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Emotional and Autonomic Responding to Auditory Stimuli

Jeremy C. Peres
jcperes@uno.edu

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Emotional and Autonomic Responding to Auditory Stimuli

A Dissertation

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy
in
Applied Biopsychology

by

Jeremy C. Peres

B.S. University of New Orleans, 2010
M.S. University of New Orleans, 2012

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Abstract

Much of the research examining emotion induction, regulation, and suppression considers solely the visual modality (e.g., pictures of faces) for emotion elicitation. In reality, emotions are cued, expressed, and interpreted through multiple modalities by employing the extensive use of auditory stimuli in addition to visual stimuli. There have been some recent efforts to offset this imbalance in modality preference by using emotional auditory stimuli alone or in addition to visual stimuli. This project aims to further investigate emotional and autonomic responding to auditory stimuli with the added component of examining differential responding across social (nonlinguistic vocal expression) and non-social auditory (music) emotional stimuli. We found mixed support indicating that our auditory stimuli induced physiological changes compared to a neutral condition. We also found that participants reported experiencing emotions congruent with those expressed by the stimuli. Most interestingly, increased autonomic activation was found in vocalizations compared to music possibly indicating more salient emotional responding to voices expressing nonverbal emotions compared to other types of less social emotional stimuli such as music. We discuss these findings through a lens that is not only interested in these potential differences as being driven by vocalizations, but also the unique nature of musical stimuli. This project presents a novel way to further our scientific understanding of the salience of auditory emotional information and the possible differences and similarities in processing more instinctive vocalizations and instrumental music.

Keywords: autonomic nervous system; emotion; auditory; vocalizations; music

Introduction

Much of the emotion literature examining emotion induction, regulation, and suppression considers solely the visual modality (e.g., being shown pictures) for emotion elicitation. In reality, human emotions are cued, decoded and interpreted by making use of all of the sensory information that is available at any given time through multiple modalities (Fingelkurts, Fingelkurts, Krause, Möttönen, & Sams, 2003). While there is no doubt that non-verbal, visually expressed information is important in facilitating social affective communication (e.g., facial expression, posture, etc.), vocally expressed emotional information is also ubiquitous in the human experience and is essential to consider. In addition, the literature often implies the social importance of emotional expression and interpretation as being a primary evolved function of these mechanisms (e.g., conveying internal state, communication, warning of danger). However, there are also times when people experience emotions in contexts where a specific evolved function is much less clear such as in the cases of viewing art or listening to music. In fact a primary purpose of the pursuit of artistic creation (e.g., writing music, painting) is often cited to be causing an emotional reaction in others (Juslin & Sloboda, 2009). While there is much scientific literature that investigates emotional responding to music in general, there has been less known work done that considers the specific differences in emotional responding to music compared to nonlinguistic vocalizations such as screaming or crying. This project aims to further investigate these aspects of emotion by examining differential responding across nonmusical-nonlinguistic emotional vocalizations (e.g., laughing, crying) and musical-nonvocal auditory emotional stimuli (instrumental music). Three emotions are examined. Specifically, happy stimuli (i.e., laughing, happy music), sad stimuli (i.e., crying, sad music), and angry stimuli (i.e., yelling, angry music) are used in the context of this project.

In this dissertation, several components of the current literature are presented. First, we clarify relevant terminology and theories by reviewing how emotions are conceptualized and measured and present our operational definition of an emotional response. Second, we present a review of the neurobiological systems involved in emotional responding, including specific mechanisms implicated in happy, sad, and angry responses. Third, we narrow the focus within the literature by reviewing the emotion research that specifically employs auditory stimuli. Fourth, we present an overview of the Autonomic Nervous System in order to set the stage for examining emotions physiologically using these fast-responding, noninvasive biomarkers. Lastly, we explore literature regarding the differences between social and non-social emotions in order to show the current lack of consensus within the literature and demonstrate a need for more specific research that directly compares such differences. We demonstrate that employing an experimental design with the components outlined above presents a unique way to further our scientific understanding of the salience of auditory emotional information and the possible differences between processing more instinctive vocalizations and instrumental music. Understanding these mechanisms could also be important for informing treatment of psychopathological disorders (e.g., music therapy).

What are Emotions? Definitions, Components, and Classification

Before discussing the research regarding how emotions react with human brains and biology, it is first necessary to make some clarifications about what exactly is implied by the word “emotion” itself and what specifically is comprised within an emotional reaction. While emotion might be used to convey a variety of different things in everyday language, for the purposes of this discussion, we would like to narrow the scope and operationally define emotion in a way that aims to be congruent with current psychological science. In addition to clarifying a working definition and identifying the components of an emotional response, this section also

aims to review the most widely acknowledged, and sometimes conflicting, theories regarding emotions and how they should be classified.

William James, widely acknowledged as a founding father of psychology, helped propose one of the first psychological theories of emotions. Around the same time as (but separately from) Carl Lange, James proposed a theory of emotion that argued for physiological processes being the cause of emotional reactions. That is, he thought that conscious emotional feelings were a product of the unconscious bodily responses to emotional stimuli (James, 1884). Around the same time, Charles Darwin proposed, based on his research, that emotions were adaptive to helping animals survive, otherwise those particular emotions which are seen so widely would not have been selected for (Darwin, 1872). An obvious example of an emotion being adaptive is that of fear in that it facilitates an aroused state that may help an organism be more efficient (i.e., run/hide faster) at avoiding potentially harmful or deadly stimuli. In this way, emotions such as anger or fear can easily parallel behavioral tendencies that are also shown to be evolutionarily adaptive such as the well-known fight or flight response.

While much psychological research has built upon and refined these initial ideas in the past century, unconscious physiological changes and emotions being universally evolved mechanisms in humans are both still core ideas that are often examined in emotion research. Past arguments in the field typically centered on whether or not physiological changes come first (e.g., Cannon, 1927; James, 1884; S. Schachter & Singer, 1962) or are the consequence of emotional response and subjective feeling states; recent discussions tend to focus more on differences in responding between types of emotions and how to differentiate emotions with the understanding that emotional responses comprise quick, relatively automatic changes in the body and brain that may then influence behavior. One prevailing view in recent history that seems to

generalize across many theories might broadly define emotions as brief, discrete, and synchronized changes across multiple subsystems in response a relevant internal or external stimulus (e.g., Ekman, 1992; Scherer, 2005). This will be our general operational definition of an emotional response throughout this paper.

Building on Darwin's initial ideas, researchers, most famously Paul Ekman, have attempted to prove that certain emotions (i.e, their facial/vocal expressions and corresponding responses) are universal to all humans regardless of culture or social influence (Paul Ekman, 1973; Scherer, Banse, & Wallbott, 2001a). One hot debate that this type of research has brought up is the controversy over how emotions should be classified. For example, Ekman (1992) and others (e.g., Vytal & Hamann, 2010) argue for the distinction between certain emotions (i.e., happiness, sadness, anger, fear, surprise, disgust) based on the idea that they are biologically basic, meaning that they cannot (or should not) be further broken down in to more basic components due to there being fundamental characteristics unique to each separate emotion (i.e., distinct physiological, facial, and subjective reactions). Models using this approach, sometimes referred to as the locationist approach, also typically hypothesize that basic emotions will consistently be localized to distinct regions or networks within the brain.

