR) for Blocks

Music and Non-Music Block Comparisons

For this analysis, the duration between blocks was varied with Music Blocks occurring for 3-minutes, Blocks 1 and 4 occurring for 15-minutes and Blocks 2 and 3 occurring for 12-minutes. To account for the varied durations, the average number of peak SCRs (nSCR) was divided by the block duration. The means in this analysis reflect the average number of peak SCRs per minute.

When comparing Music Blocks to their corresponding Testing Blocks (Non-Music Blocks), using a paired sample *t*-test, participant EDA signals displayed significantly greater number of peak SCRs (nSCR) during music blocks compared to non-music blocks (Figure 20):

Participant EDA signals displayed significantly greater number of peak SCRs (nSCR) for Music Before Testing (M= 4.5278, SE= 0.7494) compared to Block 1 (M=2.9333, SE= 0.4503), t(23)= 2.858, p<.009, r=0.5.

Participant EDA signals displayed significantly greater number of peak SCRs (nSCR) for Music for Block 2 (M=4.3472, SE= 0.5018) compared to Block 2 (M=2.7778, SE= 0.3778), t(23)= 5.196, p<.000, r=0.7.

Participant EDA signals displayed significantly greater number of peak SCRs (nSCR) for Music for Block 3 (M=2.39565, SE= 0.4890) compared to Block 3 (M=1.52712, SE= 0.3117), t(23)= -4.975, p<.000, r=0.7.



Mean Number of Peak SCRs (nSCR) for Music and Non-Music Blocks

Error Bars: 95% CI

Footnote: This figure represents the mean number of SCRs (nSCR), measured in microsiemens, music and non-music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. Non-music blocks represent the testing blocks that occurred during Blocks 1, 2, 3, and 4. For this analysis the music samples were compared to the corresponding testing blocks; Music Before Testing vs. Block 1, Music during Block 2 vs. Block 2, Music for Block 3 vs. Block 3. Data was normalized to represent the average number of peak SCRs (nSCR) per minute, with music samples occurring for 3-minutes, Block 1 occurring for 15-minutes, and Blocks 2 and 3 occurring for 12-minutes.

Figure 20. Mean Number of Peak SCRs (nSCR) for Music and Non-Music Blocks

Music Block Comparisons

When comparing Music Blocks, using a paired sample *t*-test, there was no significant difference between the number of peak SCRs (nSCR) for each music sample. (Figure 21).



Mean Number of Peak SCRs (nSCR) for Music Blocks



Footnote: This figure represents the mean number of SCRs (nSCR), measured in microsiemens, for music blocks. Music blocks occurred before testing and twice during testing for Blocks 2 and 3. All music samples were for 3-minutes.

Figure 21. Mean Number of Peak SCRs (nSCR) for Music Blocks

Block Comparisons Without Music

For this analysis, the duration between blocks was varied with Blocks 1 and 4 occurring for 15-minutes and Blocks 2 and 3 occurring for 12-minutes. To account for the varied durations, the average number of peak SCRs (nSCR) was divided by the block duration. The means in this analysis reflect the average number of peak SCRs per minute (Figure 22).

When comparing blocks without music, using a paired sample *t*-test, participant EDA signals displayed significantly greater number of peak SCRs (nSCR) for Block 1 (M= 2.9333, SE= 0.4503), compared to Block 3 (M=2.1215, SE= 0.3117), t(23)= 2.625, p<.01, r=0.5, and Block 4 (M=1.7444, SE= 0.3190), t(23)= 2.897, p<.008, r=0.5.

Also, on average, participant EDA signals displayed significantly greater number of peak SCRs (nSCR) for Block 2 (M= 2.7778, SE= 0.3778), compared to Block 3 (M=2.1215, SE= 0.3117), t(23)= 2.716, p<.01, r=0.5, and Block 4 (M=1.7444, SE= 0.3190), t(23)= 3.031, p<.006, r=0.5.



