THE EFFECTS OF MUSICAL TEMPO AND DYNAMIC RANGE ON HEART RATE VARIABILITY IN HEALTHY ADULTS: A COUNTERBALANCED, WITHIN-SUBJECTS STUDY

A Thesis
by
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Abstract

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A COUNTERBALANCED, WITHIN-SUBJECTS STUDY

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Music therapists often use music to facilitate changes in physiological functioning. In order to better inform the selection and creation of such music, this study explored the influence of tempo and dynamic range on heart rate variability. Two guitar improvisations were digitally recomposed to create fast and slow (90 and 60 beats per minute) as well as narrow and wide dynamic range conditions, while all other elements of the recordings were held constant. It was hypothesized that faster tempo and wider dynamic ranges would cause an increase in physiological arousal, indicated by decreased heart rate variability. It was also predicted that participants ($N = 32$) would perceive selections with slower tempos and smaller dynamic range as more relaxing. No significant differences were found in heart rate variability for either condition. The narrow dynamic range condition produced an elevation in average heart rate, contrary to expectations based upon previous clinical recommendations. Participants did not perceive any condition as more relaxing, but perception of relaxation level weakly correlated to increased heart rate variability. The results

from this study suggest that wider dynamic range is not necessarily contraindicated for music for relaxation and that participant input is important in choosing music for relaxation.

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Dedication

This work is dedicated to the children and adolescents with whom I have had the privilege of working. Each of you has influenced my development as a student, a therapist, and a person. Your music has played an important part in the making of my own.

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Chapter 1

Introduction

Music is a universal medium of human expression. All cultures across history have engaged in musical behavior (Hodges & Haack, 1996). A commonly accepted definition of this phenomenon by Charles Eagle (1978) defined music as “organized sounds and silences in a flow of time” (p. vi). Music is an integral part of human experience and expression and can manifest itself in intrapersonal and interpersonal ways.

Music has a unique capacity to influence both the mind and the body. It can both convey and elicit emotions, and emotions, in turn, influence human physiology and behavior (Juslin & Slobada, 2001; Oatley & Johnson-Laird, 2011). From Plato’s *Republic* to the media frenzy surrounding the suicide attempts allegedly inspired by Ozzy Osbourne’s “Suicide Solution” and other heavy metal music (Rother, 1990), the power of musical communication in the psychological and physiological realms continues to be a source of questioning, debate, and research. Because music is capable of affecting both the body and the mind, it provides an intriguing medium through which to explore the connection between the psychological and the physiological realms.

The field of psychophysiology uses the framework of physiological responses in the study of the relationship between the mind and the body (Hugdahl, 2001). Cacioppo, Tassinary, and Berntson (2000) described the far-reaching implications of psychophysiological insights into human experience and functioning: "Psychophysiology, therefore, is based on the assumptions that human perception, thought, emotion, and action are embodied phenomena, and that physical (e.g. neural and hormonal) responses can shed light on human nature" (p. 7). Psychophysiologists' work is based on the assumption that physiological responses to psychological stimuli can provide insight into reactions and responses.

By extension, psychophysiological response systems are body systems that are particularly responsive to psychological states and experiences (Hugdahl, 2001). This includes autonomic nervous system effector organs, which include a variety of structures from the sweat glands to the heart. Psychophysiological responses are responses from these systems and organs that have been triggered by a psychological experience or state (Hugdahl, 2001).

While the understanding of psychological and physiological connections is certainly fascinating from an academic standpoint, the practical and clinical applications for knowledge in this field are particularly far-reaching. According to Hugdahl (2001), "ANS [autonomic nervous system] activity mediates stress responses and emotional arousal, two concepts at the core of a psychophysiological approach to the mind-body interface, as well as many psychosomatic diseases" (p. 84). Many diseases and disorders are exacerbated or even caused by both mental and physical stress (Cohen, Janicki-Deverts, & Miller, 2007). These may include depression, cerebrovascular disease, HIV/AIDS, upper respiratory tract infections, autoimmune diseases, and many others (Cohen et al., 2007). While it is commonly accepted that reducing psychological stress produces benefits, researchers have found that altering physiological parameters can have beneficial effects on health by reducing stress on body systems (Prensner, Yowler, Smith, Steele, & Fratianne, 2001). In other words, reducing both psychological and physiological stress can have a beneficial effect on mental and physical health.

It is precisely this two-fold aspect of psychological and physiological need that makes music an effective therapeutic medium to address a variety of diseases and disorders. The therapeutic application of music can have wide-ranging beneficial effects on cognitive, social, emotional, communicative, and physical functioning (American Music Therapy Association, 2014). The American Music Therapy Association (AMTA, 2014) has defined music therapy as "the clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program" (What is music therapy? section, para. 1). The definition continues in more detail:

> Music Therapy is an established health profession in which music is used within a therapeutic relationship to address physical, emotional, cognitive, and social needs of individuals. After assessing the strengths and needs of each client, the qualified music therapist provides the indicated treatment including creating, singing, moving to, and/or listening to music. Through musical involvement in the therapeutic context, clients' abilities are strengthened and transferred to other areas of their lives. Music therapy also provides avenues for communication that can be helpful to those who find it difficult to express themselves in words. (AMTA, 2014, What is music therapy? section, para. 2)

Music therapy is used to address a wide variety of physical and psychological conditions. Reducing stress at both the psychological and the physiological level is a critical element of therapy, and past research has demonstrated the effectiveness of this medium (Bruscia, 1998).

While music therapy has been demonstrated to have beneficial effects in a variety of domains of functioning, the underlying mechanisms of change in the psychophysiological realm remain elusive. Past research into underlying psychophysiological processes has demonstrated a range of effects (Bartlett, 1996; Hodges, 2010). Researchers have demonstrated that music influences psychophysiological responses, but the musical characteristics and structures that affect psychophysiological response have rarely been isolated, and much of the existing research is inconclusive (Ellis, 2009). Additionally, the musical material typically used in music and psychophysiology literature frequently has limited therapeutic application. In order to provide the research necessary for evidence-based practice, it is important to support and expand the literature exploring the effects of music on the body. Music therapists need to understand the multiplicity of ways that the medium with which they work can affect their clients, and in this way improve the efficacy and appropriateness of treatment.

Definition of Terms

Music therapy. Music therapy is "the clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program" (AMTA, 2014, What is Music Therapy? section, para. 1).

Psychophysiological responses. Psychophysiological responses are changes in body systems triggered by psychological experiences or states; these include autonomic nervous system effector organs such as sweat glands, the heart, the diaphragm, salivary glands, and many other body structures (Hugdahl, 2001).

Dynamic range. Dynamic range is the span of gradations of volume within a selection or piece of music (Dynamics, 2007).

Tempo. Tempo is the speed of music in time; the tempo of a piece of music can fall anywhere on a spectrum from extremely slow to incredibly fast (Ottman, 1998). Tempo is subjectively indicated using descriptive words in a variety of languages, and it is objectively measured and indicated in beats per minute.

Chapter 2

Review of Literature

History of Emotions Perspectives

Any discussion of psychophysiology and music must also include a substantial exploration of the nature of emotion. It is a field of inquiry that incorporates elements of history, philosophy, biology, psychology, sociology, political science, aesthetics, and more. A brief historical overview of Western philosophical, psychological, and biological views on human emotion begins with Aristotle's writings. The definition of emotion he offers in *Rhetoric* includes both emotion's effects on reason as well as the accompanying affective experience: "that which leads one's condition to become so transformed that his judgment is affected, and which is accompanied by pleasure and pain. Examples of emotion include anger, fear, pity, and the like, as well as the opposites of these" (trans. 1967, II: 1). He also commended the ability of artistic tragedy to evoke and cleanse the emotions of pity and fear (see *Poetics*, VI). Later, the Roman Stoics furthered the concept of the conflict between emotion and reason. In his *Essays*, Seneca advocated seeking to overcome passions in order to obtain peace of mind and clarity of judgment, the keys to moral greatness and contentment (see *Essays*, III, "On Anger"). Christian writings in the Middle Ages expanded on this view, describing emotion and morality as intimately linked. Thomas Aquinas conflated vice and passion; the sins of greed, anger, lust, envy, and pride were primarily sins of feeling. By contrast, love, hope, faith, and charity were described as transcending mere emotion (cited in Solomon, 2008).

Enlightenment thinkers in the next century would return to considering the role of emotion in moral decisions and behavior. David Hume's *A Treatise on Human Nature* in 1739 defended the role of emotion as a motivator for moral behavior, while Immanuel Kant attacked the influence of fleeting "inclination" when making ethical judgments (cited in Solomon, 2008). The beginnings of the Romantic Movement in the late 1700s, however, were founded in a rejection of the Enlightenment idealization of reason. Romantic composers, artists, writers, and philosophers saw emotion as a valid mode of aesthetic expression, thought, and even truth (Mehennet, 1981).

An entirely different strain of philosophy of emotions is rooted in Descartes' (1649/1989) treatise, *On the Passions of the Soul*. He postulated a biological as well as philosophical basis for the mind-body connection, naming what is now identified as the pineal gland as the location where thought and passion, mind and body interact. Centuries later, Charles Darwin's influence extended beyond the realms of biology and ushered in a new philosophical perspective focusing on human behavior rather than human thought. *The Expression of the Emotions in Humans and Animals* (1872/1998) characterized emotional behaviors as formerly adaptive responses; for example, clenched teeth as an expression of anger was postulated as the remains of an adaptive, aggressive biting response.

Emotions theories underwent another paradigm shift in the context of the first and second world wars. Jean-Paul Sartre's (1939/1948) *Emotions: The Sketch of a Theory* explored the idea of emotions as a purposeful strategy for coping with reality. This existential twist to the ongoing exploration of emotion has continued to influence modern theories of emotion.

Theories of Emotion

In the last half-century, various theories of emotion have been proposed. Many are so specific as to limit generalization, while others so broad as to minimize practical application. For example, Frijda (2008) introduced the broad definition of emotion as "particular phenomena of feeling and behavior" (p. 68). He goes on to discuss the nature of emotions as individual phenomena and also the intrapersonal mechanisms and processes associated with emotional experience. Several approaches to emotion, however, are of particular interest to this investigation. The communicative theory of emotions proposed by Oatley and Johnson-Laird (1996; Johnson-Laird & Oatley, 2008) conceptualizes emotions as communications, involving signals that express one individual's emotional states. While this approach is founded in evolutional theory and focused primarily on behavioral manifestations, emotion as communication is a theme that has surfaced and resurfaced throughout the history of philosophy of emotion.

One tenet of the communicative theory of emotion is the division between basic and complex emotions (Oatley & Johnson-Laird, 1996; Johnson-Laird & Oatley, 2008). This concept, while controversial, is central to several other theories of emotion as well (Oatley, Keltner, & Jenkins, 1996; Russell, Bachorowski, & Fernandez-Dols, 2003). Basic emotions have psychological causes regarding the basic goals related to survival. Basic emotions can have objects but not propositional content, and they cannot be deconstructed into lower level processes. Additionally, they prime and trigger characteristic physical patterns, such as facial expression and specific patterns of behavior. The nine basic emotions are happiness, anger, sadness, hate, fear, disgust, sexual love, parental love, and love for caregivers. Other emotions are categorized as complex emotions, which are composites of basic emotions but also involve evaluations. They involve conscious conclusions and propositional content regarding the object, causes and effects, and implications of the stimulus for the emotion (Oatley & Johnson-Laird, 1996; Johnson-Laird & Oatley, 2008).

Another recent theory relevant to this study is the componential approach (Juslin & Västfjäll, 2008; Scherer, 2004). This perspective accounts for the various elements involved in emotions, separating affective from physiological elements of emotional experience while still accounting for coordination between elements. Specific components of emotional experience vary, but most lists include both physiological and subjective factors. For example, Scherer (2004) included five categories of emotional response, physiological arousal, motor expression, subjective feeling, behavior preparation, and cognitive processes. Juslin and Västfjäll (2008) also included five components: subjective feeling, physiological arousal, expression, action tendency, and regulation.