However, some theories, such as the circumplex model of affect (Posner, Russell, & Peterson, 2005; Russell, 1980), argue for a more continuous approach to interpreting emotions based on differing levels arousal and valence rather than discrete categorizations. Recent meta-analyses conducted by Barrett (2006) and others (Barrett & Wager, 2006; Phan, Wager, Taylor, & Liberzon, 2002) argue that using more dimensional approaches (also referred to as "constructionist" approaches) to categorization of emotion maps better onto how specific neural systems differentially activate in the brain and may be more appropriate for use. Regardless, it is

generally agreed upon that neurological and physiological activation are essential to the understanding of how emotions are manifested in the brain and body.

Should emotions be classified as “basic” or on dimensional scales?

Although the debate continues over the issue of whether innate emotion circuits in the human brain that reflect basic emotions truly exist (Barrett & Wager, 2006; Paul Ekman, 1992; LeDoux, 2012; Phan et al., 2002; Scherer, 2005), a great deal of brain research has been conducted over the past two decades with the basic emotions model in mind; arguments in favor using the model in this type of research abound (for meta-analyses, see Fusar-Poli et al., 2009; Vytal & Hamann, 2010). Regardless of whether or not one completely agrees that the basic model of emotions is “correct” in terms of helping us understand the evolutionary origins and biological systems that underlie emotions, the amount of research that has been conducted thus far within this theoretical framework is quite large and to ignore the contribution that this work lends to our understanding of the complexity of human emotion and its neural correlates would undoubtedly be a mistake. Additionally, even the researchers who advocate following more dimensional, constructionist approaches will frequently speak in terms of (and often directly compare their own methods to) specific emotional reactions with these same basic labels, further justifying the ubiquitous nature and universal understanding of classification of basic emotions. In other words, because basic emotions are so prominent in the literature and are also so widely understood across cultures and fields, even the critics of the system frequently explain their own classification in terms of how specific, basic emotions will fit into it, often with respect to where they fall onto a continuum (e.g., arousal, valence, approach/avoidance). It is for these reasons that the following sections of this paper will group neurobiological findings according to specific emotions that are hypothesized to be elicited by various types of emotional stimuli. Furthermore,

to acknowledge one particular theoretical orientation (i.e., basic approach) over the other (i.e., dimensional) does not at all preclude understanding the possibility that variation on, for instance, a dimensional scale might help explain real variation in neurobiological responding as well. Perhaps a system that comprehensively combines both approaches would be most accurate, but for now a focus on the basic while understanding its limitations will have to suffice.

Given the above definition of emotions and due consideration of these models regarding the measure of emotions, we have used auditory stimuli including emotional vocalizations and instrumental music, respectively, because such a comparison has apparently not been examined previously in the literature despite the fact that each type of stimuli may contain unique emotional information. First, we examine types of emotional stimuli that are typically used in a laboratory setting including visual, auditory vocalization, and music.

Emotional Stimuli in a Laboratory Setting.

Because visual stimuli (i.e., pictures and video) are often argued to be ecologically valid and easily manipulated in a laboratory setting, they are often used in research on emotional responding in such a setting. Historically, the near exclusive reliance on visual stimuli is especially true in emotion research in comparison to other stimulus modalities such as sound. More specifically, recognition and responding to emotional faces in the emotion literature using pictures of emotional faces is probably one of the most studied types of emotion elicitation stimuli (for more information and historical context, see Darwin, 1872, 1998; Ekman, 1973, 1992). Other than faces, sets of various pictures that reliably induce specific emotional states (e.g., IAPS) have also been used frequently in emotion research (Bradley & Lang, 2007). These will be the most frequently used types of stimuli in the following visual stimuli review sections of this paper.

In terms of specific types of auditory stimuli that tend to be used when studying emotions, vocal expression of emotion seems to be the auditory correlate to facial expression. Though the research studying emotional responding to vocal prosody (i.e., tone, speed, volume, etc.) in both spoken language and in non-verbal affective vocalizations (e.g., laughing, crying, screaming) has a long way to go to catch up to the breadth of research using visual stimuli, there has been a good start over the past 20 years (for review, see Klaus R. Scherer, Johnstone, & Klasmeyer, 2003). The most common types of stimuli used in these studies are phrases or non-verbal utterances (e.g., “ah”) spoken in different emotional tones by actors and vocalizations such as laughing or crying.

With respect to musical stimuli, the stimuli types seem to be rather wide ranging in terms of genre and period of music used. Classical music seems to be used fairly often in the older literature, but more contemporary music is used in recent studies as well. The area of emotional responding to music, however, seems to have been largely neglected, at least from a scientific psychological perspective, until the past 10-15 years. The first handbook (according to the authors) that attempts to provide a detailed review of the literature and inform future research in emotions and music was published in 2001 (Juslin & Sloboda, 2001). With the variety of perspectives on the research being done in this area, it is difficult to further define a certain type of stimuli that is often used other than to say it is usually relatively brief piece or section of music that is played. Often researchers might attempt to control certain characteristics of the music being played such as the mode (e.g., major or minor key), tempo (i.e., speed), average volume, instrumentation, etc. in order to identify *what* exactly about the music might be affecting affective reactions by participants.

In sum, although visual stimuli are useful for examination of emotions as defined in this dissertation, there is a precedence to examine other modalities as well. The current study proposes to use two types of auditory stimuli, sound and music, and contrast these in order to advance understanding about emotion.

Neuroimaging and Physiological Correlates of Specific Emotions

As defined above, synchronized changes across biological subsystems are an essential component of an emotional response. As frequently studied in the psychological and neuroscience literature, two systemic areas of interest examined during emotional responses include patterns of activation in brain neurocircuitry and the resulting autonomic nervous system activation. It is important to examine these physiological underpinnings of emotions because the measures can be thought of as somewhat objective and help to explain the mechanisms underlying the psychological and behavioral functions. Additionally, any differential biological mechanisms between stimulus modality and type within congruent emotional categories help to demonstrate the complexity and distinct neurological pathways involved in responding to different types of stimuli.

The sections below will examine the literature grouped according to responding to specific emotional stimuli that induce (1) happiness, (2) sadness, and (3) anger. We chose to focus on these specific emotions because of the rather obvious distinction between them, especially within the context of auditory cues. For example, fearful or surprise-oriented auditory stimuli (e.g., people screaming or harsher, startle-driven music) could potentially be eliciting more of a startle response than a fear response per se, and this might be difficult to disentangle within the current study design. Furthermore, disgust was considered but dismissed as a possible because of the lack of an obvious distinct musical correlate with regard to tone and style. Within these emotion categories, a focus will be placed on patterns in objective measured outcomes

including functional neural correlates along with a section that briefly discusses emotion-specificity in autonomic responses across emotional categories.

Happiness. Looking at evidence from functional imaging studies, several areas of the brain are implicated in happiness. A meta-analysis by Phan et al. (2002) found that 70% of studies with happiness induction reported activation of the basal ganglia (BG). With regard to stimulus types, they specify that activations in the ventral striatum and putamen (parts of the BG) have been observed in several studies in response to happy faces (Morris et al., 1998; Phillips et al., 1998) as well as in response to various pleasant pictures (Davidson & Irwin, 1999; Lane, Chua, & Dolan, 1999). Similar activation of basal ganglia areas have been shown in studies that use happiness induced recall (Damasio et al., 2000) as well as pleasant visual sexual stimuli (Redouté et al., 2000). Another more recent meta-analysis (Vytal & Hamann, 2010) showed that happiness was shown to be consistently associated with the right superior temporal gyrus and that happiness was discriminable from other emotion categories with clusters of activity in the left rostral anterior cingulate cortex and again the right superior temporal gyrus. The following paragraphs attempt to more closely examine responding to specific stimuli types.