Number of Peak SCRs (nSCR) for Blocks Without Music

Error Bars: 95% CI

Footnote: This figure represents the mean number of peak SCRs (nSCR), measured in microsiemens, for blocks without music. Music was not implemented during Blocks 1 and 4, but was implemented during Blocks 2 and 3. The 3-minute music sample was removed during the analysis resulting in duration of 12-minutes for Blocks 2 and 3. Data was normalized to represent the average number of peak SCRs (nSCR) per minute.

Figure 22. Number of Peak SCRs (nSCR) for Blocks Without Music

Mean Number of Skin Conductance Response (nSCR)

Block Comparisons: The data displayed significantly fewer peak responses (nSCR) during Block 4 compared to all other blocks. Block 2 had significantly more peak responses (nSCR) compared to Block 3.

- *Music and Non-Music Block Comparisons*: The data show that the number of peak SCRs (nSCR) were significantly higher during all music blocks compared to non-music blocks.
- *Music Comparisons:* The data showed no significant difference between the number of peak SCRs (nSCR) during each music sample.

Block Comparisons Without Music: The data displayed that Block 1 had significantly higher numbers of peak SCRs (nSCRs) compared to Blocks 3 and 4, and Block 2 had significantly higher numbers of peak SCRs (nSCRs) compared to Block 3 and 4. There was no significant difference between Blocks 1 and 2. This is inconsistent with the analysis for block comparisons with music, showing that all blocks had significantly higher numbers of peak SCRs (nSCRs) compared to Block 4, but is consistent with Block 2 having significantly higher number of peak SCRs (nSCR) compared to Block 3.
CHAPTER V

DISCUSSION

Results of Outcome Measures

The analysis for this study consisted of a comparison between testing blocks with music, which consisted of 15-minutes of testing for Blocks 2 and 3 (where music was presented during the first three minutes of the blocks) and 15-minutes of testing for Block 1 (where 3-minutes of music preceded the block) and Block 4 (where no music was presented prior to or during the block). Music blocks compared to non-music blocks were also compared which included Music Before Testing compared to Block 1, Music for Block 2 compared to Block 2 and Music for Block 3 compared to Block 3. Music-to-music blocks (lasting 3-minutes) and no music-to-no music blocks (Block 1=15 mins, Block 2 & 3=12 mins, Block 4= 15 mins) were analyzed as well. For all analyses, the outcome measurements used were mean slope, mean skin conductance level (SCL), mean skin conductance response ($\overline{x}SCR$) and number of peak SCRs (nSCR).

The different analyses were run to assess a decay effect in arousal and to compare arousal during testing material, music samples, and the difference between the two. With the different analyses, the results of this study support the hypothesis that time has an effect on arousal as measured by electrodermal activity. The results also suggest that music had an impact on arousal levels. An overall comparison between analyses for each measurement will be used to discuss the results of this study.

Mean Slope

When analyzing block comparisons, Block 1 had a significantly different mean slope compared to all other blocks as it is the only block with a positive slope. The data suggest that arousal, as measured by electrodermal activity, may start high at the beginning of a test (Block 1 with a positive mean slope) and decay over time, with all other blocks displaying a negative sloped mean.

When analyzing music blocks compared to non-music blocks, Music for Block 2 had a significantly more positive mean slope compared to Block 2. Block 1 was again the only block with a positive slope, though it was not significantly different compared to Music Before Testing.

When analyzing music blocks, the mean slope was similar between music samples, with all music samples displaying a negative slope. This suggests that music may be subject to a decay effect in arousal during a 3-minute sample, which is suggested in the literature (Ünal, et al., 2013; Hilz, et al., 2014; Dousty, Deaneshvar, & Haghjoo, 2011).

When analyzing testing blocks without music, the data showed Block 1 with a significantly different mean slope compared to all other blocks; only Block 1 yielded a positive slope, which is consistent with the analysis for testing blocks with music.