Theories of Music and Emotion

Given the integrative character of emotion in music and the ability that music has to express and elicit emotions, the complicated relationship between these two phenomena has continued to spark debate regarding meaning and mechanism. Meyer's (1956) theory of emotion and music is one of the most familiar and pervasive explanations for the unprecedented ability of music to influence emotion. According to Meyer, the inherent structure of music, combined with knowledge of musical style, creates expectations in the listener. The listener responds accordingly when the resolution to these expectations is delayed and experiences a different response when the resolution finally arrives. In this model, the basic concept of tension and resolution is responsible for the affective and aesthetic power of music. One issue of note regarding Meyer's theory is dishabituation. As a listener becomes attuned to repeated musical patterns, he or she comes to expect the same experience, and the music becomes less emotionally evocative. It is the variations in the music that dishabituate the listener from the established patterns and result in higher arousal.

One of Meyer's contemporaries, Langer, propounded an alternate theory in 1957 proposing that music acts as symbols for emotion, rather than resulting in emotion in the listener. In this sense, it is the ambiguity in music that allows listeners to draw various emotions from the music, depending upon their own experience and the meaning they ascribe to these musical symbols (Langer, 1957). In 1970, Berlyne proposed a very different idea; namely, that an optimal balance of complexity and familiarity in music causes pleasure in listeners. Overly complex music loses hedonic value, as does music that is familiar to the point of causing boredom. Berlyne also takes into account individual and cultural associations with specific genres, composers, artists, or pieces of music that also may affect the associated emotional experience.

Later theorists attempted to distinguish between emotions than can and cannot be expressed or evoked by music (Putnam, 1987; Kivy, 1980). The concept was that only certain emotions were musically relevant and that musically relevant emotions were general and mood-based and did not require knowledge of the cause of the emotions. These ideas have been supported in the literature to a certain extent (Collier, 2002).

While there are various theories attempting to describe how music influences emotions, there is little doubt that it does. Music is typically used to assist in self-regulation of mood and emotional states. The power of music to assist in the regulation of emotions is seen as one of the more critical functions of music (Baumgartner, Esslen, & Jancke, 2006; Krumhansl, 1997; Panksepp, 1998).

Psychophysiological Processes and Responses

Autonomic nervous system. Any discussion of somatic emotional experiences must include an overview of the division of the nervous system responsible for physiological expressions of emotion. The nervous system is divided into the central nervous system and the peripheral nervous system. Brain and spinal cord compose the central nervous system, while the peripheral nervous system communicates between the central nervous system and the rest of the body. The peripheral nervous system is further dividend into the autonomic and somatic nervous systems (Larsen, Berntson, Poehlamnn, Ito, & Cacioppo, 2008). While the somatic nervous system is associated with voluntary movement, the autonomic nervous system is responsible for maintaining homeostasis, the internal stability of the body (Jänig, 2003). The final major subdivision is the division of the autonomic nervous system (ANS) into the sympathetic and parasympathetic nervous systems (Thibodeau & Patton, 2008). The sympathetic nervous system increases levels of arousal to prepare the body to respond to stressors. On the other hand, the parasympathetic nervous system decreases arousal in many body systems, while stimulating other functions consistent with a secure context such as digestion and reproduction (Thibodeau & Patton, 2008). The ANS is far more complicated than a simple on-off switch and regulates complex interactions between endocrine, gastrointestinal, cardiovascular, respiratory, and other systems (Hodges, 2010; Levenson, 2003).

Emotional processes are intimately linked to ANS activity; the somatic experiences that accompany emotions are the product of this connection. As described earlier in the componential approach to emotion, the physiological response is the emotion component that encompasses this somatic reaction to stimuli (Juslin & Västfjäll, 2008; Scherer, 2004). Unfortunately, because of the complexity of the interaction between emotion and the ANS, it is difficult to isolate various components. One consideration is that of entrainment, the synchronization of two rhythmic patterns. Physical expressions of musical experiences can affect rhythmic body processes, such as respiration or heart rate (Rassler & Kohl, 1996). Some studies have specifically requested participants to avoid tapping their feet or fingers to the beat to avoid "artefactual" entrainment (Bernardi et al., 2009). In pianists, breathing changes during playing and is influenced by the meter of the music (Ebert, Hefter, Binkofski, & Freund, 2002). In fact, even imagining motor movements can cause changes in respiration (Decety, Jeannerod, Durozard, & Baverel, 1993).

Also of note are issues of perception, both of the music itself and of the emotions expressed or evoked. Van der Zwaag, Westerink, and van den Broek (2011) have postulated that part of the reasoning for using psychophysiological measures to examine emotion is specifically because subconscious responses may take place even before a person is consciously aware of their own emotional experience. Yet another issue is that of emotions expressed by the music versus emotions evoked in the listener. Researchers have not always accounted for this distinction; studies often have focused on expressed rather than felt emotion (Scherer, 2004).

Measures of psychophysiological response. As psychophysiological response affects a wide variety of body systems, there is a range of measures that have been used to study the effects of music and emotion on the body. The most frequently studied factor is heart rate—measured as the number of beats per minute—which is typically recorded with an electrocardiogram (Hodges, 2010). One of the earliest published explorations dates to the mid-1700s, when Gretry, a French musician, observed his own pulse while singing (Bartlett, 1996). Since then, the majority of studies has indicated that heart rate increases with what is termed “stimulative” or “high arousal” music and slows with “sedative” music (Bartlett, 1996; Hodges, 2010). These findings, however, have not been uncontested. Some studies have noted an increase in heart rate with any type of music as compared to silence (Krumhansl, 1997). Others have found no change in heart rate (Hodges, 2010).

While heart rate is a common variable to measure when studying the effects of music and emotion on the body, recent scholarship suggests that average heart rate is an over-simplified measure of the complex interchange that occurs between the cardiovascular system and the autonomic nervous system (Ellis, 2009). Heart rate is controlled by both divisions of the ANS. Under resting conditions, the parasympathetic nervous system maintains a typical heart rate between 60-80 beats per minute. Without the inhibitory function of the parasympathetic nervous system, pacemaker cells fire at a higher intrinsic rate, approximately 105 beats per minute (Brownley, Hurwitz, & Schneiderman, 2000). The sympathetic nervous system also influences heart rate, although the heart responds more slowly to sympathetic input than parasympathetic input because of differences in neurotransmitters (Ellis, 2009). Heart rate variability (HRV) is a statistical measure of the level of variation in time between interbeat intervals and provides a more complete picture of an individual's ANS functioning (Ellis, 2009; Nunan, Sandercock, & Brodie, 2010). It provides a little-explored area in regards the effects of music on the body, with potential for illuminating the lack of consensus regarding heart rate responses.

Breathing and emotional response are closely connected. Breathing is also an integral part of experiencing music. In a review published in 2010, Hodges listed 19 studies that found changes in respiration related to music. Other studies have explored the difference between listening to and performing music on breathing (Ebert et al., 2002). Entrainment is more prominent in respiration than in other measures of psychophysiological response, and multiple studies have explored this aspect of music and respiration specifically (Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006; Haas, Distenfeld, & Axen, 1986; Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008).

Skin conductivity, also known as galvanic skin response or electrodermal response, is a measure of skin's electrical resistance (Andreassi, 2007). Due to the relative activity of sweat glands, skin conductance increases when an individual is aroused, and resistance increases under sedative conditions as secretions decrease and the quality of those secretions changes (Andreassi, 2007; Hodges, 2010). Bartlett's (1996) review listed 14 studies that reported a significant effect on skin conductivity as related to music and sound stimuli and 8 studies that listed no significant effect.

Studies involving electromyographic measures have also yielded inconclusive results. Surface electromyography (EMG) measures muscle contractile activity using surface electrodes placed over the selected muscle group. Surface electromyography is used both to target more generalized tension as well as specific muscle groups. It often is used in music and emotion studies as an objective measure of facial expression by targeting zygomatic muscle activity, a principle muscle group responsible for smiling. Other muscle groups of interest include the corrugator muscle, which causes eyebrow movement during frowning, and the orbicularis oculi, the muscle that encircles the eye and controls eyelid movement (Andreassi, 2007). Findings in the literature strongly support the idea the music influences muscle tension (Hodges, 2010).

Oxygen saturation is a convenient and informative measure of the well-being of hospitalized and medically compromised individuals. An oximeter measures the level of oxygen saturation in the blood. It often is used with hospitalized individuals and generally is recognized as a strong indicator of medical well-being in the moment (Del Olmo, Rodríguez Garrido, & Ruza Tarrío, 2010; Longhi & Pickett, 2008). Music exposure increases oxygen saturation in patients in neonatal and pediatric intensive care units (Cassidy & Standley, 1995; Del Olmo et al., 2010; Longhi & Pickett, 2008). Its applicability is less certain when the population of interest is healthy.

A more complex measure of psychophysiological arousal includes what are commonly described as “chills” or “thrills.” This is a more subjective measure that typically relies on self-report and attempts to measure the distinct experience accompanied by a sensation of “shivers down the spine” or “goose-pimples” (Grewe, Nagel, Kopiez, &

Altenmüller, 2007; Panksepp, 1995; Sloboda, 1991). Not all people report experiencing chills (Goldstein, 1980), which differentiates this variable from universal measures such as heart rate or respiration rate.

Recent research has demonstrated a growth in interest in biochemical responses to autonomic arousal, arising partly out of the relatively new field of psychoneuroimmunology (Hodges, 2010). The interaction between experience of stress, as regulated by the ANS, and related hormone changes is complex, but there are some distinct chemical markers that can be easily measured. Stress-related hormones and antibodies, such as cortisol and IgA, are two frequently examined biochemical indicators of the body's response to music. Most studies examining these variables have published significant results, but there is still a comparatively small number of studies using biochemical response as a dependent variable (Bartlett, 1996; Hodges, 2010).

Other variables of interest include blood pressure, blood volume, skin temperature, gastric motility, body movements, and pupillary reflex (Bartlett, 1996). A decreasing interest in some of these variables has been evident in the literature published in the past decade, while some of them have rarely been studied. Even so, most of those published have found significant changes related to music (Bartlett, 1996; Hodges, 2010).

Music Therapy and Psychophysiological Response to Music

Exploring the body's response to music is undoubtedly of interest, but the clinical applications of such a topic are equally, if not more, important. Increasing our understanding of the way the body responds to music will increase our therapeutic efficacy and sensitivity. Music therapists use music in a variety of therapeutic settings and with a wide range of goal areas, with the use of music being the unifying constant. The power of music is the keystone of the practice, and understanding its effects as much as possible is essential to the safe, ethical, and effective application of music.

Receptive Methods of Music Therapy

Receptive methods of music therapy is a major category of interventions that puts the intrinsic ability of music to change mental and physical ways of being and processing at the very forefront of the intervention (Grocke & Wigram, 2007). Receptive experiences are differentiated from active music therapy experiences by the fact that the client or patient is the recipient of the music, rather than an active music maker. Receptive experiences are two-part, involving the receiving of the music and the response to that experience. Many different kinds and styles of music and modes of presentation are used, and responses also may be in one or more of many modalities. The focus of both the receiving and the responding is determined by the goals towards which the client is working (Grocke & Wigram, 2007). Bruscia (1998) listed types of receptive experiences, including music relaxation, song discussion or reminiscence, imaginal listening, music collage, somatic and eurhythmic listening, music appreciation activities, and music listening experiences based on the client's preferred music. While all of these types of receptive experiences are related to psychophysiological response, music relaxation is closely linked to the different subdivisions of the autonomic nervous system.