Emotional faces are a very common type of visual stimuli used in emotion induction studies. One meta-analysis examined 105 studies that used only emotional facial stimuli and found that processing of emotional faces in general was associated with activation in a wide range of areas including visual, limbic, temporoparietal cortices, PFC, cerebellum, and the putamen (Fusar-Poli et al., 2009). With regard to happiness, they found that happy, sad, and fearful faces all activated the amygdala, while angry or disgusted faces did not. However, they found that amygdala sensitivity was greater in response to fearful compared to happy or sad

faces. They also found that activation of the visual cortex and cerebellum occurred in response to all facial stimuli (Fusar-Poli et al., 2009).

Sometimes defined as hedonic happiness, pleasure has been linked to activation in the orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), nucleus accumbens, and amygdala (Berridge & Kringelbach, 2011; Kringelbach & Berridge, 2009) while well-being has been linked to activation of the left prefrontal cortex, modulation of amygdala activation, and fast recovery from negative or stressful emotional states (Davidson, 2004). Additionally, one study that used mood induction instructions (i.e., “try to become happy (sad)”) and happy/sad pictures of faces found significant activation in the amygdala, hippocampal area, parahippocampal gyrus, PFC, temporal cortex, and the ACC compared to controls. Compared to sadness, happiness produced stronger activations in the dorsolateral PFC, cingulate gyrus, inferior temporal gyrus, and cerebellum (Habel, Klein, Kellermann, Shah, & Schneider, 2005). As one might expect, these examples that are somewhat more specific to continuous feeling states (as opposed to quick, unconscious emotional changes) seem to exhibit more activation of prefrontal areas, likely due to the added cognitive reappraisal and regulative processes that they help subserve in these cases compared to shorter emotional reactions.

With regard to auditory stimuli, in one study that used voice expression stimuli, Johnstone et al. (2006) found that happy voices (compared to angry voices) elicited more activation in the right anterior and posterior middle temporal gyrus (MTG), left posterior MTG and right inferior frontal gyrus. The MTG has been implicated in previous research of processing happy vocal expressions as well (Pourtois, de Gelder, Bol, & Crommelinck, 2005). Blood and Zatorre (2001) conducted a PET study to examine the neural mechanisms involved in pleasant emotional responding to music. This study, however, studied a phenomenon that is

somewhat unique to musical stimuli. They used subject-selected music that elicited highly pleasurable bodily sensations described as "chills" or "shivers-down-the-spine". The authors found that as the intensity of these chills increased, changes in blood flow were observed in reward emotions centers including the ventral striatum, midbrain, amygdala, orbitofrontal cortex (OFC), and ventral medial PFC. Most of these structures are similarly activated in response to other "euphoria-inducing" stimuli such as sex, drugs, and food (Blood & Zatorre, 2001). In sum, the neurocircuitry underlying visual or auditory happy stimuli is partially distinct, but overlaps in areas involved in longer term emotion regulatory areas like the OFC or in reward-related circuitry like the striatum.

Sadness. With respect to sadness, in general, activation of the amygdala has been implicated (Schneider, Habel, Kessler, Salloum, & Posse, 2000) as well as activation of the subcallosal cingulate (Phan et al., 2002); in addition, the dorsolateral PFC and the OFC have been implicated as important in the voluntary suppression of sadness (Lévesque et al., 2003). More specifically, Phan et al.'s (2002) meta-analysis found that sadness induction was most significantly associated with differential activation (compared to other emotions) of the subcallosal cingulate cortex (SCC). However, past researchers have posited the caveat that because ACC activity has previously been found in recall-generated sadness but not film-induced sadness, such SCC activations may be more specific to a more cognitive process of generating sadness rather than sadness itself (Reiman et al., 1997). Phan et al. (2002) also point out that SCC hypometabolism and hypoperfusion has been found in the SCC in patients with clinical depression (a disorder typically characterized by more sustained sad emotions/moods; Drevets et al., 1997; Mayberg, 1994). Further implicating the importance of ACC/SCC-related structures in sadness, Vytal and Hamann's meta-analytic findings (2010) found that sadness consistently

and uniquely (compared to happiness, anger, fear, and disgust) activated the caudate/subgenual ACC in addition to the medial frontal gyrus. Considering how easy it is to make the logical inference that a purpose of sadness might be act as a deterrent mechanism towards particular stimuli, these findings fit relatively well with similar research that has implicated the importance of the cingulate's influence on linking behavior to motivational processes (Hayden & Platt, 2010) as well as the ACC's prominent role in the experience of physical pain (typically thought of as a highly relevant mechanisms for increasing avoidance certain stimuli; Davis, Taylor, Crawley, Wood, & Mikulis, 1997).

Studies using music stimuli show somewhat mixed findings in terms of areas activated. For example, an fMRI study by Khalifa and colleagues (2005) showed that sad music (minor mode) differentially activated left orbitofrontal cortex and mid-dorsolateral frontal cortex, indicating these areas possible importance in determining the difference between happy (major) and sad (minor) modes in music. One clinical study that investigated responding to emotions (sadness included) in music in patients with frontotemporal lobar degeneration found similar support for the importance of orbitofrontal regions as being important for recognizing emotion in music in addition to several more areas including the insula, ACC, medial PFC, various temporal cortices, as well as the amygdala (Omar, 2013). Although the limited literature makes strong conclusions challenging, this again shows some distinction in visual vs auditory stimuli but the basic emotion-related structures like the ACC or insula may be conserved across modality.

Anger. Vytal and Hamann's (2010) meta-analytic review provided statistical evidence from multiple studies indicating that anger was consistently associated with activation of the inferior frontal gyrus (IFG) and parahippocampal gyrus and that both of the regions differentiated anger from happiness, sadness, fear, and disgust. Phan and colleague's (2002)

meta-analysis, however, did not find that anger differentially activated any brain areas more than other emotions. Another meta-analysis the next year, again however, found that anger reliably and distinctly did activate certain areas, specifically the globus pallidus and lateral OFC (Murphy, Nimmo-Smith, & Lawrence, 2003). Reasons for these discrepancies between meta-analyses likely has much to do with differences between techniques employed in the statistical analyses as well as particular theoretical orientations (i.e., locationist vs constructionist approaches) somewhat influencing interpretations. This applies to inconsistent cross-study results from previous emotion sections citing meta-analytic findings above as well.

Fusar-poli et al. (2009) conducted a meta-analysis of studies using facial stimuli that found insular activation that was specific to angry and disgusted faces, though insular sensitivity was greater for disgusted faces compared to angry faces. Other studies using facial stimuli have found activation in the posterior right cingulate gyrus and left medial temporal gyrus as well (Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998), while a study using dynamic anger faces found activation in various areas of the right frontal cortex and cerebellum (Kilts, Egan, Gideon, Ely, & Hoffman, 2003). With respect to imagined emotional states, Pietrini et al. (2000) found that mood induction of anger through imagined aggressive situations caused significant reductions in cerebral blood flow to the ventromedial PFC, an area important for inhibition and executive functioning, indicating that functional deactivation of inhibitory/regulatory cortical areas may occur in situation where anger or aggression may be elicited.