Mean Skin Conductance Level (SCL)

When analyzing block comparisons, the mean skin Conductance level (SCL) for Block 1 was significantly higher than that of Blocks 2 and 3 but not Block 4 (p>0.051). This suggests that the tonic level for EDA sat at a higher microsiemen level during Block 1 but decayed over time. When analyzing music blocks compared to non-music blocks, the mean skin conductance level (SCL) displayed no statistically significant difference. The data suggest that the EDA tonic levels are relatively the same level when comparing music blocks to their corresponding testing blocks, but there is a statistically significant difference in EDA tonic level among music blocks.

When analyzing music blocks, Music Before Testing was significantly higher than Music for Block 3. Participants listened to the same music sample three times, and these results may suggest that the music sample became less stimulating by the third time.

When analyzing blocks without music, Block 1 features a significantly higher mean than Blocks 2 and 3, but not Block 4. This is also consistent with the analysis for Question 1. *Mean Skin Conductance Response (\overline{x}SCR)*

When analyzing block comparisons, the mean skin conductance response (SCR) for Block 1 had the highest mean (M= 0.1161), followed by Block 2 (M= 0.1061), Block 3 (M= 0.1011), and finally Block 4 (M= 0.0852): the only significant difference in means were between Block 1 and Block 4. The data suggest that means for SCR were highest at the start of testing and lowest at the end of testing, but the difference between the means were more gradual causing a significant difference to only occur between Block 1 and Block 4. The data for mean SCR still suggest a decay effect in arousal from the start of testing to the end of testing.

When analyzing music blocks compared to non-music blocks, there was a significant difference between the mean skin conductance response ($\overline{x}SCR$), as Music for Blocks 2 and 3 displayed higher SCR means than their corresponding blocks. Block 1 had a significantly

higher mean compared to Music Before Testing. The data suggest that when comparing mean SCR in the EDA signal, music displays higher means than non-music blocks. Even though non-music blocks were longer compared to music blocks, music samples had higher mean SCRs. This could suggest that music impacts arousal more than testing material, or that testing material loses participants' interest and causes a decrease in peak response over time, as seen in the results for mean slope. Block 1 had a higher SCR mean compared to Music Before testing, which could have occurred for a number of reasons. First, Music Before Testing was the only music sample that did not occur during testing material; this may suggest that music combined with a task has an increased impact on arousal levels. Mean SCR during Block 1 may have been higher because the testing material started during this block, causing an increase in arousal which decayed as time passed; the novelty of the activity may have also increased arousal levels compared to listening to music before testing.

When analyzing music blocks, Music for Block 2 was significantly higher compared to all other music samples. It is unclear why Music for Block 2 had the highest mean SCR, but it may be due to the timing of stimulus introduction. Music Before Testing is the only music sample that did not occur during testing, suggesting that music samples are more stimulating when paired with a task. The music sample for Block 3 may have had a lower mean SCR compared to Music for Block 2 because it was the third time that the participants had heard the same music sample, causing the music to be less stimulating.

When analyzing blocks without music, Block 1 is significantly higher compared to all other blocks; this is inconsistent with the analysis for testing blocks with music as Block 1 was previously found to only have a significantly higher mean SCR to Block 4. This

difference may be explained through the elimination of music. When music was taken out of the analysis for Block 2 and Block 3, the maximum peak levels were lower causing Block 1 to have a significantly higher mean than all other blocks. This is supported in the analysis of music segments compared to their corresponding blocks, as both Music for Block 2 and Music for Block 3 display significantly higher mean SCR compared to their corresponding blocks.

Mean Number of Peak Skin Conductance Response (nSCR)

When analyzing block comparisons, the number of peak SCRs (nSCR) were significantly lower for Block 4 compared to all other blocks, and Block 3 was significantly lower compared to Block 2. When reviewing means, Block 2 recorded the highest number of peak responses (M= 47.5417), followed by Block 1 ((M= 44.0000), Block 3 (M= 38.9167), and finally Block 4 (M= 26.7917). This data is slightly different compared to mean slope, mean SCL or mean SCR because it is the only data in which Block 2 displayed the highest mean; all other analyses result in Block 1 displaying the highest means. The reason for Block 2 showing more peak responses compared to Block 1 will be explained in the blocks without music analysis, but the data does show significant evidence that Block 4 recorded the lowest number of peak SCRs (nSCR) followed by Block 3 displaying a decay effect towards the end of testing.