Benefits of Receptive Methods

The benefits of receptive methods of music therapy, and more specifically music relaxation, are widespread. One of the most common settings for music relaxation is in medical settings, in which these interventions can reduce stress and tension (Bruscia, 1998; Hanser, 1996, 1999; Kibler & Rider, 1983; Pelletier, 2004), reduce anxiety before medical procedures (Metzler & Berman, 1991; Saperston, 1999), act as an audioanalgesic in general situations as well as for specific procedures (Rider, 1985; Barker, 1991), and regulate breathing (Hanser, 1996, 1999). In mental health settings, music relaxation also assists in the reduction of stress, agitation, and anxiety. Additionally, music may assist in orientation (Grocke & Wigram, 2007). In work with older adults, music is frequently employed to assist in the reduction of agitation, especially when such agitation is poorly controlled by pharmacologic methods (Okada et al., 2009). Music relaxation can be used in both individual and group settings (Grocke & Wigram, 2007).

While all of these benefits are clinically significant, there is one element that bears further explanation because of its wide-ranging influences on physical and mental health, as well as overall quality of life. The experience of stress is intimately linked with autonomic arousal and may originate from physical or psychological stressors, events that are perceived as taxing or overwhelming an individual’s inner and outer resources (Turner & Carroll, 1985).

Reducing stress has health benefits that extend into the realms of both physical and mental health (Cohen et al., 2007). Reducing the rate of physiological parameters such as heart and respiration rate correlates with a reduction in the level of stress on related physiological systems (Prensner et al., 2001). Addressing mental stress may assist with reducing physical stress, and vice versa (Cohen et al., 2007).

Certain diseases have been strongly linked to high levels of stress, most notably depression, cerebrovascular disease, and HIV/AIDS. Other disorders in which stress level plays a critical role include upper respiratory tract infections, autoimmune diseases, asthma, and wound healing (Cohen et al., 2007). Stress and immune function are closely related, and multiple studies in many populations have found this to be the case. Examination stress was found to impair immune function and result in more frequent illness in college students (Glaser et al., 1987; Glaser, Kiecolt-Glaser, Stout, Tarr, Speicher, & Holliday, 1985). A similar study with a different population found that caregivers of individuals with Alzheimer’s disease also experienced deficits in immunity and also experienced longer durations of illnesses (Kiecolt-Glaser & Glaser, 1987). Stress also impacts neurological functioning (Pacák & Palkovits, 2001). In one particularly disturbing statistic, Mittleman et al. (1995) noted that the likelihood of a heart attack approximately doubles in the 2 hours following an episode of intense anger. Emotional and environmental stress directly impacts health in a variety of ways.

The impact stress has on health is illustrated by the elevation of psychophysological responses. While many of the variables previously discussed have a long-standing, respected position in the measurement of psychophysiological response, HRV does not have an equal history of use as a dependent variable. HRV, however, has been found to be a remarkable indicator of overall health, and also as a strong diagnostic tool for certain cardiac conditions (Nunan et al., 2010; Thayer & Lane, 2007). Low HRV has also been associated with increased risk of mortality regardless of cause (Thayer & Lane, 2007).

Music Therapy and Psychophysiological Measures

Even though psychophysiological indicators are a good measure of health and stress, the music therapy literature has not utilized such parameters extensively. Medical music therapy has been a notable exception, particularly in the area of the Neonatal Intensive Care Unit (NICU). Outside of the hospital, however, comparatively few studies have measured the impact of music therapy on psychophysiological dependent variables. A wealth of investigation into psychophysiological response to music exists, but the majority of these studies do not involve music therapy provided by a certified professional. Moreover, the music selections are often not compatible with those typically used in music therapy settings.

Physiological measures can provide valuable insight into an individual's well-being. This insight can be especially important when working with populations with whom verbal communication is limited. For example, physiological parameters are accepted as an accurate indicator of well-being for infants in the NICU (del Olmo et al., 2010).

Standley and Whipple (2003) reported a meta-analysis of the existing NICU music therapy literature. They found a large effect size of nearly a standard deviation and a remarkable level of consistency in results. Physiological variables measured in this population include heart rate, respiration rate, and oxygen saturation (Standley, 2002). Interventions typically consist of live or recorded music that is carefully selected according to strict guidelines. Standley and Whipple (2003) suggested that music in the NICU be nonalerting, with only voice or one accompanying instrument, steady rhythm, minimal dynamic variation, higher ranges, and in a major mode. Music that meets these criteria and is played at an appropriate volume for 1.5 hours a day for 30 minutes at a time has significant, beneficial effects on infants, with patients demonstrating lower heart and respiration rates and higher oxygen saturation (Caine, 1991; Cassidy & Standley 1995; Coleman, Pratt, Stoddard, Gerstmann, & Abel, 1997; Flowers, McCain, & Hilker, 1999; Teckenberg-Jansson, Huotilainen, Polkki, Lipsanen, & Jarvenpaa, 2011). While the effect that music has on infants in the NICU has been well documented, premature infants experience very different responses to all stimuli, including music, making findings in NICU music therapy literature difficult to generalize to other populations.

Researchers have also studied the effects of music therapy on physiological response in children in medical settings. Some of these studies involve procedural support, a process in which the music therapist assists and supports the child through medical procedures, often providing an alternate focus of engagement and as well as facilitating relaxation. Some procedural support studies have produced inconclusive results regarding physiological measures (Robb, Nichols, Rutan, Bishop, & Parker, 1995; Whitehead-Pleaux, Zebrowski, Baryza, & Sheridan, 2007). Others have indicated significant results. Whitehead-Pleaux, Baryza, and Sheridan (2006) found that burn patients experiencing a dressing change experienced a significantly greater drop in heart rate during a music therapy interaction as compared to patients in a verbal intervention condition. Another intriguing area of research that has not received as much attention is the effect of music therapy on immune system function. Lane (1995) found a significant increase in secretory IgA, a measure of immune function, in pediatric patients immediately after a music therapy session.

Adults in medical settings have not been as extensively studied as younger patients, but some recent studies have used physiological indicators to explore the effect of music therapy. Adults being weaned from a mechanical ventilator demonstrated significantly less anxiety during trials when music therapy was provided, and significant differences have been found in heart and respiratory rate (Oliva, Hunter, Sahler, Gaisser, & Salipante, 2009). Working with oncology patients, Ferrer (2007) found significant decreases in diastolic blood pressure in patients undergoing chemotherapy after a brief music therapy session consisting of live, familiar music. While the music therapy studies involving physiological measures in adult medical settings are sparse, the findings are promising.

Immune function in healthy adults is an additional area of interest that has not been extensively researched but shows promise. Two studies examining the effect of the Bonny Method of Guided Imagery and Music, an advanced practice method of receptive music therapy, have found significant decreases in basal levels of cortisol. Participants demonstrated significant decreases in levels of cortisol at follow-up after six bi-weekly Bonny Method sessions (McKinney, Antoni, Kumar, Tims, & McCabe, 1997).

A few studies have measured physiological response to music therapy in other populations. Bergström-Isacsson, Julu, and Witt-Engerström (2007) explored the effects of different music stimuli on the autonomic response of persons with Rett syndrome. This study is unique in that “calming” and “activating” music was chosen by the caregivers of participants; other stimuli included selections of horn music designed to be “activating” and vibroacoustic therapy. The authors found that the autonomic response to music was not always what caregivers expected and noted that responses were difficult to detect by behavioral observation alone and required more formal monitoring. Mean arterial pressure, cardiac sensitivity to baroreflex, and cardiac vagal tone were measured. Results were mixed, but did indicate that the horn music was the most effective at provoking a sympathetic response, and that vibroacoustic therapy, both with and without calming music, was effective for stimulating a parasympathetic response.

Okada et al. (2009) studied the effect of music therapy sessions with older adults with cerebrovascular disease and dementia. Their findings indicated that parasympathetic activity increased and sympathetic activity decreased significantly after music therapy sessions, as demonstrated through an increase in HRV and endocrine changes, such as reduced levels of plasma adrenaline and noradrenalin. The authors noted that agitation and its accompanying behaviors are some of the greatest challenges for this population and that directly influencing autonomic response may assist in reducing signs of agitation. While there has been extensive research on the effect of music on psychophysiological response, research in autonomic response within a music therapy setting has received comparatively little attention. This area of research offers promising possibilities to further support the growing effort in evidence-based practice.

Music Selection for Therapeutic Application

The benefits of using music for therapeutic goals has been discussed, but the process of choosing appropriate music with the goal of effecting change in psychophysiological state is a complex one. Many factors, such as preference, familiarity, and associations must be considered, as well as the fundamental characteristics of the music itself. Mode of presentation also must be considered. The influence of this multiplicity of factors on the client's experience of music is complex and still poorly understood. Many general recommendations based on clinical experience, however, have emerged over the years.

Grocke and Wigram (2007) offered key points from their recommendations regarding selecting music for relaxation and imagery, including a specific focus on choosing music to facilitate the relaxation response.

It is generally accepted that it is most effective to use the client's preferred genre or incorporate elements of the client's preferred styles (Grocke & Wigram, 2007). A client's preferences may or may not be appropriate for a specific goal, however, and group settings do not allow for all individual preferences to be taken into account. Considering these issues, one of the most common genres used by music therapists for relaxation is classical music. Other genres frequently used include new age, light jazz, occasionally trance music, music written and recorded for meditation, and Celtic music (Grocke & Wigram, 2007).

An additional consideration should be cultural or personal associations with music (Grocke & Wigram, 2007). Some pieces of music serve specific functions, such as music commonly used at weddings or funerals which may carry strong associations that may interfere with the relaxation response. Other pieces carry connotations or associations at an individual level because of past experience. These associations can extend to specific instruments or voice types. Grocke and Wigram (2007) recommended careful consideration of vocal elements, due to the immediacy of the associations with the human voice.

Recommendations in the literature also include suggestions regarding specific elements and characteristics of music chosen for receptive music therapy. Generally speaking, sedative music features a slow tempo, simple orchestration, narrow dynamic range, and few changes. Stimulative music typically has a faster tempo, more complex orchestration, greater dynamic variation, and more frequent changes in elements (Grocke &

Wigram, 2007). More specific recommendations are summarized in Table 1, which has been synthesized from several sources (Dellacherie, Roy, Hugueville, Peretz, & Samson 2011; Ellis, 2009; Grocke & Wigram, 2007; Khalfa et al., 2008; Steinbeis, Koelsch & Sloboda, 2006; van der Zwaag et al., 2011).

While there is a remarkable level of consistency in recommendations based on clinical experience, studies systematically measuring psychophysiological response to elements of music are few, and frequently exhibit low external validity, at least from a music therapy standpoint.

Studies Examining Psychophysiological Response to Music Elements or Characteristics

While there is a substantial body of literature that examines psychophysiological responses to music, many authors fail to specify the musical selections used or describe specific criteria. Only studies that consider specific characteristics and elements of music will be discussed here. For a comprehensive literature review, see Hodges (2010) or Bartlett (1996). Eight studies were identified that examined isolated elements of music and its effect on listeners. Two of these studies systematically manipulated musical elements and utilized subjective, participant-assigned measures of arousal.

Holbrook and Anand (1990) examined the effects of tempo on perceived activity and affect. The researchers chose an obscure jazz piece, *I Found Love*, performed by Sarah Vaughan, which was highly unlikely to be familiar to participants. The song was transcribed and programmed into a Casio 701 keyboard, and 14 different recordings of the piece were created at different tempi ranging between 57 and 348 BPM. Participants ($N = 44$) were drawn from undergraduate university students.

Table 1
Characteristics of Music for Receptive Methods of Music Therapy

Elements	Sedative	Stimulative
Tempo	Slow, steady	Fast, featuring both sudden and gradual changes
Mode	Typically major	May include minor
Harmony	Simple and predictable	Complex harmonies, unexpected progressions
Timbre	Minimal instrumentation, some timbres (brass and percussion) used with caution	Complex orchestration, including a variety of timbres
Articulation	Principally legato	Staccato, accents, and heavy emphasis
Texture	Consistent texture	Dense texture and/or changes in texture
Melody	Narrow ranges, often stepwise/conjunct melodies	Wide ranges, disjunct melodies
Rhythm	Consistent, light emphasis	Frequent changes, heavy emphasis, syncopation
Consonance/Dissonance	Principally consonant	Higher levels of dissonance
Form	Repetition (both motives and larger sections) is a major component	Variation (violation of expectancy)
Dynamics	Narrow range, few changes, quieter overall level	Wide range, frequent and sudden changes
Meter	Steady, familiar meters	Mixed or unfamiliar meters

Note. Information in Table 1 was synthesized from multiple sources: Dellacherie, Roy, Hugueville, Peretz, & Samson 2011; Ellis, 2009; Grocke & Wigram, 2007; Khalfa et al., 2008; Steinbeis, Koelsch & Sloboda, 2006; and van der Zwaag et al., 2011.