A few investigations into angry voice prosody have been conducted as well. Studies using emotional vocal prosody stimuli have found that angry voice prosody activates areas including the right amygdala, bilateral superior temporal sulcus, orbitofrontal cortex and the cuneus in the medial occipital cortex (Grandjean et al., 2005; Sander et al., 2005) with the

authors presenting evidence for the possible differential importance of the OFC and cuneus in attentional modulation when participants are instructed to pay attention to (as opposed to ignore) certain stimuli. In sum, as for happiness or sadness, the literature on anger demonstrates activation of both emotion- and emotion-regulation related structures in presentation of the stimuli, regardless of modality although it is difficult to draw strong conclusions from the limited research on sound. Despite the dearth of information, below we consider a broader consideration of emotions from the auditory modality.

Emotions from the Auditory Modality

Though not enjoying the expansive breadth and interest that has been shown to work on facial expression and visual stimuli in general, there is now a growing body of scientific literature focused on how emotion is communicated via auditory signals such as vocal sounds. The auditory modality seems to be as an integral part of our emotional experience that should not be overlooked. Although different sensory pathways are initially processed in different brain areas, people consciously interpret the information as a unified perceptual experience (Fingelkurts et al., 2003). In the real world, emotional signals conveyed through different modalities are typically congruent, facilitating efficient processing and integration of the emotional signals (de Gelder, Böcker, Tuomainen, Hensen, & Vroomen, 1999). It makes sense that congruent information interpreted through multiple channels would increase the salience and recognizability of that information; however, emotions are often discrepant between modalities as well in their both their content and discriminability. One meta-analysis (Elfenbein & Ambady, 2002), for example, found that anger was relatively accurately understood in the voice compared to the face while happiness was better understood in the face. They interpret these findings as indicating that “different nonverbal channels do not merely carry redundant information but rather each may have certain specialized functions in the communication of

emotion” (Elfenbein & Ambady, 2002). Additionally emphasizing the social and evolutionary importance of studying auditory emotion is the fact that vocal cues have detectability advantages over facial cues in that they can travel in all directions across far distances while facial expressions must be seen. Vocal cues are therefore shown to be especially effective for communicating emotions and drawing attention (or providing a warning) in the absence of visual information such as facial expression or posture (Johnstone & Scherer, 2000; Scherer, 1994). Given the importance of understanding the differential mechanisms of emotional expression and perception through sound, we feel it is important to examine multiple types of information conveyed through auditory means. As noted, the types chosen for investigation in the current project include emotional vocalizations and music.

With regard to nonverbal cues in speech, the literature now supports fairly well that humans are able to accurately discriminate between specific emotions in vocal prosody in speech (e.g., Banse & Scherer, 1996; Johnstone & Scherer, 2000; Juslin & Laukka, 2001); this has also been demonstrated in cross-cultural research, supporting vocally expressed nonverbal cues in speech as being universal evolved mechanisms (Sauter, Eisner, Ekman, & Scott, 2010; Scherer, Banse, & Wallbott, 2001b). Though spoken language is now a primary means of communication for humans, we must not neglect the importance of examining and understanding more primitive, prelingual methods of emotional vocal communication, especially due to their probable importance in our evolutionary development of emotions.

While much of the auditory emotion literature examines emotion conveyed through nonverbal cues (i.e., vocal prosody) in speech (e.g., pitch, volume, speed, and tone of speech), fewer studies have been conducted that examine nonlinguistic affect vocalizations (e.g., laughing, crying, screaming; Hawk, Van Kleef, Fischer, & Van der Schalk, 2009; for review, see

Scherer, 1994). Despite having fewer investigations, as one might guess, there is still evidence supporting our ability to discriminate emotions in these brief vocalizations. One pair of studies found that both hearing and reproducing vocalizations of anger, disgust, happiness, and sadness resulted in congruent facial behaviors and self-reported emotions (Hawk, Fischer, & Van Kleef, 2012). Another study showed more accurate decoding of emotions in affect vocalizations compared to speech-embedded vocal prosody (Hawk et al., 2009); this same study also had participants showing superior decoding of anger, contempt, disgust, fear, sadness, and surprise in vocalizations compared to in images of faces. The above research largely considers auditory context that involves the human voice as its source. While vocal affective information is essential to consider, one goal of the proposed project is to also consider and compare emotional reactions to nonvocal stimuli such as instrumental music. The following section briefly reviews some of the research examining emotional responding to music.

Emotions and Music

Juslin and Slobdoba (2009) note that studies have shown that the “most common motive for listening to music is to influence emotions—listeners use music to change emotions, to release emotions, to match their current emotion, to enjoy or to comfort themselves, or to relieve stress.” Despite the fact that music psychology has been considered an established subfield for some time now, and regardless of this obvious notion that the connection between emotions and music is fundamental, the body of research specifically looking at emotional responding to music, though growing, has historically been lacking. In the last 20 years, however, progress has been made in the examination of music as it relates to discrete emotion elicitation and neurophysiological activation in listeners. A meta-analysis by Juslin and Laukka (2003) that included 41 studies on music performance (including both vocal and instrumental) found that

detection of basic emotions (i.e., anger, sadness, happiness, fear) in music performance is accurate and well above chance. With regard to music activating emotion circuitry in the brain, one fMRI study showed that unpleasant (dissonant) music activated the amygdala, hippocampus, parahippocampal gyrus, and temporal poles, areas previously implicated in the processing of negative emotional stimuli (Koelsch, Fritz, Müller, & Friederici, 2006). Additionally, highly pleasurable responses (i.e., producing “chills”) to music have been associated with activation of pleasure and reward-related brain systems (Blood & Zatorre, 2001). Music has also shown been shown to differentially activate the autonomic nervous system compared to what has been shown in nonmusical stimuli. For example, while most studies show sadness increasing heart rate, sad music has actually been shown to decrease heart rate (Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006; Krumhansl, 1997). One criticism that should be noted is that considering affective responses to music as being emotions in the first place may be inappropriate whereas use of terminology implying slower, more consciously produced “feelings” that integrate cognitive and physiological effects may be more accurate (Scherer, 2004). However, this issue still seems to be up for debate, and regardless of possible differential temporal dynamics of activation (i.e., slower increasing activation over time; Koelsch et al., 2006) and potentially more cognitive control being involved, current research interests still seem abundant for studying automatic (whether slower or not) emotional responses across systems to music without consideration of changing this specific terminology. In sum, the above section helps illustrate the unique and important contribution of the auditory modality toward our emotional communication and understanding.

Autonomic Nervous System

While changes in the brain as observed by functional neuroimaging techniques gives investigators invaluable information regarding responding to stimuli and changes instantiated

within the Central Nervous System, these changes are only part of the picture. Fluctuations in internal cues as measured by physiological responding in the peripheral nervous system can more broadly show what is happening in the rest of the body during these emotional responses as well. In addition, such peripheral reactivity is an important indicator of automatic arousal and the salience of the interpretation of any meaningful stimuli. In the current study, we are examining such physiological responding to emotional stimuli by using measurements of the Autonomic Nervous System (ANS). This is beneficial because autonomic responsiveness occurs quickly, on the order of seconds; therefore, reactivity to brief clips of auditory stimuli can be observed. In the following sections, we review the structure and function of the ANS in order to demonstrate how and why the ANS responds quickly to meaningful stimuli. In order to understand how and why the ANS responds to emotional stimuli, it is essential to first understand its organization and function.