When analyzing music blocks compared to non-music blocks, an additional analysis was required to normalize the difference in duration between the blocks (Music blocks were 3-minutes, Block 1 was 15-minutes, and Blocks 2 and 3 were 12-minutes). This was achieved by dividing the mean number of peak SCRs by the block duration. Results

displayed that all music blocks had significantly higher number of peak SCRs compared to their corresponding non-music block. These data support the hypothesis that music increases arousal levels more compared to blocks with no music.

When analyzing music blocks, there was no significant difference between music samples with Music Before Testing having a mean of (M=13.5833), Music for Block 2 (M=13.0417), and Music for Block 3 (M=11.000). The data shows little difference between Music Before Testing and Music for Block 2, but it reveals a decrease in the number of peak responses for Music for Block 3: this continues to suggest that the music sample may have become less stimulating by the third time it was introduced.

When analyzing blocks without music, Block 1 had a significantly larger number of peak SCRs compared to Blocks 3 and 4, and Block 2 had a significantly larger number of peak SCRs compared to Blocks 3 and 4. Comparison of Block 1 and Block 2 did not yield a significant difference in number of peak SCRs and neither did the comparison of Blocks 3 and 4. These results are inconsistent with the analysis for testing blocks with music. When reviewing means for testing blocks with music, Block 2 had the highest number of peak responses followed by Block 1, Block 3 and finally Block 4. The difference in results may suggest that Block 2 exhibited more peak responses when music was included in the analysis. The results also suggest a decay effect in arousal as there were more peak SCRs during the first two blocks and a significant drop in peak SCRs in the last two blocks.

Summary of Results

The combination of all results (block comparisons, music blocks compared to nonmusic blocks, music blocks and blocks without music) reveals a few common themes. First, Block 1 displayed a significant difference compared to the other blocks for mean slope, mean skin conductance level (SCL), mean skin conductance response ($\overline{x}SCR$) and total number of peak SCRs (nSCR). This may suggest that arousal levels are highest when testing material is first presented and decay over time, which supports the hypothesis that time has an effect on arousal levels.

For research questions that compared the differences in arousal between music blocks to the corresponding testing blocks, music blocks and blocks without music results displayed more variety. One common theme that occurred was the impact music had on skin conductance response, with music displaying higher mean SCRs (\overline{xSCR}) and number of peak SCRs (nSCR) compared to non-music blocks. This suggests that music does have an effect on arousal by increasing the number of peak responses and the overall mean of SCRs.

Another common result was Block 4 exhibiting a slight increase in mean slope, mean SCL and the number of peak SCRs compared to Block 3, but it was not significant. The cause of a slight arousal increase during Block 4 is unknown; however, there was an issue during the first half of data collection, with a few participants displaying an increase in full body movements during Block 4. In the original test script, subjects were instructed to keep the non-dominant hand still for the full duration of testing; however, the test script did not mention other body movements. A few subjects were observed performing full body stretches while keeping the non-dominant hand still, which caused increased peak responses in the EDA signal. Revisions to the test script were made to include instructions to refrain from moving the non-dominant hand while also limiting other body movements. Though the test script was changed, it may have impacted results for Block 4.

Limitations

For this research project, EDA was analyzed consistently throughout testing, which introduces more possibility for signal error. For this study, there were a few factors that may have impacted the EDA signal. First, larger movements and coughing from a few subjects produced an increase in EDA response. Researchers attempted to consider these changes during the analysis, but they may have impacted the results. Cold hands may have also affected the EDA signal. According to the Biopac website (EDA FAQ, n.d.), cold hands may corrupt the EDA signal as they reduce the skin conductance response size. One subject did have cold hands resulting in minimal SCR responses in the EDA signal. Researchers attempted to resolve this issue by covering the hand with a towel, and this improved data collection for the remaining subjects.