They were randomly assigned to high and low arousal conditions, with the high arousal group participating in a challenging anagram task and the low arousal group sitting still with their eyes closed during the presentation of the music stimuli. Participants marked perceived activity on 7-point continua between eight sets of adjective antonym pairs (agitated/calm, energetic/listless, slow/fast, etc.). Affect was measured in the same way using six different pairs of adjectives (displeasing/pleasing, unpleasant/pleasant, like/dislike, etc.). Internal reliabilities of the measures were high, with coefficient alphas of .98 and .95 respectively. The results indicated that perceived activity increased as tempo increased. The affective measure demonstrated similar results to the inverted U-shaped curve of hedonic value postulated by Berlyne (1970), although the variable of interest was tempo, not complexity. Peak preference was found at 108 BPM, with the level of preference decreasing as the tempo increased or decreased from that point.

While this study examined perception and preference more than psychophysiological effects, the techniques for manipulation of musical elements are of interest in this study. Holbrook and Anand (1990) noted that keeping all elements constant—other than the element of interest—is essential to isolating what characteristics of music affect listeners, and many more recent studies have featured very little control over the music stimuli presented.

Husain, Thompson, and Schellenberg’s (2002) more recent exploration was structured in a manner similar to that of Holdbrook and Anand’s (1990) study. In an extension of examinations of the so-called Mozart effect, Husain et al. manipulated the tempo and mode of a MIDI file of Mozart’s two-piano sonata K. 448 and measured the effects on performance of a spatial task, arousal, and mood. Undergraduate students in a psychology course (N = 36) listened to one of four combinations: major/fast tempo, minor/fast tempo, major/slow tempo, and minor/slow tempo before participating in a task requiring them to visualize how a piece of paper would look after being folded and cut a certain way. Participants also rated mood and arousal using a revised version of the Profile of Mood States and the Affect Grid. As expected, participants in the major/fast tempo condition performed best on the spatial task. Fast tempo resulted in increased ratings of arousal regardless of mode, although some interaction was noted between mode and tempo as minor mode appeared to moderate the effect of tempo slightly. The minor mode music stimuli elicited negative shifts in mood. This study also demonstrated good control over music elements, although the dependent variables are of less interest to the current investigation.

The previous studies have demonstrated different methods of manipulating musical elements. These next four studies, on the other hand, include specific psychophysiologial dependent variables. The musical stimuli vary, but do incorporate or attempt to measure specific elements of interest.

Lingham and Theorell (2009) broke ground in a little-researched area, using self-selected, familiar music as the stimuli. Participants (N = 38) were instructed to choose two pieces of familiar, favorite music, one stimulative (joyful, uplifting) and one sedative (relaxing, slow, gentle). Participants rated stimulatory emotions using a visual analog scale before and after each selection. Order effects were controlled by randomizing the order of presentation, and a three minute rest period was allotted between selections. Heart rate, respiration rate, and expiratory carbon dioxide were measured continuously. The results were much more pronounced for stimulatory music, with strong significant increases in heart rate and a decrease in expiratory CO_2. For sedative music, researchers found a slight, but statistically significant increase in heart rate, with the other physiological measures remaining constant. Lingham and Theorell (2009) suggested that this effect may have been due to the participants' inability to "make the 'correct' selections themselves" (p. 160), although understanding of the instructions was confirmed at the time of the experiment. The authors also noted that music listening may produce physiological arousal while simultaneously reducing physiological markers of anxiety.

Arousal and mood are two different concepts, and this study differentiated between the two quite well. The authors mentioned that both stimulative and sedative selections evoked positive feelings in the listeners. Many previous studies have assumed that music conditions that decreased arousal (such as slow tempo) also increased negative affect, but the interaction is clearly more complex. Husain et al, (2002) noted several additional observations of interest, including that some participants demonstrated a noticeable increase in heart and respiration rate during self-selected "sedative" music. In other words, music that an individual may find "relaxing" may actually increase psychophysiological measures of arousal. Distinguishing between the subjective experience of relaxation and actual change in psychophysiological parameters is important for music therapists, especially those working with individuals with medical conditions.

Gomez and Danuser (2007) examined relationships between a variety of musical elements and psychophysiological measures of emotion. Participants (N = 31) were presented with 16 selections of standard classical repertoire, drawn from previous studies, and presented in a mixed order. Three musical experts rated eleven characteristics of the music on a 7-point scale: tempo, rhythm, accentuation, rhythmic articulation, pitch level, pitch range, melodic direction, mode, harmonic complexity, consonance, and sound intensity. Participants filled out a 9-point Self-Assessment Manikin, designed to measure felt valence (as opposed to expressed valence) and arousal. Respiratory parameters, including inspiratory time, expiratory time, inspiratory volume, expiratory volume, and percentage of ribcage contraction were measured, as well as skin conductance level and heart rate. Faster tempo, more accentuated, and staccato rhythms were associated with shorter inspiration and expiration times. Faster tempo also was associated with faster heart rate, although the connection was marginal. This study is notable in that the authors attempted to quantify a wide variety of musical elements. The authors recommended that future studies incorporate a factorial design and systematically vary selected musical features.

Van der Zwaag, Westerink, and van den Broek (2011) repeated a similar study, but using popular styles rather than classical. In this study, participants (N = 32) listened to 16 rock and 16 pop songs, selected to provide two songs for each combination of characteristics of interest: tempo, mode, and percussiveness. Researchers asked the participants to complete a simulated office task while listening to approximate a realistic everyday environment. Participants also filled out 7-point Likert scales rating arousal, positive feelings, negative feelings, and tension. Fast tempo music elicited higher ratings of arousal and tension, and minor mode pieces elicited higher arousal ratings as well. Psychophysiological measures included HRV and skin conductance level. HRV was lower during fast tempo music, and higher reactions in skin conductance level were found with highly percussive music. The use of rock and pop styles adds an interesting dimension to the discussion, specifically because the classical excerpts often used may or may not carry associations based on style.

Khalfa et al., (2008) considered the role of entrainment in participant differentiation between happy and sad music. Participants (*N* = 50), all without formal musical training, listened to 1-minute MIDI files of classical music. Musical examples were selected to provide unambiguously happy or sad excerpts, and included Albinoni's *Adagio*; Rodrigo's *Concerto de Aranjuez*; Grieg's *Peer Gynt Suite,* No. 2; Saint-Saëns' *Finale* from the *Carnaval des animaux*; and Mozart's *Concerto* No. 23 (3rd movement) and *Eine klein Nachtmusik* (1st movement). The researchers also removed the pitch variations from some of the excerpts, creating a rhythm-only condition. Heart rate, blood pressure, respiration rate, skin conductance, and zygomatic and corrugator muscle activity were measured. Participants verbally rated each excerpt as happy or sad, and then rated valence and arousal on a numeric scale of 1-10. Participants accurately identified happy/sad music at rates higher than 89%, although not in the rhythm only condition. No differences in heart and respiration rates were found between happy and sad excerpts. Muscle activity, skin conductance level, and blood pressure increased during happy as compared to sad excerpts. The authors postulated that the melodic component of music was necessary to create the emotion-driven psychophysiological response.

While explorations of the effect of music on psychophysiological response are fairly common, there are relatively few that attempt to focus on specific characteristics within the music. Studies of psychophysioloigcal response and music that systematically manipulate individual elements while keeping other aspects of the music constant are even rarer. Only three studies meeting these criteria were identified.

Dellacherie et al., (2011) examined psychophysiological response to dissonance. The authors found that skin conductance rate and electromyograpic responses were sensitive to levels of dissonance in music. They clarified, however, that they were not exploring “musical dissonance,” but rather “sensory dissonance.” The musical excerpts tested consisted of classical excerpts with the leading voice shifted up or down a semitone in the dissonant version. In other words, the excerpts were manipulated to be artificially bitonal, in an effort to generate unpleasant sounds, rather than harmonic dissonance. What the authors refer to as “sensory dissonance” is clearly distinguished from the meaningful dissonance inherent in music used in a therapeutic sense.

Stenbeis, Koelsch, and Sloboda (2006) examined the role of harmony, specifically harmonic expectancy violations, in physiological, neural, and subjective response. Both musicians and non-musicians (n = 12, n = 12, respectively) participated in this study. Participants listened to MIDI files of excerpts from six different chorales by J. S. Bach. The musical examples were manipulated by altering a chosen chord to be either less expected (moving to the Neapolitan Sixth) or more expected (moving to the tonic), with three levels of expectancy, expected—tonic, unexpected—original, and very unexpected—Neapolitan Sixth. The recordings were otherwise identical, without expressive features and with constant tempo and dynamic level throughout.

Participants rated either the extent of emotional response or perceived tension using a computerized slider on a scale marked 0-100, as well as a rating of 1-10 of the overall emotionality of the music. Interbeat interval and electrodermal activity were recorded in a second exposure to the musical stimuli, while participants were asked to indicate whether the excerpt was shorter or longer than the previous one to ensure they were paying attention to the music. An electroencephalogram was obtained to record participant's neurological response. Electrodermal response was found to increase with harmonic unexpectedness. The interbeat interval did not increase. The authors hypothesized that as heart rate has been noted to vary more with valence of stimuli than tension, heart rate may not be as responsive to harmonic changes as to electrodermal response. Local ratings of emotionality did not increase with harmonic unexpectedness, but local ratings of tension did. Overall emotionality ratings did increase with harmonic unexpectedness, and the authors noted that the potential of a single chord to alter the perceived emotionality of an entire excerpt was surprising.

These results imply the possibility of some intriguing ramifications. One is that certain psychophysiological parameters may respond more dramatically to specific elements of music. Another is that a single unexpected chord change has a strong effect on the perception of the larger piece. Regardless, the psychophysioloigcal response can be influenced by a single chord in an excerpt. The interaction between musical elements and psychophysiological response is complex and intricate and merits further exploration.

One final study that merits closer examination is one of a series of studies conducted by Ellis (2009). In this particular study, 24 college students listened to MIDI files of six Scott Joplin and Joseph Lamb rags digitally recomposed at 60, 90, and 120 BPM. Participants rated arousal and valence on a Likert scale. Each participant listened to six different 2.5 minute selections, alternated with equal periods of silence. As is consistent with other studies, tempo was found to affect perceived arousal more than perceived valence, but faster stimuli were rated as both more arousing and more pleasant. What was most interesting about this study, however, was the results of the psychophysiological measures. No significant differences were found in heart rate, interbeat interval, or respiration rate. Both measures of HRV—high frequency power and square root of the mean of squared successive interbeat interval differences—did indicate significant change related to tempo. These results supported Ellis' hypothesis that HRV is a more sensitive and accurate measure of psychophysiological response than heart rate. These findings partially explain the persistent inconsistencies in responses to music as measured using heart rate alone.

Ellis' (2009) use of ragtime music created a strongly rhythmic stimulus appropriate for recomposition. Ragtime music, however, is rarely used in receptive music therapy and features distinctive stylistic characteristics and associations that would be undesirable for most receptive methods. Another factor to consider is that music in this style is almost always performed at a fast tempo, which may have altered listener perceptions.

These eight studies are noteworthy in that the researchers have attempted to isolate and specific components, characteristics, or elements of music while recording psychophysiological response. Musical elements studied varied widely, and included tempo, mode, percussiveness, articulation, pitch level, pitch range, melodic direction, harmonic complexity, consonance/dissonance, and sound intensity. Psychophysiological factors studied also included a wide range of different variables, including heart rate, respiration rate and other respiration variables, skin conductance, blood pressure, and electromyographic response. Out of these eight studies, Stenbeis, Koelsch, and Sloboda (2006) and Ellis (2009) systematically manipulated elements while keeping other aspects of the music constant in addition to recording psychophysiological parameters, a critical distinction when trying to identify the different effects of different elements of music. The limited nature of the number of such studies alone warrants additional research in this area.