Autonomic Nervous System: Organization and Function

The autonomic nervous system is often described as being primarily unconsciously controlled or involuntary. This is one way in which the ANS is distinct from the somatic nervous system which is associated with voluntary control through direct connections of the brain and spinal cord to muscles and organs throughout the rest of the body. Somatic neurons are anatomically distinct from those in the autonomic branch in that somatic cell bodies are in the central nervous system and directly innervate the intended target tissue. This centrally-controlled, direct connection allows neural signals through the somatic system to be responsible for voluntary movement of skeletal muscles.

The ANS, however, is comprised of specialized neurons which have their cell bodies within the brain or spinal cord but which terminate outside of the central nervous system onto

interneurons that then innervate target tissues. These pathways allow the ANS to be responsible for regulating involuntary visceral functions such as heart rate, digestion, respiratory rate, perspiration, and sexual arousal (Berntson et al., 1994; Berntson, Sarter, & Cacioppo, 2003) by receiving and providing information to the brain via the spinal cord.

Though the ANS is typically conceptualized as governing functions that cannot be controlled consciously, this is not always the case. One example of exhibiting a degree of conscious control over autonomic function is through the use of biofeedback, a treatment intervention employed in a variety of stress-related psychopathologies, in which people use information (feedback) about their own ANS functioning to learn to manipulate certain physiological parameters usually with the goal of inducing a relaxation response and inhibiting a sympathetic response (e.g., increasing heart rate variability, parasympathetic activation, Karavidas et al., 2007). Within the context of emotional responding, such manipulation of automatic responding might be appropriately compared to emotion regulation processes, which similarly involve conscious control to cope with or manipulate physiological and emotional responding. Regarding structure, the ANS is divided into the parasympathetic and sympathetic branches which are distinct from each other in both form (neurochemical pathways) and function (effect on target tissue).

Parasympathetic vs. Sympathetic Branches

Anatomically, the Parasympathetic Nervous System (PNS) is differentiated from the Sympathetic Nervous system (SNS) in that neuronal cell bodies of the PNS are more distal from the spinal cord and closer to the target tissue, whereas SNS cell bodies are located proximal to the spinal cord in parallel nerve fibers called the sympathetic trunk. Also, whereas the SNS initially relies on acetylcholine in the chemical pathway and later peripheral epinephrine and

norepinephrine release, the PNS largely exerts control directly through the vagus nerve which descends from the nucleus ambiguus to act as an inhibitor or brake on SNS activation.

From a functional standpoint, the parasympathetic branch is responsible for “rest and digest” functions such as stimulating components of relaxation, digestion, and social interaction or also for inhibiting active bodily processes such as heart rate and respiration rate. Conversely, a primary mechanism of the SNS is to activate arousal mechanisms that prepare the body for anticipated action. For instance, sympathetic activation is responsible for changes including increasing heart rate, increasing respiration rate, dilating pupils, etc. (Berntson et al., 2003; Berntson et al., 1994). SNS activation is also sometimes referred to as a “fight-or-flight” response in reference to its engaging of bodily resources to respond to danger (e.g., a predator) by either escaping or otherwise overcoming the threat (e.g., physically fighting the predator).

During ANS responses to a challenge, typically PNS and SNS responding will be conversely associated with one another through “reciprocal activation” (Berntson, Cacioppo, & Quigley, 1991). However, not all target tissues are dually innervated and functions are not necessarily always opposing (e.g., both PNS and SNS activation can stimulate salivation). Furthermore, certain conditions and functions can require coactivation of both branches such as male erection and ejaculation (Berntson et al., 2003). A recent study also found coactivation of the PNS and SNS in participants during the extreme challenge of skydiving (Allison et al., 2012). Nevertheless, a typical ANS response to most stressors will involve reciprocal control.

Autonomic Specificity of Emotions

In addition to functional neuroimaging research reviewed in the previous section, some investigations into differential autonomic nervous system activation during emotions have also been conducted. It is worth noting that research into the autonomic specificity of emotion in

general is much fuzzier compared to functional imaging findings. While fMRI and PET resolution and differentiation ability between brain structure activation is relatively high, a major limitation of autonomic research is the use of indices that are “activated” continuously by noting changes (e.g., increase or decrease in heart rate, skin temperature, skin conductance) which can then help the inference of parasympathetic or sympathetic nervous system branch activations. The main point is that, while there is certainly research supporting autonomic specificity, this research should be viewed in a more of a broad way typically due to such limited resolution in changes across time (e.g., orientation towards a stimuli itself causes autonomic changes that can be difficult to distinguish from the “emotional” component of the response; as discussed in, e.g., Levenson, 2003).

There is generally mixed support but sustained interest in the idea that specific emotions can differentially activate these branches of the ANS. While some researchers maintain that results are inconsistent and ANS measures alone should not be used to differentiate emotional reactivity (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000; Zajonc & McIntosh, 1992), there is still persistent interest in the study of specific differential activation of the ANS across emotions in addition to supporting evidence (P. Ekman, Levenson, & Friesen, 1983; R. W. Levenson, Ekman, & Friesen, 1990; Stephens, Christie, & Friedman, 2010). In addition, even some critics admit that, when added to other indices of emotion and when differentiating between positive and negative emotions, ANS indices can demonstrate measurable differences in responses to these opposing emotions (e.g., sadness is associated with greater heart rate acceleration compared to happiness; Cacioppo et al., 2000). The current project will address these concerns by including self-report measures that indicate the participants’ appraisal and interpretation of the emotion by identifying which emotion is conveyed by the stimuli and also

internally experienced. This will allow for the integration of information regarding the cognitive appraisal and interpretation of the emotional response as well as the automatic physiological reactivity as measured through the ANS indices used in this project which are discussed in the following section.

Selection of ANS Measures

While there are no direct, noninvasive measures of ANS functioning (i.e., measuring specific neuron firing), there are well-validated noninvasive measures which provide researchers and clinicians with indirect information about the activity specific to the SNS and PNS. In order to provide a more complete picture of what is happening to the participant's physiology while in responding to stimuli as well as at rest, multiple indices of these branches of the ANS were selected as measures in the present study. The measures used include heart rate (HR), pre-ejection period (PEP), respiratory sinus arrhythmia (RSA), and galvanic skin conductance (GSC).

Heart rate. Heart rate is typically measured as the number of times the ventricles contract within a minute (i.e., when using beats-per-minute metric, bpm). Due to its ease of measurement and conceptual simplicity, HR is frequently used in studies by itself or with other measures to infer changes in ANS reactivity (Allison et al., 2012; Bush, Alkon, Obradović, Stamperdahl, & Thomas Boyce, 2011; Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004; Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004). In addition to the obvious and well-studied medical implications regarding physical health, the HR response also has clinical implications regarding psychological functioning. For example, the HR response has been associated with self-reported anxiety symptoms in children (Weems, Zakem, Costa, Cannon, & Watts, 2005) or is elevated at resting levels in children with separation anxiety

disorder, whereas children with conduct disorder had lower resting heart rates compared to normal subjects (Rogeness, Cepeda, Macedo, Fisher, & Harris, 1990). Lowered resting HR and blunted HR responding to stressors is strongly linked with antisocial behavior in children and adolescents (Ortiz & Raine, 2004). In studies specific to emotional responding, HR has previously been shown to typically increase during anger (Hamer, Tanaka, Okamura, Tsuda, & Steptoe, 2007; Neumann & Waldstein, 2001; Prkachin, Williams-Avery, Zwaal, & Mills, 1999; H. Schachter, 1957; Sinha, Lovallo, & Parsons, 1992) and increase during happiness (Boiten, 1996; Rainville, Bechara, Naqvi, & Damasio, 2006; Ritz, George, & Dahme, 2000; Theall-Honey & Schmidt, 2006; for comprehensive review, see Kreibig, 2010)

Changes in heart rate can be due to influence from either the PNS or the SNS branch. For instance, if heart rate increases, it is difficult to disentangle whether PNS withdrawal or SNS activation is more responsible for causing the change. Because of this challenge, more specific indirect measures of sympathetic activity are often advocated for when trying to specifically measure SNS activity in relative isolation (Newlin & Levenson, 1979). One such measure is PEP.