Though the music was participant-preferred, the subjects heard the same song three times during testing, so there was question as to whether the song would lose its appeal each time it was played. Results suggest a reduced appeal, as mean SCL, mean SCR (\bar{x} SCR) and number of peak SCRs (nSCR) were lower for Music during Block 3 compared to the other music samples. Also, there was question as to whether the amplitude of the music between each subject may have affected arousal levels. Researchers attempted to account for this by playing the music sample before testing and allowing the subjects to adjust the music to the preferred amplitude level; however, the loudness of the music is individually sensitive, which may have impacted arousal levels as some subjects' music may have been louder than others and research has shown that amplitude affects EDA levels (Dean, Balles, & Schubert, 2011).

Finally, although there was a specification that song choices should be at least 90 beats per minutes, there were two songs that were below 90 bpm (75bpm and 80 bpm) (Appendix D). The researchers did not put the 90-bpm specification in the music preference form (Appendix C) but maintained the written definition. This may have caused two subjects' arousal levels to not reach their highest mean peak potential due to the slower tempo. There is also question as to whether there should have been a tempo marking cap as to not overstimulate subjects when taking the testing material. Displaying a clear range of tempos may keep music samples consistent among subjects and should be a consideration, if this study is replicated.

There was also question as to whether music should have been implemented during Block 4 to maintain consistency among blocks. Music was eliminated from Block 4 as a result of the pilot study; during the pilot study, some subjects finished testing material early and therefore missed all or part of the final music condition. The researchers countered this issue by changing music implementation from 20-minute intervals to 15-minute intervals and selecting specific questions for the interval duration. The researchers were still concerned that subjects may not participate in all music conditions, so the three music samples were placed toward the beginning of testing with no music during the final block. Multiple subjects did complete the testing material 1-5 minutes early, but one subject completed the test at 38 minutes and did not participate during Block 4.

Finally, a silent condition was not created for this research design as the researcher sought to assess what would happen to arousal levels when music was implemented during testing. This information was to serve as a foundation for future research in music and cognition for the arousal hypothesis. A silent condition technically occurred during Block 4 but as it was always presented last, the results are confounded and were not used to analyze the difference between testing blocks with music and without music.

Musical Choices

For this thesis project, subjects selected the music; literature supports participantpreferred music over pre-selected music, as preferred music yields a stronger arousal response (Blood & Zatorre, 2001; Craig, 2005). Though the music was preferred, subjects were instructed to choose an upbeat song which induced a strong emotional response but did not relax or over-stimulate the subject. Subjects chose music from a variety of genres, and the most common genres were Pop and Alternative, each with 5 subjects selecting from the genre. The next most popular genres were Country and Hardcore tied each with 3 of the 24 subjects. Remaining genres included Electronic, Rock, R&B and Hip Hop. There was one song that was chosen twice, "Don't Stop Believing" by Journey, and one artist, Bruno Mars, that was selected twice (subjects chose different songs). To see a full list of artists, songs, genres and tempos see Appendix D.

Suggestions for Future Research

There is little to no research on music and cognition that assesses the arousal hypothesis for test performance. As a result, the purpose of this study was to provide the preliminary work to answer the question: does time effect arousal levels during testing? This study purposely created a within subjects design with all subjects receiving the same order of music samples to assess the impact on arousal when music is implemented during testing, and if time impacts arousal. This design was selected to help answer whether the arousal

hypothesis should be assessed more frequently in music and cognition research and cognitive performance research. The results suggest that arousal levels decay over time, supporting the arousal hypothesis.