Purpose of the Study

While many of the studies discussed demonstrate particular strengths and insights, a review of the literature did not indicate a clear conclusion regarding psychophysiological responses to music (Bartlett, 1996; Hodges, 2010). While it is evident that music does influence psychophysiological response, this interaction is complex and still poorly understood. It is important to further our understanding of how music influences response by isolating and manipulating individual characteristics or elements of music while keeping all other aspects of the stimuli constant in future research (Gomez & Danuser, 2007). Ellis (2009) demonstrated the need for more research incorporating HRV in addition to heart rate or interbeat interval in order to reflect the complex interaction between the sympathetic and parasympathetic nervous systems. HRV is a parameter that has demonstrated the potential to illuminate some of the contradictions and inconsistencies in the literature (Ellis, 2009). Music can affect psychophysiological response, but what characteristics of the music are responsible for these responses are still unknown (Gomez & Danuser, 2007). It is essential to understand the effects of different elements of music on the body when choosing music for therapeutic interventions (Grocke & Wigram, 2007).

The purpose of this study was to examine the effects of tempo and dynamic range on psychophysiological response to music in order to better inform music selection for therapeutic application in music therapy practice. It was hypothesized that:

1. Musical selections featuring a faster tempo would result in physiological measures indicating higher levels of arousal than musical selections with a slower tempo.
2. Musical selections featuring a wider dynamic range would result in physiological measures indicating higher levels of arousal than musical selections with a narrower dynamic range.
3. Participants would perceive musical selections with a slower tempo and narrower dynamic range as less arousing.

Chapter 3

Method

Participants

Volunteers for the study were recruited from undergraduate university students enrolled in general education music classes at Appalachian State University. The researcher visited classes with permission from instructors, gave a verbal description of the study, and provided contact information to all students (see Appendix A). The researcher obtained informed consent prior to participation (see Appendix B) and screened participants for self-reported hearing loss and cardiac history using a written screening questionnaire (see Appendix C). Students with significant hearing loss or cardiac anomalies were not eligible to participate. All participants reported no significant hearing loss and no cardiac conditions.

Participants (N = 32) included 17 males and 15 females with an average age of 19.3 years (ranging from 18 to 24). The majority (n = 26) of the participants were underclassmen, and all were university students enrolled in undergraduate general education music courses. Of the participants, seven identified as Hispanic. Most participants (n = 28) identified as White, with one participant identifying as Puerto Rican, two listing no race, and one identifying as multi-racial. The majority of them played an instrument or sang, while eight participants did not. Musical training ranged from 0-16 years, with an average of 3.8 years per participant. Participants were also asked about musical tastes, and a wide variety of genres were identified. Rock was the most frequently listed genre (*n* = 25) followed by pop (*n* = 19) and alternative (*n* = 18). The number of genres checked ranged from 2 to 13, with an average of 5.6 genres marked as "preferred." See Table 2 for a full listing of preferred genres and frequencies with which each genre was checked.

Table 2
Genre Preference Totals

Preferred genre	Number of participants
Rock	25
Pop	19
Alternative	18
Hip-Hop	16
Indie Pop	16
Classical	12
Electronic	11
Folk	11
Blues	9
Reggae	9
Country	8
Jazz	8
R&B/Soul	6
Other	5
Latin	4
World Music	4
Easy Listening	3
New Age	2

Note. The total number of genres checked exceeds the number of participants, as participants indicated as many as applicable, ranging from 2-13 with an average of 5.6 genres chosen.

The researcher also gathered data on caffeine and nicotine consumption. See Table 3 for self-reported consumption of caffeine and nicotine. Of the participants, 3 listed no caffeine sources, 12 listed one source, 11 listed two sources, and 6 listed three or more sources of caffeine.

Table 3
Self-Reported Consumption of Caffeine and Nicotine

	Caffeine		Nicotine	
	Number of Participants	Percentage	Number of Participants	Percentage
Never	6	18.8%	25	78.1%
Intermittently	19	59.4%	3	9.4%
Daily	7	21.9%	2	6.3%
Frequently	0	0.0%	2	6.3%
Very Frequently	0	0.0%	0	0.0%

Previous literature was examined in order to determine reasonable expectations for the effect size. Due to the limited nature of previous research involving tempo and heart rate variability, only Ellis' (2009) study was sufficiently similar in both independent and dependent variables; no studies involving dynamic range were identified. Ellis (2009) did not report effect size, but the results of his linear trend analysis of the effects of tempo on heart rate variability suggested a medium or possibly large effect size. The researcher used a medium effect size in the power analysis. The total sample size necessary to detect medium differences, as determined by a statistical power analysis using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) was indicated to be 39 (d = .5, α = .05, β = .20). A total of 62 students expressed interest in the study, but only 32 completed the protocol.

Music Selections

To prevent boredom and possible irritation on the part of participants which could potentially influence physiological results, two different musical selections were used, one for each of the independent variables. Two selections of music were improvised by a board-certified music therapist and recorded. The music therapist improvised on steel string acoustic guitar two selections of music appropriate for relaxation. The therapist was requested to improvise selections in the same meter and consisting of similar harmonic complexity, dynamic variability, key, and modality. The researcher chose this instrumentation (solo guitar) and musical parameters based on current music therapy practice and recommendations in the literature for music for relaxation (Grocke & Wigram, 2007).

This study utilized recomposition in order to control as many elements of the music as possible. This technique was recommended by Ellis (2009) in order to minimize confounds within in the music selection. Each music selection was digitally manipulated using the Garageband music editing software to produce two different levels of the independent variables (Apple, 2014). The raw recording featured several distracting high pitched sounds caused by the music therapist shifting between chord shapes up and down the neck of the guitar, as well as white noise in both selections. The music therapist expressed concern about the disproportionately high sound level of the squeaks as present on the recording, and requested that these be addressed through editing if possible. Both the white noise and the string squeaks were minimized in all music selections. Based on the recommendations of a sound engineer, the volume of frequencies of the artifacts was reduced using a multiband compressor. Narrow band compression was applied between 1563 Hertz and 4960 Hertz to address string squeaks. A shelving equalizer with a 16 decibel cut at 6200 Hertz was used to minimize the white noise in the raw recording. In both cases, the frequencies were chosen to target the artifacts without affecting the pitches of the recording. The aim of this processing was to prevent these sounds from causing an alerting response in participants and thus affecting the data collected.

A version of the selection chosen for dynamic manipulation was created with only the above edits. An additional version, the low dynamic sample, was created of the same selection with both the above edits as well as an additional compressor applied to minimize the dynamic variability across the entire selection. The compressor was set at -49 decibel threshold with 15 decibels of headroom. Attack time was set at 0.001 seconds, and the release time was set at 0.023 seconds. This process functionally created another copy of the same selection with the dynamic variations dramatically minimized. The sound engineer estimated that the dynamic range was approximately 15% of the dynamic variability of the unaltered selection. This level of compression was the highest possible without introducing noticeable elements of distortion, which could potentially introduce additional variables.

The selection selected for tempo manipulation evinced some variability of tempo. In order to more accurately reflect a realistic environment in which a music therapist might improvise, the guitarist was requested to play without a click track or metronome. Average tempo was calculated by sampling multiple different selections throughout the recording. The original recording was at a speed of approximately 65 BPM. The same edits to compensate for string squeaks and for white noise as described above were applied. The recording was digitally manipulated to produce two tracks, one at an average tempo of 60 BPM and another at an average tempo of 90 BPM using Garageband’s Tempo Adjustment feature. These specific tempi have been used in previous research (Ellis, 2009). As dramatically decreasing tempo with this feature introduces a perceptible amount of distortion, the end quality of both the slower and the faster recording was comparable, despite the fact that a greater adjustment was made in the case of the faster selection.

All of the tracks had their final level of audio adjusted to have an approximate equal level of average volume. All other aspects of the music were kept as identical as possible. Each selection was approximately 3 minutes long.

Equipment and Instruments

The researcher recorded heart rate data using a Polar™ Heart Rate Monitor device, model number V800 (HRM USA, Inc., Warminster, PA). Heart rate variability was calculated using the accompanying software package designed to interface with the device. In previous literature, both time domain methods such as Root Mean Square Successive Differences (RMSSD) and frequency domain methods have been used to calculate heart rate variability (Ellis, 2009; van der Zwaag et al., 2011). While frequency domain analysis would have been preferable for this study, the equipment necessary to do so was unavailable, so RMSSD was used as the measure of heart rate variability.

The researcher placed a stereo speaker approximately 18 inches directly behind the participant's head. This placement allowed for binaural presentation of the music. Each participant determined the volume according to comfort level using a brief selection from the first track. Following the presentation of each selection, each participant completed a visual analog scale rating each selection from *not at all relaxing* to *totally relaxing* (see Appendix D).

Procedure

The researcher met with volunteers to provide information about the study, answered questions, and secured written consent for participation. Those who consented to participate completed the demographic and screening questionnaire. Participants were asked to abstain from alcohol for 24 hours and caffeine and nicotine use for 4 hours preceding the study; data on caffeine and nicotine consumption were collected using a brief questionnaire administered at the beginning of each appointment (see Appendix E). All participants reported abstaining from caffeine and nicotine for the 4 hrs preceding their appointment; however, a few appointments had to be rescheduled because of reported noncompliance.

Participants were seen on an individual basis for the music listening experience and were provided with several opportunities to ask questions regarding the experiment both before the appointment and also at the beginning of their appointed time. After the participant put on the heart rate monitor, the participant assisted the researcher setting the speaker volume at a comfortable level by listening to a few seconds of the first track. The researcher then instructed participants to take time to make themselves comfortable and informed them that they might keep their eyes open or closed depending on their preference. Participants were asked to avoid extraneous or excessive movement during the experiment. Following these instructions, the researcher collected 5 minutes of pretest heart rate data. Next, each of the four stimuli (fast/slow tempo, wide/narrow dynamic range) were presented in random order, with a 30-second period of silence between selections. After each selection, the participant rated how relaxing each selection was using a visual analog scale. Physiological parameters were collected continuously. After the last selection, 5 additional minutes of posttest information were recorded. The researcher debriefed participants regarding the purpose and hypotheses of the study and also offered the opportunity to request more information about the findings of the study upon its completion. Participants were compensated for their time with $10, which was partially funded through a grant from the

Appalachian State University Office of Student Research. The time commitment for participation in the experiment was approximately 15 minutes for the initial meeting plus 30-45 minutes for the appointment for each participant.

Design and Data Analysis

This study featured a counterbalanced repeated measures design incorporating two separate independent variables. Random order of presentation was used to control for order effects. Alpha was set at 0.05 for all statistical tests. All data distributions were examined to see if they met assumptions of normality. Variables meeting assumptions for normal distribution were subjected to paired samples *t*-test, and those without normal distribution were subjected to Wilcoxon signed-rank tests.

Chapter 4

Results

This chapter presents the results from the study as well as some exploratory analysis of average heart rate across experimental conditions. It was predicted that musical selections featuring a faster tempo and a wider dynamic range would result in physiological measures indicating higher levels of arousal (e.g., lower heart rate variability). See Table 4 for a presentation of means and standard deviations.

Heart rate variability (HRV), a measure of the amount of variation in time between heartbeats, and average heart rate (HR) means between all conditions were similar, and standard deviations were high. Pretest and posttest HRV and HR were also similar across conditions with a large standard deviation.

Prior to running statistical analyses, all dependent and exploratory variables were examined to ensure that they met assumptions of normality. Skewness and kurtosis of the distribution of the difference scores for the pairs of related variables were examined to determine distribution. Dependent variables included physiological arousal as measured through HRV levels and perceived relaxation as measured through visual analog scales (VAS). Average HR was examined as an exploratory variable. HRV difference scores failed to meet assumptions for normal distribution (see Table 5). Variables with difference scores that met the assumption of normal distribution included VAS and HR for all conditions (see Table 5).