Pre-ejection period. PEP refers to the time period from ventricular depolarization to the opening of the aortic valve. Compared to heart rate, PEP has been shown to be a selective index of SNS activation. Decreases in PEP intervals reflect SNS activation while increases infer SNS inhibition (Berntson, Lozano, Chen, & Cacioppo, 2004; Bush et al., 2011; Newlin & Levenson, 1979). PEP is frequently used in combination with other ANS measures to establish patterns of ANS reactivity that can, for instance, help to distinguish children with internalizing and externalizing symptoms and those without symptoms (Boyce et al., 2001). In this particular study, children with internalizing symptoms showed higher parasympathetic reactivity compared

to low-symptom children while children with externalizing symptoms showed lower reactivity in both branches compared to low-symptom children. In emotion-related studies, PEP has previously been shown to decrease during anger (Montoya, Campos, & Schandry, 2005; Neumann & Waldstein, 2001; Pauls & Stemmler, 2003; Sinha et al., 1992) and increase during happiness (Nyklicek, Thayer, & Doornen, 1997). In the current study, PEP helps to establish the levels of sympathetic activation in response to the emotional stimuli and will also help to create a more complete picture of autonomic activity when combined with other SNS indices such as HR increase and PNS indices such as RSA.

Galvanic Skin Conductance. GSC, also known in the literature as galvanic skin response (GSR) or simply skin conductance, is a method used for measuring the electrical conductance of the skin which varies depending on the amount of moisture on the skin. GSC is able to be used as an indirect measure of sympathetic arousal because the SNS controls the sweat glands on the skin (Fowles et al., 1981). When one is physiologically aroused, sympathetic activation causes the hands to sweat and this sweat, in turn will cause the electrical conductance of the skin to due to the added moisture (i.e., when electrodes are attached to provide and measure a small electrical current). As with other sympathetic indices, blunted GSR responding (to stressors) has been demonstrated in populations with externalizing problems (Herpertz et al., 2003) and antisocial personality disorder (Raine, Lencz, Bihrlé, LaCasse, & Colletti, 2000). Kreibig's review (2010) shows that Skin Conductance Level (SCL) generally increases during anger (Christie & Friedman, 2004; Ritz, Steptoe, DeWilde, & Costa, 2000; G. Stemmler, Heldmann, Pauls, & Scherer, 2001) and either increases (Gerhard Stemmler & Fahrenberg, 1989; Vianna & Tranel, 2006) or remains unchanged (Levenson, Ekman, Heider, & Friesen, 1992; Marci, Glick, Loh, & Dougherty, 2007) in happiness.

Respiratory Sinus Arrhythmia. RSA refers to a naturally occurring physiological phenomenon where heart rate varies as a function of the respiratory cycle. It is a valid index of heart-rate variability (HRV) which has been frequently studied throughout the physiological and psychophysiological literature. Specifically, RSA is the natural tendency of HR to increase (shortened inter-beat intervals) during inspiration and decrease (prolonged inter-beat intervals) during expiration (Gary G. Berntson, Cacioppo, & Quigley, 1993; G G Berntson et al., 1997). RSA has been shown to be an index of cardiac vagal tone (i.e., activity) and therefore a reliable indicator of PNS activation. That is, increases in RSA indicate PNS control while decreases signify withdrawal (Porges, 2009). In children, higher RSA responding (increased PNS control) during a social challenge has been linked to fewer internalizing and externalizing problems and better self-regulation behavior (Hastings et al., 2008). Also, clinical depression has been associated with lowered resting RSV (e.g., Carney, Freedland, & Veith, 2005). As shown in Kreibig's review (2010), in emotion studies, RSA has been shown to decrease or remain unchanged in both anger and happiness (Marci et al., 2007; Rainville et al., 2006; Ritz, George, et al., 2000).

Regarding the trends in emotion studies cited above from Kreibig's (2010) extensive review, it should be noted that the author identifies studies demonstrating exceptions to many of these responses in each type of emotion. For instance, in some cases viewing pictures of angry faces has been shown to be associated with increased parasympathetic control and sympathetic deactivation (Dimberg & Thunberg, 2007; Jönsson & Sonnby-Borgström, 2003), which may be indicative of fear-oriented responding to the stimuli. Additionally, some studies have shown happy pictures and film clips to be associated with decreased or unchanged HR (Gruber, Oveis, Keltner, & Johnson, 2008; Ritz, Thöns, Fahrenkrug, & Dahme, 2005) rather than the typical

sympathetic increase in HR. Furthermore, sadness was not discussed in the above sections because it has been shown to be characterized by two opposing types of responses. Kreibig describes a sadness “activating response” characterized by increased cardiovascular sympathetic control and a “deactivating response” characterized by sympathetic withdrawal. She also suggests that these patterns are associated with physiological responding involved in crying such that the activating response partially overlaps with crying sadness and the deactivating response is associated with non-crying sadness.

In sum, non-invasive measures of sympathetic and parasympathetic activity have advantages in that they are validated and informative for understanding physiology and associated emotions and behaviors. There are disadvantages, however, in that no single method captures purely SNS or PNS activation alone or perfectly. Nonetheless, by examining all four measures together, a more complete picture of ANS activation can be inferred. It is anticipated that emotional responding may be demonstrated through autonomic activation in response to the emotional stimuli through responses such as those indicated in the previous sections. Though the expected fight-or-flight response to challenge or stress is characterized by the typical parasympathetic withdrawal and sympathetic activation, the quicker and more subtle responses to brief emotional cues are not nearly as straightforward. Rather, one aim of this study is to examine whether people exhibit different autonomic responses to different types of emotional stimuli that may involve more complex responding than the typical more straight-forward reciprocal activation involved in fight-or-flight. One such way to demonstrate this differential responding is to show different combinations of response patterns based on these 4 autonomic measures. The following section begins to explore the importance of the types of stimuli used in

emotion-induction research. Specifically, the distinction between emotional stimuli that is inherently more or less social is considered.

What are the Differences between Social and Non-social Emotions?

A large majority of the research discussed up to this point has focused on the use of stimuli that would typically be considered “social” in nature. Facial expressions in pictures or video are arguably the most studied emotion stimuli in the past 10-15 years (see Phan et al., 2002; Vytal & Hamann, 2010). It is easy to see why these would be considered social emotional stimuli considering the stimuli represents an emotion being conveyed by another person, therefore social communication is implicit in the content. The same is arguably true for emotional prosody being used as stimuli considering it would be readily apparent to most people that a person (or animal) was speaking or making sounds with their voice even if there is no visual representation. Examples of stimuli that this author would argue to be nonsocial (or at least fundamentally less social) but still emotion-inducing would include those that do not include another person or inherent social interaction such as instrumental music, nonperson object or situation-induced emotions (e.g., fear of thunder or heights, happiness at viewing a landscape), and physical pain. However, research attempting to directly compare these kinds of subsets of emotional stimuli to more social stimuli are extremely lacking in the literature. Additionally, the clarification of how a social dimension of emotions should even be characterized is rather confusing and past researchers have not necessarily approached their own differentiation in the way presented here or in any other seemingly consistent manner across research groups.