This research can be used as the foundation of future research into music and cognition such as assessing when music should be implemented. The data suggest that music before testing does not impact arousal for testing; Block 1 displayed significantly higher means for SCL, SCR (xSCR) and number of SCRs (nSCR), and it was the only block with a positive sloped tonic level. This suggests that music implemented before testing may not be needed, as arousal levels are already high at the beginning of testing. Research also suggests that music implemented during testing may be more beneficial, as arousal levels were shown to decay over time. This is supported by the analyses for the number of peak SCRs for block comparisons with music and without music. The results showed that Block 2 had the highest mean number of peak SCRs (nSCR) when music occurred in the analysis but had the second highest mean number of peak SCRs when music was not included in the analysis. This was also true for Block 3 as it displayed the third highest number of peak SCRs (nSCR) when music was included and the lowest number of peak SCRs when music was not included in the analyses. Though music was shown to increase arousal levels, the best time to implement music during testing is beyond the scope of this project, but would be worthwhile to assess for future research.

Testing material, EDA test script and music samples should be modified from this study, if replicated. For the testing material, it is recommended that more than 69 questions are provided in order to ensure that subjects will not complete the testing material early. It is also recommended that the same questions style is used. This study utilized questions from the Verbal Processing section of the GRE, but the GRE contains both reading comprehension and discrete questions. It is recommended that only discrete questions are used, as reading comprehension questions take longer to read, and there is more variation in testing abilities for reading comprehension between subjects.

Finally, there are a few recommendations for measurement of EDA and implementing music during testing, should this study be replicated. When assessing arousal through electrodermal activity (EDA) for a long period of time, subject's hands frequently became cold by the end of testing. It is suggested that subjects' hands are covered with a towel or warmed before testing. Second, it is important to notify subjects to limit all body movements. Third, for music samples during testing, researchers should consider the number of times the music is implemented, as the song may become less stimulating each time it is heard. Either providing a variety of songs or only implementing the song once or twice might have a better impact on arousal levels.

The results of this study support the arousal hypothesis stating that when a stimulus is presented in an environment, it can help increase arousal levels, which may have an impact on test performance. In this study, participants were asked to take a challenging test that did not show variety over a long period of time. As stated in Yerkes and Dodson (1908), if a person is challenged with a difficult task, they may become frustrated and lose motivation to perform. It was also stated that if there is a lack of change in an environment or a task is seen as boring, then arousal levels can decrease (Pfaff, 2006; Shannon, 1958). The results of this study and previous research suggest that when a challenging task that does not change over

time, arousal levels will decrease, which may impact your testing performance. Posner (1975) also said that arousal levels naturally decrease unless provided with a stimulus to boost arousal. This was also seen in our study, as arousal did decay over time in the last three time blocks, but it increased when music was presented. Music may have an impact on test performance, but it should be viewed as an auditory stimulus to boost arousal.

This study and other research states that music can impact arousal levels, but further development regarding how arousal impacts test performance should be conducted. Research supports the use of participate-preferred music, as it creates a stronger arousal response compared to pre-selected music (Blood & Zatorre, 2001; Craig, 2005). It has also been shown that faster tempos cause an increase in Skin Conductance Response (Dillman Carpenter, & Potter, 2007). This suggests that the type of stimulus used to increase arousal must be assessed to ensure that it will impact arousal. Music has proven to increase arousal, and it is cost effective, individually sensitive and easily transferred to different settings; however, it is not the only stimulus that can be used to increase arousal levels.

This study has the potential to reshape traditional views of cognitive performance. Too often, standardized tests require individuals to sit and take testing material for long periods of time, with no changes in the environment to counteract decaying arousal levels. One cannot perform well after growing disinterested, discouraged or bored (Yerkes & Dodson, 1908), and the same is also true for clinical settings. It is common for clients to grow tired or over-stimulated in a therapeutic session, and a better therapeutic output may be achieved if, in consideration of the arousal hypothesis, a therapist is able to observe a change in arousal levels and provides a different stimulus to support the client in achieving more optimal levels of arousal (Hebb, 1995; Zuckerman, 2014). The arousal hypothesis transfers to a number of disciplines as it is seen as the foundation of cognition (Pfaff, 2006; Parenté & Herrmann, 1996). As more research analyzes how tasks impact arousal levels, we may begin to better understand how to counteract, manipulate and create protocol to maintain arousal levels at optimal levels and support better performance on tasks.