Table 4

Means and Standard Deviations for Dependent Variables across Conditions

Dependent Variables	Conditions	*M*	*SD*
HRV	Pretest	55.6	34.2
	90 BPM	52.2	28.4
	60 BPM	54.6	33.3
	Uncompressed	53.7	30.4
	Compressed	52.1	31.4
	Posttest	55.2	31.5
VAS	90 BPM	75.5	17.9
	60 BPM	78.6	18.5
	Uncompressed	75.7	19.5
	Compressed	75.4	23.5
	1^{st} condition	77.8	17.7
	2^{nd} condition	75.0	18.6
	3^{rd} condition	75.8	21.9
	4^{th} condition	76.6	21.5
HR	Pretest	74.9	12.4
	90 BPM	74.1	11.5
	60 BPM	73.7	11.3
	Uncompressed	73.4	11.6
	Compressed	74.4	11.5
	Posttest	74.5	11.2

Note. Visual analog scale scores were also arranged by order of presentation to examine for possible order effects.

Notched box plots were also created to allow for visual inspection of the data. The following figures illustrate the distribution of the HRV and HR data (See Figures 1 and 2).

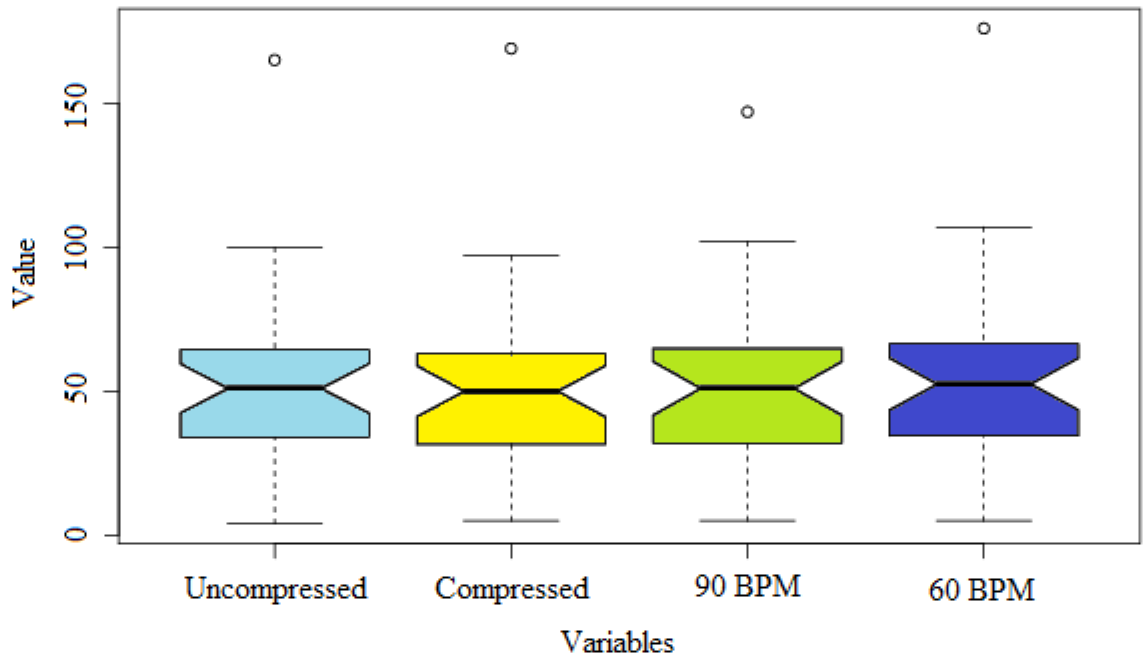

Figure 1. Notched box plots for heart rate variability across conditions

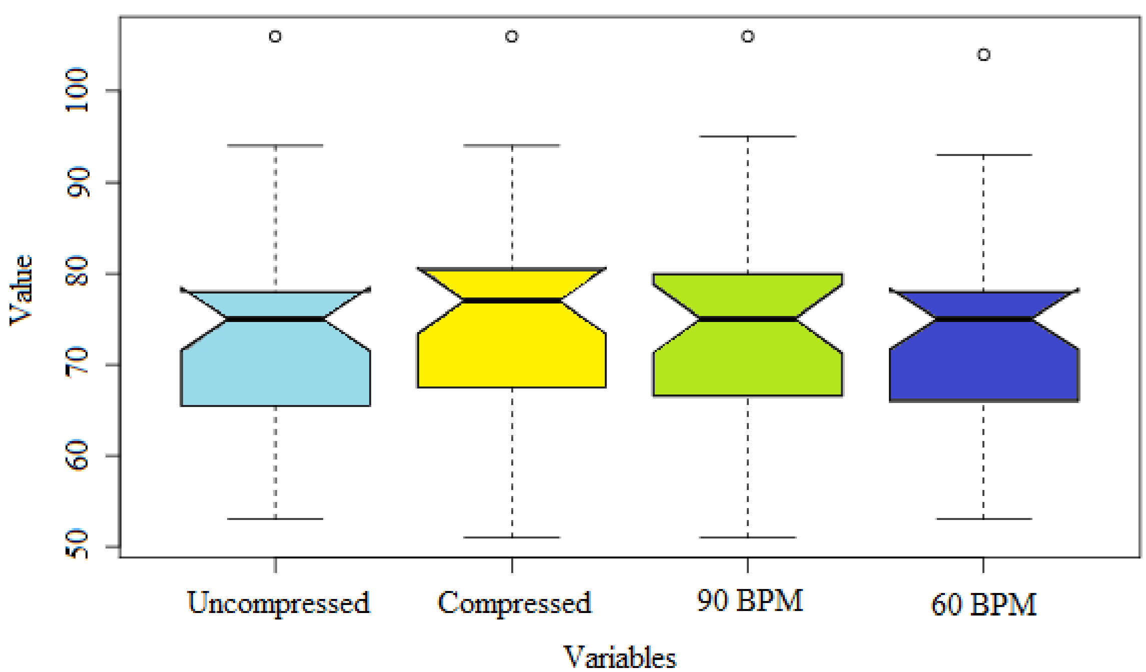

Figure 2. Notched box plots for heart rate across conditions

In order to see if there was an intervention effect following presentations of all experimental conditions, a Wilcoxon signed-rank text was performed on the pretest and posttest HRV levels. No statistically significant differences were found (Z = -0.52, based on negative ranks; p = .60). As HR pretest and posttest difference scores met assumptions for normal distribution, a paired samples t-test was performed. No statistically significant differences were found ($t(31)$ = 0.55, p = .59).

Table 5

Skewness and Kurtosis for Distribution of Difference Scores

Difference Scores	Skewness	Kurtosis
HRV Pre/Posttest Conditions	1.30	3.49
HRV Tempo Conditions	–3.63	16.34
HRV Dynamic Range Conditions	1.79	6.22
VAS Tempo Conditions	.07	–.08
VAS Dynamic Range Conditions	.27	–.55
HR Pre/Posttest Conditions	–.16	–.64
HR Tempo Conditions	.29	–.63
HR Dynamic Range Conditions	–.50	–.53

Note. Skewness standard error = .41; kurtosis standard error = .81.

Tempo and Heart Rate Variability

HRV levels for the pretest and posttest, fast tempo, and slow tempo conditions were submitted to Wilcoxon signed-rank tests. These revealed that there were no statistically significant differences (see Table 6).

In an effort to normalize HRV data, various transformations were attempted. No transformation achieved normal distribution of difference scores. Next, data were trimmed by deleting all difference scores greater than three standard deviations from the mean difference. One score was deleted for the tempo condition. Once a reciprocal transformation was applied to the trimmed data, the distribution was approximately normal for the tempo condition (skewness = –.57, kurtosis = 3.26). However, a paired samples *t*-test of the trimmed and transformed data found no significant differences ($t(29) = –.44$, $p = .67$).

Table 6
Z-Scores and Asymptotic Significance for Pre/Posttest and Tempo Conditions

Variable Pairs	*z*	Asymp. Sig. (2-tailed)
HRV 90 BPM/ HRV 60 BPM	–0.26*	.80
HRV Pretest/ HRV 90 BPM	–0.08*	.94
HRV Posttest/ HRV 90 BPM	–1.19*	.24
HRV Pretest/ HRV 60 BPM	–0.08*	.94
HRV Posttest/ HRV 60 BPM	–0.65*	.52

*Based on positive ranks.
Note. Asymp. Sig. = asymptotic significance.

Dynamic Range and Heart Rate Variability

Similarly, HRV levels for pretest and posttest, wide dynamic range, and narrow dynamic range conditions were submitted to Wilcoxon signed-rank tests to determine if there were any significant differences. No statistically significant differences were found between conditions (see Table 7).

Transformations were also attempted on the HRV data for the dynamic range condition. Similarly, no transformation achieved normal distribution of difference scores. Once again, data were trimmed by deleting all difference scores greater than three standard deviations from the mean difference. One score satisfied this requirement and was deleted for the dynamic range condition. Following trimming, a reciprocal transformation was applied; however, the difference scores still did not demonstrate normal distribution (skewness = 1.58, kurtosis 12.17).

Table 7

Z-Scores and Asymptotic Significance of Pre/Posttest and Dynamic Range Conditions

Variable Pairs	*z*	Asymp. Sig. (2-tailed)
HRV Uncompressed/ HRV Compressed	–0.18*	.86
HRV Pretest/ HRV Uncompressed	–1.05*	.40
HRV Posttest/ HRV Uncompressed	–0.85*	.39
HRV Pretest/ HRV Compressed	–0.84*	.29
HRV Posttest/ HRV Compressed	–1.64*	.10

*Based on positive ranks

Note: Asymp. Sig. = asymptotic significance.

Visual Analog Scales, Tempo, Dynamic Range, and Order Effects

The researcher predicted that participants would perceive musical selections with either slower tempo or narrow dynamic ranges as more relaxing than faster tempo or wide dynamic range selections. See Table 4 for VAS means by condition and order of presentation. Because difference scores for VAS data met assumptions of normal distribution, VAS data by experimental condition was subjected to a paired samples *t*-test. No significant differences were found for either condition. See Table 8 for results.

Table 8

T-*Test results for Visual Analog Scales for Tempo and Dynamic Range Conditions*

Variable Pair	*M*	*SD*	*SEM*	*95% CI*		*t*(31)	*p*
				LL	*UL*		
90 BPM/ 60 BPM	–3.1	25.3	4.5	–12.21	6.02	–.69	.49
Uncompressed/ Compressed	0.3	19.3	3.4	–6.67	7.23	.08	.94

Note. *CI* = confidence interval; *LL* = lower level; *UL* = upper level.

Exploratory Data Analysis: Average Heart Rate and Visual Analog Scale Correlations

For exploratory purposes, changes in average HR between conditions were examined. As HR difference scores were normally distributed for all conditions, HR for tempo and dynamic range conditions was subjected to paired samples *t*-tests. No statistically significant differences were found for the tempo condition; the dynamic range condition did feature statistically significant differences between the wide dynamic range and the low dynamic range conditions (t = –2.18, Cohen's d = –.39, p = .04). An examination of means showed that participants had a higher HR in the narrow dynamic range condition than in the wide dynamic range condition. This trend was the opposite of what was predicted. See Table 9 for specifics.

Table 9

Means, Standard Deviations, Standard Error of the Mean, and 95% Confidence Intervals of Average Heart Rate Differences for Tempo and Dynamic Conditions

Variable Pair	*M*	*SD*	*SEM*	*95% CI*		*t*(31)	*p*
				LL	*UL*		
90 BPM/60 BPM	.41	2.61	.46	–.54	1.35	.88	.39
Uncompressed/Compressed	–1.06	2.76	.49	–2.06	–.07	–2.18	.04

Note. *CI* = confidence interval; *LL* = lower level; *UL* = upper level.