For example, Britton et al. (2006) differentiate between social and nonsocial emotions based on basic biological drives (nonsocial) and social interaction. They give examples of

nonsocial emotions as being appetite and disgust while social emotions would include joy/humor and sadness because they tend to emerge in social interactions with other individuals and are "embedded in structures of social relationship, intentionality, and meaning". Their initial juxtaposition of sadness and happiness being inherently social and appetite/disgust being nonsocial seems especially flawed in certain circumstances. While the distinction between a stronger biological drive component in appetite/disgust compared to other emotions is valid considering how fast and strong such "emotions" are shown to be, there are some obvious flaws. One obvious social component to disgust is that it involves a unique facial expression that can in fact elicit feelings of disgust (disgust faces; e.g., Wicker et al., 2003). Additionally, happiness and sadness can certainly occur in response to stimuli that do not involve a person or animal (i.e., pleasant landscapes, happy/sad music recording). Perhaps the distinction they make in this particular study should be of a dimension regarding biologically basic drives as opposed to one of the socialness of emotions. Nonetheless, we examine the details of their findings considering the limited availability of these types of studies attempting to directly compare and contrast responses to social and nonsocial stimuli in the literature. With respect to unique responding to social positive and negative emotional stimuli, Britton et. al (2006) found that the amygdala and sublenticular extended amygdala seemed particularly important in responding to social stimuli with the additional components of superior temporal gyrus, hippocampus, and posterior cingulate. In contrast, they found that insula and visual cortex activations were specific to their nonsocial emotions. Similar implications of the importance of the amygdala have been found in other investigations as well.

A review by Adolphs (2003) discusses past findings regarding the amygdala's role in recognizing emotions in facial expressions. They cite lesion studies of patients with bilateral

amygdala damage severely impairing one's ability to make judgements about basic emotions in face pictures (Adolphs, Tranel, Damasio, & Damasio, 1994) with the addition of frequent amygdala activation in normal emotional processing of facial expressions in healthy participants (e.g. see Fusar-poli et al. 2009). In Adolphs and Spezio's (2006) review, they again argue for the amygdala playing an essential role in social cognition with the addition that it may be particularly important in directing attention, especially with regard to visual stimuli such as faces.

Costafreda et al.'s (2008) meta-analysis of 385 emotion studies found further support for Adolphs's theories. They found that the probability of amygdala activation was significantly higher for social emotions compared to neutral stimuli. More interestingly with respect to social vs. nonsocial emotions, they found that faces caused higher probability of amygdala activation compared to other types of visual emotional stimuli. Similarly to Adolphs (2003) they defined social emotions as those that are "dependent on a social context and which participant in the regulation of social behavior" and therefore included stimuli representing guilt, embarrassment, shame, abandonment, pride, admiration, attachment, friendship, love and moral dilemmas (Adolphs, 2003). As discussed above, this vastly different conceptualization of social emotions (compared to, e.g., Britton et al. 2006) still seems flawed and limited in some respects. While they are including "social" emotions as those that are highly dependent on outside-person perceptions/judgements of one's self, such emotions could arguably still be experienced in a self-focused type of way that does not necessarily involve another person. Additionally, they, for some reason, use the five basic emotions (fear, disgust, sadness, happiness, anger) with the additions of humor and sex as being excluded from their social category. Again, this directly contradicts common sense in addition to other similar research (e.g., Britton et al., 2006) It is the

opinion of this author that these vastly different interpretations of what makes an emotion or an emotional stimulus "social" is a huge problem with attempting to answer these types of questions in the literature. A more thorough discussion and consensus is needed. However, the consistent appearance of the amygdala's importance in responding to social stimuli such as facial expressions and the additional overlapping of activation in these varied definitions of social stimuli is certainly interesting.

One additional instance in which social emotional stimuli is affected by amygdala activation is as follows. Investigations into patients with Williams Syndrome, a neurodevelopmental disorder characterized by various physical characteristics and developmental delays, who are also typically hypersocial in that they love being around people have also found differential functioning of the amygdala. Muñoz et al. (2010) found that participants with Williams Syndrome exhibited increase amygdala activation to non-social scenes (non-social IAPS pictures) compared to faces. The authors believe this is indicative of amygdala-prefrontal pathway disruptions in individuals with Williams Syndrome, and similar results have been shown in other Williams Syndrome studies as well (Meyer-Lindenberg et al., 2005).

Implications for Understanding Empathy

The proposed research contrasts social (i.e., vocal) stimuli and less social (i.e., music) stimuli with emotional valence. Although this is not definitionally "empathy," it is useful to consider how this contrast has bearing on the understanding of empathy – sharing of another's emotions – given that empathy likely involves social more so than nonsocial emotions.

The concept of empathy has been the subject of much debate and discussion across psychological, neurological, philosophical, and theological fields. While the general idea is held

somewhat consistent, there is still discrepancy regarding a single specific definition and the contexts in which it applies. In psychological research, empathy has often been defined as one's identifying with and feeling another's emotional state. Though there is some disagreement on an encompassing operational definition, empirical data of empathy still holds consistent, even across species (Preston & de Waal, 2002). A primary neural mechanism of empathy is a relatively recent phenomenon called the mirror neuron system which involves the activation of the same neural circuits in the brain that would be involved in carrying out a particular action when one is, rather, just observing another person or animal engage in said action (e.g., see (Rizzolatti & Craighero, 2004).

Other operational definitions of empathy have narrowed their focus to three components: "(a) affective expression (i.e. an emotional joining in), (b) cognition (i.e. apprehending or understanding the other's experience) and (c) physiology (i.e. autonomic nervous system activity, and more recently hormonal and neural substrates)" (Hastings, Zahn-Waxler, & McShane, 2006). Empathy should be distinguished from the analogous concepts of compassion and sympathy. While similar, sympathy primarily entails focus on another's distress or pain and feelings of concern or sadness for the person rather than the more congruent emotions and perspective taking that occurs in empathy. Prosocial behavior (actions performed in order to benefit the well-being of another) is another distinct but highly related and relevant construct. (Hastings, Zahn-Waxler, & McShane, 2006). Types of prosocial behavior are discussed by Preston & de Waal (2002) as being connected to either (or both) "proximate" (affecting the individual's immediate internal state) or "ultimate" (affecting the DNA code for the entire species) causes. Ultimate causes of empathy would be related to situations involving examples such as mother-infant bonding and inclusive fitness (the idea that an organism can be successful evolutionarily

by demonstrating cooperative social behavior). Proximate causes of empathy involve individual internal mechanisms such as autonomic physiological reactions and conscious emotional responses and affects (Preston and de Waal, 2002).

The importance of empathy as a significant emotional process and internal condition (that affects more than just immediate mood or emotional state) is illustrated by its activation of multiple physiological and neurological pathways and its appearance across species at different points of the evolutionary spectrum. Furthermore, empathy's implication as being not only of importance to an individual's immediate environment and internal state but also as having the potential to indirectly help pass on the genetic makeup of a species by increasing rates of collective fitness and survival exhibits the deep evolutionarily engrained processes that are occurring when people experience empathy and exhibit prosocial behavior.