APPENDIX A

Recruitment Flyer

VOLUNTEERS NEEDED For music and cognitive arousal research study *Elevible scheduling is available*

Flexible scheduling is available										
Compensation						Requirements:				
Compensation will be provided in the form of a \$40.00 gift card.						 Must speak English as a first language No more than one year of formal music training Between the ages of 18 and 65 No hearing, visual, or cognitive impairments You must be a WMU student 				
For more information contact:										
Meghan Feeman, MT-BC meghan e feeman@wmich edu										
Ian Kells, MT-BC										
ian.t.kells@wmich.edu									1	
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APPENDIX B

Consent Form

Western Michigan University Department Music Therapy

Principal Investigator: Student Investigator: Title of Study: Edward Roth, MM, MT-BC Meghan Feeman, MT-BC; Ian Kells, MT-BC The effect of auditory stimuli on the arousal hypothesis as measured by EDA testing through verbal processing

You have been invited to participate in a research project titled "*The effect of auditory stimuli* on the arousal hypothesis as measured by EDA testing through verbal processing." This project will serve as Meghan Feeman and Ian Kells's thesis for the requirements of the Masters of Music Therapy. This consent document will explain the purpose of this research project and will go over all the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project. Please read this consent form carefully and completely and please ask any questions if you need more clarification.

What are we trying to find out in this study?

The purpose of this study is to investigate preferred music listening, auditory arousal, and its potential effect on an individual's performance on certain testing criteria.

Who can participate in this study?

This study is open to individuals between the ages of 18-65 who have had less than one year of formal music training. 24 subjects will participate in the study and our inclusionary criteria for participation in the study are as follows:

- Must be between the ages of 18 and 65 years old
- Must have less than one year of formal music training
- Have English as your first language
- Must not have any hearing or visual impairment
- No deficits in cognition or reading abilities

Exclusionary criteria include individuals younger than 18 and older than 65 years old, as well as those who have hearing, visual, or cognitive impairments or more than one year of formal music training. All assessment of this information will be made at the discretion of the investigators utilizing a brief interview script for identifying the above listed inclusionary and exclusionary criterion

Where will this study take place?

Data collection for this study will take place in the Brain Research and Interdisciplinary Neurosciences (B.R.A.I.N.) Lab, room #2019, in the Health and Human Services building at Western Michigan University.

What is the time commitment for participating in this study?

This study requires the subjects to participate in one seventy-three-minute research session.

What will you be asked to do if you choose to participate in this study?

If you choose to participate in this study you will be instructed to provide a preferred song that you find personally motivating or energizing. There will be no limitation on song choice except for the duration of the song, which should be longer than three-minutes. We will use this song during the data collection process.

Once the data collection process begins, you will be asked to wear headphones and an Electro-dermal Activity (EDA) monitor on your third and fourth digits to monitor physiological arousal. These items will be worn for the duration of each testing period. You will then be given brief verbal instructions from the investigators so that you will know how to take the exam. The test itself will contain a portion of the Graduate Records Exam (GRE) using the MATLAB platform on a computer provided by the WMU B.R.A.I.N. Lab.

During the exam you will hear the preferred song you have chosen at various times. The test will be timed and will stop after 60 minutes. The test will be monitored for accuracy, so the speed at which the test is completed will not be important.

What information is being measured during the study?

This section will describe the measurements that we are going to take during your participation in the study.

Two outcomes will be measured during this study:

- The accuracy of questions answered
- The level of physiological arousal.

MATLAB will then be used to monitor the accuracy of the answers provided by you for each of the questions on the test. Physiological arousal will be measured using the EDA monitor that will be placed on your third and fourth digits at the beginning of testing.

What are the risks of participating in this study and how will these risks be minimized?

The risks associated with participating this study include fatigue due to the longer amount of time required to participate in the exam. There may also be slight discomfort due to keeping your non-dominant hand still for EDA analysis and wearing headphones for the full duration of 63 minutes during each testing condition.

What are the benefits of participating in this study?

There are no known direct benefits to you for participating in this study. Your participation may contribute to the knowledge base regarding the implications of using music and auditory stimulation for improving performance on certain tasks.