In addition to exploring average HR for tempo and dynamic range conditions, all VAS and HRV levels also were examined for correlations. In order to standardize HRV response, HRV difference scores were calculated by subtracting pretest HRV levels from each condition. All HRV difference scores were paired with the respective VAS scores and a Pearson product-moment correlation coefficient was calculated. Change in HRV from pretest was weakly positively correlated with VAS scores ($r = .25$, $p = .00$).

Chapter 5

Discussion

This study examined the effects of tempo and dynamic range on physiological responses of heart rate (HR) and heart rate variability (HRV). A better understanding of this relationship would assist music therapists in selecting music for relaxation and other applications. The findings of the study suggest that music with a narrow dynamic range may be more stimulating and music with a wider dynamic range more relaxing, contrary to expectations based on clinical recommendations (Grocke & Wigram, 2007). Tempo did not have an effect on physiological response in this study. Therefore, individual input is a valuable and necessary tool in identifying what music is most relaxing for individual clients.

Heart Rate Variability

No statistically significant differences in HRV were found between pretest, posttest, tempo, or dynamic range conditions. These results are somewhat unexpected, given that HRV was recommended as a more sensitive measure of autonomic response, as compared to other measures such as average HR or respiration rate (Ellis, 2009; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Ellis (2009) and van der Zwaag et al. (2011) found significant differences in HRV between different levels of various elements of music. The most sensitive method of calculating HRV, however, is frequency domain methods, not time domain methods such as Root Mean Square Successive Differences (RMSSD) (Ellis, 2009; van der Zwaag et al., 2011). Because of equipment limitations, measurement of HRV on this study was restricted to the RMSSD method of calculation. Not being able to separate HRV into high and low frequency components reduced the sensitivity of the measure; this project is therefore not equivalent to Ellis' (2009) study and comparable results could not be expected.

Due to the use of RMSSD instead of frequency domain methods, conclusions that can be drawn from these findings are limited. The lack of significant findings could be due to legitimate lack of group differences, but it is also likely that the measure was not sensitive enough to detect actual group differences. It is also possible that the less rhythmic nature of the musical selections in this study would not have the same effect on HRV as the highly rhythmic selections used in both of the other studies (Ellis, 2009; van der Zwaag et al., 2011).

Another consideration is that other studies investigating tempo frequently used faster selections with more consistent tempos. As the music for this study was improvised in a manner consistent with what music therapists would use for facilitating relaxation, a certain amount of natural rubato was present in the musical selections. The natural ebb and flow of tempo present in most improvisations is a different experience from musical selections created with MIDI programming, as in Ellis' (2009) study. The lack of significant differences could possibly be attributed to the rubato present in the improvisations, or possibly to the fact that genuinely fast tempi (such as over 120 BPM) were not present in this study. Dynamic range presents a similar issue; the dynamic range employed in the original, uncompressed recording was comparatively narrow even before compression. Differences based on dynamic range may have been found had more extreme dynamic changes been employed.

Visual Analog Scales

There were also no statistically significant differences in the participants' perceptions of the different conditions. Once again, this finding was not what was expected based on previous research. Husain et al. (2002) as well as Gomez and Danuser (2007) found higher subjective ratings of arousal with higher tempo. Several participants in this study informally commented on noticing the difference in tempo, although such comments certainly do not constitute a formal designation of perceptibility of the recomposition. While the difference in tempo appeared easily perceptible and featured a significant change of a fifty percent increase in speed, it did not influence ratings of level of relaxation. It is possible that participants were able to perceive the change in tempo and yet still did not rate the slower version of the piece as more relaxing. It is also possible that, as both selections were of a comparatively moderate tempo, more dramatic tempo differences would have been necessary for differences in ratings to become apparent. The application of audio compression to reduce dynamic range was much a more subtle alteration, and none of the participants commented on it. It is not known whether or not this change was easily perceptible to participants; ratings did not significantly differ between conditions.

The more interesting finding is the correlation between ratings of level of relaxation and physiological markers of relaxation. While only a weak correlation, the level of significance was high. The findings suggest that, despite the lack of differences between tempo and dynamic range conditions, participants were able to self-select the musical elements that were most relaxing for them personally. In other words, general recommendations such as ‘slow tempo and narrow dynamic range’ may not be as effective as music with elements specifically tailored to what individuals personally find relaxing.

When synthesizing these findings with prior research, however, a different picture emerges. Lingham and Theorell (2009) and Husain et al. (2002) found that listening to self-selected “relaxing music” resulted in higher levels of physiological arousal. These two studies implied that participants may choose music that results in physical arousal, even though they think of it as relaxing. In the context of this study, however, participants were able to identify the music that produced physical markers of relaxation better than generalized professional recommendations. The implication of these seemingly contradictory findings may be that individual choice guided by the informed opinion of a music therapist may be the best way to create music that results in the maximum level of physiological relaxation.

Average Heart Rate

Average HR was not initially considered as an independent variable. Once data analysis revealed that the time domain HRV was not sensitive enough to detect differences, HR was considered as an additional variable that was more accurately recorded by the equipment. No significant differences were found for tempo, but a statistically significant difference was found for the dynamic range condition. The change was not in the expected direction, as HR increased as dynamic range increased. If this change is due to the comparatively limited dynamic range, the findings may prove controversial, as they are contrary to most clinical recommendations for music for relaxation.

Dynamic change is an inherent part of the experience of music, with practical, metaphorical, and philosophical repercussions. Limiting this element of music within the already narrow range of fingerstyle guitar may have unintended consequences beyond the simple expectation that less dynamic change is more relaxing. As both musical selections in this study featured relatively gradual and limited dynamic change, extrapolating and assuming that excessive and sudden dynamic change would result in a decrease in average HR would be misguided. It does suggest, however, that music therapists should allow for a natural ebb and flow of dynamic change in quiet improvisations without being overly concerned about alerting responses. The same applies to selections of recorded music featuring similar instrumentation; music therapists should not eliminate choices based solely on moderate changes in dynamic levels.

The method of recomposition that was used to create a narrow dynamic range condition involved audio compression. The increase in HR may have been an artifact of the compression process itself, not just of the alteration in dynamic range. Audio compression can have the effect of increasing background noises present in the recording process, as all quiet sounds are increased and loud sounds are decreased using a digital filter. Regardless, this finding has implications for audio processing. With the advent of personal mp3 players, audio compression has become more and more common. If the process of audio compression and its resultant limited dynamic range increase HR even in young, healthy adults, there may be more important consequences to casual music listening than one might expect. Another interesting consideration is comparative dynamic range across genres. While it is difficult to quantify general differences across different genres, popular music does have considerably less dynamic variation as compared to classical music. Classical music is the most popular genre of music for relaxation (Grocke & Wigram, 2007); the dynamic variation in classical music may be, in part, one of the reasons for its popularity for this purpose. It may also have general implications regarding what genres are most appropriate to support relaxation. There are, however, dramatic differences in instrumentation between popular and classical music, which add an entirely different element of music not explored in this study. More research in this area is certainly necessary before drawing any definite conclusions from these findings.

Implications for Music Therapy Theory and Practice

While some specific suggestions and applications of this study have been discussed, there are broader implications of the research as well. It is clear that mechanisms of receptive methods of music therapy still are not well understood, and the ramifications of this study must be considered in the greater context of a complex phenomenon of how humans react to music that they hear.

One interesting consideration is that while many music therapists do target the relaxation response, it is also appropriate with some clients to try and increase levels of arousal and energy. The study may have implications in either direction; however, more research with genuinely fast tempo music (>120 BPM) is needed to confirm these applications. The study suggests that at slower tempos, restricting dynamic range may increase HR. Whether or not this implication holds true at faster tempos remains to be seen, and would be a fascinating area for further research.

Even if the discussion is restricted to music used to promote relaxation, however, the process is far from simple. The basic, linear idea of direct cause and effect is not applicable to this experience. Multiple factors including music preference, current psychological and physiological states, conscious or unconscious associations, previous experience, and interpersonal factors all interplay to influence psychophysiological responses to music. While this study attempted to isolate only musical elements, many of these factors cannot be controlled or even accurately measured.

Music therapists applying concepts of complexity science have suggested that music itself functions as a complex system (Crowe, 2004). Complex systems are more than the sum of parts. In complex systems, altering a single part—such as tempo or dynamic range—can have unintended and unexpected consequences to the interactions that create the whole experience.

The idea of complex systems may partially explain why compressing the dynamic range of the music had the opposite effect as was expected based on clinical recommendations and—to borrow the colloquialism—plain common sense. Small interactions in complex systems can have far-reaching effects that can change the entire nature of the experience (Guastello & Liebovitch, 2009). From this standpoint, making general recommendations as to characteristics and qualities of music used for relaxation may be unhelpful, even counter-productive. It is, however, very difficult, if not impossible, to create a standard of clinical practice without making generalizations, even if they are not always effective.

With that said, the lack of differences between the tempo conditions becomes more understandable. Several participants commented to the researcher that they preferred the faster tempo selection; the increased pleasure of hearing it may have counteracted the increased heart rate that one would have expected from faster tempo stimulus. Increased enjoyment, however, may contribute to physiological arousal (Lingham & Theorell, 2009; Husain et al., 2002). The complexity of the experience of listening and responding to music is so far beyond our current understanding; it is difficult to draw any conclusions as to how tempo influences the listener's experience.

Another implication is the suggestion, once findings from this study are synthesized with others, that a collaborative effort between therapist and client may be the best practice for choosing music that the individual finds relaxing. While there are many commercially available CDs of music marketed as relaxing, this 'one size fits all' approach may not be as effective as the result of collaboration between the expertise of a therapist and the personal experience and preference of a client. Individual ratings of how relaxing the selections were did correlate with physiological response, albeit weakly, while conditions that were predicted to facilitate relaxation did not produce the expected effects. This finding suggests that individuals may be more adept at choosing music for relaxation than music therapists. Other research, however, suggests that independently self-selected "relaxing" music may result in increased physiological arousal (Lingham & Theorell, 2009; Husain et al., 2002). How are we to reconcile these seemingly contradictory findings?

An important consideration in this reconciliation is that this study provided participants with four selections of music, all of which fulfilled professional recommendations for music for relaxation. While the fast tempo condition was not as slow as clinical recommendations regarding tempo, it was only fast by comparison (90 BPM is not especially fast), and the "wide dynamic range" condition was merely the unedited recorded selection as originally improvised on a steel string acoustic guitar. The selections were improvised by a board-certified music therapist in a manner appropriate for relaxation and featured simple instrumentation, gradual dynamic change, consonant harmonic vocabulary, and predictable patterns of melodic contour. In other words, by limiting the options rather than providing free choice as Lingham and Theorell (2009) and Husain et al. (2002) did, the study involved a distant form of collaboration between a music therapist and the participants. The musical options were, effectively, a realistic selection of what a music therapist could offer a client in an actual session. In this context, the participants' ability to identify which of these selections was most relaxing would be an asset. This finding provides support for the collaboration of both the therapist and the client in finding music that is relaxing for that individual.

In the case of this study, this collaboration took place only in an abstract sense. Musical selections were provided by the therapist and researcher, and individuals indicated which selections they found the most relaxing. In the context of a therapeutic relationship involving trust and understanding between the therapist and client, one could reasonably hope that this beneficial effect of combining music therapy expertise and intuition with personal taste and experience would be much more effective.

One final suggesting arising from this study is to reinforce the importance of balancing knowledge gained from clinical experience and knowledge gained through research. In this case, the research suggested findings that are not consistent with general clinical recommendations for reducing the dynamic range in music for relaxation. This disparity could be due to many factors but hopefully will serve as a reminder to apply suggestions from both clinical experience and research findings with a healthy level of caution. What is best for that particular client in that particular moment is the best standard of practice, especially when disparities may exist in the literature. Careful consideration of different ways of knowing is one of the necessary skills and strengths of the profession of music therapy.