Are there any costs associated with participating in this study?

There are no costs associated with participation in the study, with the exception of 73minutes of time.

Is there any compensation for participating in this study?

There will be a compensation of \$40.00 in the form of a gift card provided to each participant upon completion of the study. This study may also qualify for those students who may be required to participate in a study as part of their course work.

Who will have access to the information collected during this study?

Only the two student investigators, BRAIN Lab manager, and the principal investigator will have access to the information gathered during this study. All forms and data collected will be stored in a password-protected computer file, on a password-protected computer, in the locked WMU BRAIN Lab.

The identities of all participants will be coded using a set of numbers in chronological order to maintain personal confidentiality. This information will be stored in a password-protected computer file, on a password-protected computer, in the locked WMU BRAIN Lab.

What if you want to stop participating in this study?

You can choose to stop participating in the study at any time for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study with the exception of your loss of monetary compensation.

The investigator can also decide to stop your participation in the study without your consent.

Should you have any questions prior to or during the study, you can contact the primary student investigators, Meghan Feeman, at 317-437-8418 or <u>meghan.e.feeman@wmich.edu</u>, and Ian Kells, at (630) 930-0309 or <u>ian.t.kells@wmich.edu</u>, or the primary faculty advisor, Edward Roth, at (269) 387-5415 or <u>edward.roth@wmich.edu</u>. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

I have read this informed consent document. The risks and benefits have been explained to me. I agree to take part in this study.

Please Print Your Name

Participant's signature

Date

APPENDIX C

Music Preference Form

For this research study, it is requested that you provide the researchers one song that you find personally motivating. This will be defined as a song that is upbeat, that you greatly enjoy, and that induces a strong emotional response, but neither relaxes nor over-stimulates you. You must provide the researcher the song selection before beginning the study. It is also requested that the song only last 3 minutes. If your song selection is shorter than 3 minutes you may not choose it. If the song is over 3 minutes please specify which 3 minutes you would like to be used (for example 0:00-3:00, 1:35-4:35).

Song Title:

Artist:

Specified Time Range:

APPENDIX D

Participant Song Choices

	Artist	Song Title	Genre	Tempo	
1	Silversun Pickups	"Lazy Eye"	Alternative	127 bpm	
2	Odesza	"Kusanagi"	Electronic	75 bpm	
3	Whitney	"Golden Days"	Alternative	153 bpm	
4	M83	"Midnight City"	Alternative	105 bpm	
5	Ookay	"Thief"	Electronic	150 bpm	
6	Thomas Rhett	"Star of the Show"	Country	125 bpm	
7	Ed Sheeran	"Shape of You"	Рор	96 bpm	
8	Luke Bryan	"Fast"	Country	130 bpm	
9	Fergie	"Fergalicious"	Рор	129 bpm	
10	Rise Against	"Savior"	Hardcore	112 bpm	
11	Kelly Clarkson	"Stronger"	Рор	116 bpm	
12	A Day to Remember	"Sine U Been Gone"	Metal	128 bpm	
13	Arcade Fire	"Wake Up"	Alternative	139 bpm	
14	Pink	The Great Escape	Рор	80 bpm	
15	Journey	"Don't Stop Believing"	Classic Rock	119 bpm	
16	Bruno Mars	"That's What I Like"	R&B	134 bpm	
17	Journey	"Don't Stop Believing"	Classic Rock	119 bpm	
18	Faith Evans and	"Hope"	Hip Hop	107 bpm	
	Twista				
19	Born of Osiris	"Machine"	Metal	155 bpm	
20	Bruno Mars	"24k Magic"	R&B	107 bpm	
21	Madonna	"Into the Groove"	Рор	116 bpm	
22	Darius Rucker	"Alright"	Country	90 bpm	
23	Oasis	"Live Forever"	Alternative	90 bpm	
24	Rick Springfield	"Jessie's Girl"	Rock	101 bpm	

APPENDIX E

HSIRB Approval Letter



Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination:

October 10, 2017

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