Limitations

There were several limitations to this study. First of all, the study used recorded rather than live music. While recorded music was used in order to allow for the use of the recomposition technique, music therapists employ both live and recorded music when using receptive music methods. Live music offers the advantage of being able to tailor the music in the moment and to alter it based on client response, but it cannot be used outside of the music therapy session in the way that a CD of recorded music can be sent home with a client. Because of this limitation, the study's findings apply to recorded fingerstyle guitar improvisations, but may not generalize to live music or music of other instruments.

Second, professional, studio quality recording equipment was not available when recording the guitar improvisations. While the recording quality was satisfactory—indeed, one participant commented on the good quality of the audio—it did not conform to the high standards associated with professional quality equipment. Higher quality recording equipment would have provided the best and most faithful reproduction of the live performance.

The major limitation of this study was the use of time-domain methods of calculating HRV. Frequency domain methods are more appropriate for short term recordings (Ellis, 2009; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; van der Zwaag et al., 2011). The use of RMSSD provided a limited picture of HRV that was not sensitive enough to respond to the subtle changes in autonomic function in response to musical change.

Finally, the study did not present a sympathetic challenge, an event that would have caused a physiological response such as a tilt table test. A sympathetic challenge would have allowed the researcher to examine autonomic response in resting conditions and also in conditions involving a challenge to homeostasis. This would have provided a more sensitive and complete picture of how young, healthy adults respond to music in different situations.

Recommendations for Future Research

Many questions remain unanswered in this area of research. It is recommended that future researchers continue the use of the recomposition technique in an effort to isolate specific elements of music, rather than comparing two different selections of music. This process eliminates many confounding variables and may provide some more clarity in the formulation of recommendations regarding specific elements of music designed to facilitate autonomic change.

Researchers should also use professional recording equipment and seek the assistance of a qualified audio engineer in the recomposition process. While many computer programs enable users to make simple audio edits, these tools often introduce artifacts into the recording that require professional assistance in order to manage. More importantly, researchers are urged to use frequency domain methods of calculating HRV. This method provides a much more nuanced and sensitive picture of autonomic response for short-term recordings and may be capable of detecting the subtle changes in autonomic function so critical to this type of research.

Finally, it is recommended that future researchers utilize a tilt table test or other form of sympathetic challenge to provide a disturbance to participant's resting autonomic function. Comparing how participants respond to changes in music during resting conditions is helpful, but exploring how music influences autonomic recovery following a disturbance would provide a more complete picture. Exploring autonomic response in other states is important, as many music therapy clients do not fall into the category of young, typical, and healthy adults.

Summary and Conclusion

Findings from this study suggest that increased dynamic range may cause reduced HR in young, healthy adults, and that individual ratings were positively correlated with physiological measures of relaxation. It is suggested that music therapists consider incorporating a natural ebb and flow of dynamic levels in their choices for and creation of music for relaxation. It is also recommended that music therapists collaborate with their clients to combine clinical expertise with the client's personal experience in order to choose the music most effective to facilitate a change in autonomic functioning. The ways in which listening to music influences psychophysiological response are still not well understood, and additional research is needed in this area as music continues to be such an integral part of the human experience.

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Appendix A

Recruitment Materials

To recruit participants for the study, the researcher will contacted faculty teaching music-related general education classes for the fall semester of 2014 and requested permission to visit their classes in order to recruit for the study. Upon receiving instructors' consent, a convenient date was scheduled for the researcher to visit the classroom. The researcher provided her contact information (phone and email) to the students using slips of paper as well as emailing the information to the instructor after the presentation. The researcher will introduced and provided a verbal description of the study based on the following script:

> I am a music therapy graduate student interested in the effects of certain elements of music on the body. Music therapists use music to work towards all kinds of different goals, but the ways that different elements of music affect the human body are not very well understood. Students in general education music classes in the fall semester of 2014 are being invited to participate in this study, which involves listening to music while your heart activity is monitored using a watch-style heart rate monitor. Participation in the study will take about 30 minutes, and you will be paid $10 for participating.
>
> Participation is completely voluntary. If you choose to participate after reviewing the consent form, you will need to complete a brief initial questionnaire. I will schedule a mutually convenient time for you to come to the off-campus lab located in The

Institute for Health and Human Services. You will be asked to abstain from alcohol for the 24 hours preceding your appointment, and from caffeine and nicotine for 4 hours preceding your appointment. At your appointment, I will assist you to put on the monitor, which looks like a wristwatch. The heart rate monitor will record how your heart rate changes over time. Next, you will lie down quietly and listen to music for 15-20 minutes while I monitor the activity of your heart. Last, you will answer a few simple questions about your experience. You will receive $10 upon completion of the study.

This is a safe procedure. It's also completely confidential; your information and responses will not be connected to your name at any point throughout the study.

If you are interested in helping learn more about how music affects your body and you would like to participate, please let me know. I've passed around my contact information. The study is limited to 40 participants, so if you are interested, please contact me as soon as possible. If you have questions about the study, I am also happy to answer those by phone, email, or right now in person.

The description of the study will be followed by time for questions regarding study participation.

Appendix B

Informed Consent Form

Consent to Participate in Research

Information to Consider about this Research

The Effects of Musical Tempo and Dynamic Range on Heart Rate Variability in Healthy Adults

Principal Investigator: Chelsea Stith

Department: Hayes School of Music

Contact Information: (919) 357-5942, stithcc1@appstate.edu

Faculty Advisor: Dr. Cathy McKinney

What is the purpose of this research?

Music therapists use music to help improve physical, cognitive, and emotional functioning. They work with people of all ages and with many different diagnoses. Despite previous research efforts, the effects that listening to music can have on the body are not very well understood. This study aims to explore how different elements of music affect physiological responses. These results will assist music therapists in selecting the most appropriate music for therapeutic application so that they may better serve their clients. To this end, the principal researcher, under the guidance of her faculty advisor, may submit the results to scholarly music therapy publications.

Why am I being invited to take part in this research?

Students in general education music classes in the fall semester of 2014 are being invited to participate.

What will I be asked to do?

You will need to complete a brief initial questionnaire. The researcher will schedule a time for you to come to the off-campus facility located at the Institute for Health and Human Services. You will be asked to abstain from alcohol use for the 24 hours preceding your appointment, and caffeine and nicotine for 4 hours preceding your appointment. Once you arrive at the lab, you will complete a brief questionnaire. Then the researcher will show you to a private room where she will give you a Polar Heart Rate Monitor, which resembles a wristwatch, to put on. The device measures the electrical activity of your heart, and will provide information on how your heart rate changes over time. After this, you will lie down quietly and listen to music for 15-20 minutes, before answering a few simple questions about your experience. The entire appointment should last less than half an hour.

What are possible harms or discomforts that I might experience during the research?

No harm or discomfort greater than what you would experience in daily life is anticipated. The physiological data collection (heart rate) is non-invasive, and should feel comparable to wearing a watch. Feel free to let the researcher know about any concerns you may have at any point.

What are some possible benefits?

Most people have positive experiences while listening to music. Taking time out of your day to listen to music is typically an enjoyable experience.

Will I be paid for taking part in the research?

You will be paid $10 upon completing the study for your participation.

What will it cost me to take part in this research?

Participation in this study will not cost anything but the brief time commitment required.

How will you keep my information confidential?

Your information and responses will not be connected to your name at any point throughout the study. The only information linking you personally to participation in the study will be a receipt with your signature indicating you received the $10. This receipt will be used only to receive reimbursement for funds through the Office of Student Research, and will be kept in a secure location.

Whom can I contact if I have a question?

Please feel free to contact Chelsea Stith, the principal investigator, with any questions you may have. Her email is stithcc1@appstate.edu and her cell phone number is (919) 357-5942. If you have additional concerns, you also may contact Dr. Cathy McKinney, the faculty advisor, at mckinneych@appstate.edu. If you have questions about your rights as someone taking part in research, contact the Appalachian Institutional Review Board Administrator at 828-262-2130 (days), through email at irb@appstate.edu or at Appalachian State University, Office of Research and Sponsored Programs, IRB Administrator, Boone, NC 28608.

Do I have to participate?

Participation in this study is completely voluntary, and you may withdraw from participation at any point without penalty.

This research has been approved on 6/4/2014 by the Institutional Review Board (IRB) at Appalachian State University. This approval will expire on 6/3/2015 unless the IRB renews the approval of this research.

I have decided I want to take part in this research. What should I do now?

If you have read this form, had the opportunity to ask questions about the research and received satisfactory answers, and want to participate, then sign the consent form and keep a copy for you records.

Name (print): ___________________________________

Signature: ______________________________________

Date: ____

Appendix C

Initial Questionnaire

Participant # ________________

This information will not be connected with your name at any point. It is being collected in an effort to better understand if the results of the study are representative, and if musical background or preference influence the results of the study.

Sex: _____ **Age:** _____ **Class (circle):** Freshman Sophomore Junior Senior

Ethnic/cultural/racial background:

Do you identify as Hispanic or Latino? □ Yes □ No

Check all that apply: (adapted from the 2010 US Census)

□ White
□ Black or African American
□ Native American or Alaskan Native
□ Indian
□ Chinese
□ Filipino
□ Other Asian
□ Japanese
□ Korean
□ Vietnamese
□ Native Hawaiian
□ Guamianian or Chamorro
□ Samoan
□ Other Pacific Islander
□ Other:____________

Do you play an instrument or sing? □ Yes □ No

Have you ever received musical training or lessons? □ Yes □ No

If so, for how many years? _______

What are your preferred styles of music?

□ Alternative
□ Blues
□ Classical
□ Country
□ Easy Listening
□ Electronic
□ Folk
□ Hip-Hop/Rap
□ Indie Pop
□ Jazz
□ Latin
□ New Age
□ Pop
□ R&B/Soul
□ Reggae
□ Rock
□ World Music
□ Other: ____________

EFFECTS OF TEMPO AND DYNAMIC RANGE

1. Have you experienced any significant hearing loss or deafness? □ Yes □ No

2. Have you ever been diagnosed with a cardiac condition, such as an arrhythmia, heart failure, heart valve disease, heart attack, or other condition? □ Yes □ No

3. Please describe your typical tobacco/nicotine use:

□ None □ Intermittent □ Daily (1-3 times per day)
□ Frequent (3-6 times per day) □ Very frequent (more than 6 times per day)

4. Please describe your typical caffeine use:

□ None □ Intermittent □ Daily (1-3 servings per day)
□ Frequent (3-6 servings per day) □ Very frequent (more than 6 servings per day)

5. Please describe your typical source of caffeine:

□ Coffee
□ Tea
□ Soft drinks
□ Energy drinks
□ Chocolate
□ Other: ____________________

Appendix D

Visual Analog Scales for Rating Perceived Relaxation

Participant #: __________ Selection: _________

Please rate the piece of music you just heard.

not at all relaxing |————————————————| very relaxing

✂- -

Participant #: __________ Selection: _________

Please rate the piece of music you just heard.

not at all relaxing |————————————————| very relaxing

✂- -

Participant #: __________ Selection: _________

Please rate the piece of music you just heard.

not at all relaxing |————————————————| very relaxing

Appendix E

Caffeine/Nicotine Questionnaire

Participant # ________________

Describe your caffeine consumption in the past 4 hours (including coffee, tea, soft drinks, energy drinks, chocolate):

Time:____________ Amount:___________ Source:_________________________

Describe your tobacco/nicotine consumption in the past 4 hours (including tobacco use, nicotine patches or gum, etc.):

Time:____________ Amount:___________ Source:_________________________

Vita

Chelsea Stith was born in Chapel Hill, NC, the oldest of the five children of Mark and Michelle Stith. She graduated from Meredith College in Raleigh, NC, and was awarded a Bachelor of Music degree in piano performance and a Bachelor of Arts degree in composition in May 2011. She accepted the Provost's Fellowship and entered the combined Equivalency and Master of Music Therapy program at Appalachian State University in August 2011. Ms. Stith completed her music therapy internship at Children's Mercy Hospitals and Clinics in 2013 and earned board certification as a music therapist in January of 2014.

Ms. Stith currently works as the district music therapist for Caldwell County Schools and resides in Deep Gap, NC.