The above information helps to illustrate the inseparable connection between empathy and social-emotional interactions. Beyond the mechanisms involved in mirror neurons, the neural correlates discussed in the previous section, most notably the amygdala and sublentiform extended amygdala, may also have important implications for empathic processes and this has been implicated in past research and reviews (e.g., Decety, 2010). Other areas are also implicated as important in empathy processes as well. For example, Schulte-Rüther, Markowitsch, Fink, & Piefke (2007) used a self and other-directed task with emotional faces and examined fMRI activation in order to try to disentangle empathy-related processes. They found that empathy-related processing tended to activate areas involved in mirror neuron and theory of mind mechanisms with the medial PFC, the precuneus, and temporo-parietal regions being uniquely activated in the self-directed task. Also, mirror neurons were involved in emotional cognition as well as motor cognition. They posit that this connection of theory-of-mind and

mirror neuron mechanisms is important in self-other distinguishing during empathy.

Additionally, one meta-analysis of 32 fMRI pain/empathy studies indicated a core network of the anterior insula and the medial/anterior cingulate cortex being activated in empathic experienced of pain (e.g., seeing bodies in painful situations) which directly overlap with areas activated during directly experienced pain (Lamm, Meltzoff, & Decety, 2010). Singer et al., (2004) found that “only that part of the pain network associated with its affective qualities, but not its sensory qualities, mediates empathy”; specifically the rostral ACC, but not the sensorimotor cortex (which activates in pain), activated in empathic pain responding but not during pain itself.

Looking at the above literature, it becomes apparent that many interesting and highly differential neural correlates seem to be implicated in responding to social stimuli and nonsocial stimuli. Furthermore, with respect to the current study’s use of ANS measures, the unique mechanisms involved in empathy play a particularly important role due to its role as one of several important neurological systems involved in empathic responding. We propose that differential responding within the ANS may uniquely map onto these apparent differences involved in social and nonsocial emotional experiences and, therefore, may be of particular interest when examining differential responding between stimuli that are fundamentally social and those that are not.

Beyond the more general reasoning that using different types of auditory stimuli (e.g., musical vs nonmusical) that differ in how they are produced (vocal vs. nonvocal) may lead to a more comprehensive understanding of the mechanisms that underlie our emotional processing of auditory stimuli, this project also aims to explore the social component as a potentially important factor by comparing inherently social emotional vocalizations to the less social music. When not lyrical and lacking a vocal component, it is proposed that (1) music can be operationalized as

nonsocial emotional auditory stimuli that will involve inherently different processing from nonlinguistic affective vocalizations and that (2), across these conditions, the emotional and autonomic responses elicited may differ. This project will investigate these hypotheses by having participants listen to emotional auditory stimuli including nonlinguistic vocalizations and instrumental music. Participants' autonomic responding is recorded throughout the listening sessions and participants also provide self-reported measures of their subjective emotional states.

Present Study

An overarching general goal of the present study is to investigate people's autonomic and emotional responding to emotional vocalizations and brief clips of music. Additionally, we wish to frame our aims in a somewhat exploratory manner due to the lack of clear consistency in the prior literature regarding patterns of autonomic responding to emotional stimuli. While the following hypotheses are phrased in the affirmative in order to test for statistical significance, partial confirmation will still provide valuable information regarding the general goal of exploring responding in the context of these different auditory stimulus types. With this in mind, our specific hypotheses are as follows:

- 1. Participants will demonstrate autonomic nervous system responding to the auditory stimuli.** We predict that indices of autonomic responding including HR, PEP, GSC, and RSA will differ between baseline and stimulus presentation, with this change from baseline indicating a response.
- 2. Participant will experience emotions congruent with the stimulus.** We predict that participants' self-reported emotions during stimulus presentation will be congruent with the intended emotion conveyed by the stimulus. Emotions include happiness, sadness and anger.

- 3. Participants' autonomic responding will differ across stimulus emotion type.** We predict that responding of the above autonomic indices will differ across the types of emotions conveyed in the auditory clips (happiness, sadness, anger). We also predict that patterns of responding across the indices will differ across emotion type.
- 4. Participants' autonomic responding will differ between social and nonsocial stimuli.** We predict that autonomic responding will differ across auditory clips of emotional vocalizations (social) and music (nonsocial) within congruent emotion types conveyed. We again also predict that autonomic patterns of responding will differ across types of stimuli.
- 5. Autonomic responses will be associated with self-reported emotions.** We also will explore how autonomic responding may be associated with increased emotions felt during the stimuli as indicated by self-report.

Methods

Participants

50 participants (28 females and 22 males) were recruited from the University of New Orleans via class announcements. In order to be invited to participate, interested participants were required to be between 18 and 50 years old, have 5 years or less of formal music experience, and have no current hearing problems.

Procedure

Participants were asked to come to the laboratory for 1.5 hours at a prescheduled time. Upon arrival, participants were provided with informed consent. The experimenter then proceeded to apply 9 electrodes to the participant's upper body and connect them to a small ambulatory monitoring device (Mindware Technologies, LTD.) which was then clipped to the

back of the chair where the participant remained seated for the remainder of the protocol. This physiological recording setup is noninvasive and has been used previously in multiple studies in the SPIT Lab at the University of New Orleans with no adverse effects. After being connected, physiological measures were collected continuously throughout the laboratory visit via wireless transmission to an unseen data acquisition computer in another room. Participants were then asked to complete questionnaires on a laptop computer until was time for the stimulus presentation.

Stimulus Presentation. During the stimulus presentation portion of the protocol, participants were presented with a series of auditory clips of nonlinguistic affective vocalizations (i.e., laughing, crying, and angry yells/grunts; stimuli from Hawk et al., 2012, 2009) and nonvocal, emotionally inducing instrumental music (happy, sad, and angry music; created by Eerola & Vuoskoski, 2010) . These are ordinary sounds that participants could expect to hear in their everyday life. Visual stimuli (e.g., instructions, ratings) were presented on a computer monitor, and auditory stimuli will be heard through studio quality stereo headphones. Prior to the presentation of the experimental stimuli, participants were shown instructions and stimuli for three resting periods lasting 150 seconds each. For the first 150 second period, the participants were asked to relax and sit quietly while listening to white noise that is matched to the average volume of the experimental stimuli while baseline physiological recordings are gathered. During the second neutral period, participants were then presented pink noise (similar to white noise but with reduced amplitude for higher frequencies) for 150 seconds. For the last 150 second resting period, participants sat in silence while continuing to wear the headphones. Next, the emotional stimuli were presented in six 150 second blocks during which six randomly ordered emotionally congruent clips (i.e., different clips of laughing, different clips of happy music, etc.) lasting for

15 seconds were presented with 10 second periods of silence between the clips. Between blocks, participants were prompted to rate their levels of happiness, sadness, anger, fear, surprise, and disgust experienced during the previous block using a keyboard on a scale of 1-7. All auditory stimuli were normalized in volume by matching the root mean square average decibels (dB) across clips in audio editing software. Additionally, to control for presentation order effects, two task versions were created: one that presented the music blocks first and one that presented the 3 vocalization blocks first. Emotions within those groups of three blocks were always presented in the same order: happy, sad, then angry.

Measures

ANS. Autonomic data was collected via an ambulatory electro-impedance cardiograph (Model: MW1000A; Mindware Technologies, LTD.) and streamed wirelessly via Wi-Fi to a data acquisition computer running Mindware's Biolab acquisition software. The ambulatory device includes 9 electrodes with leads connecting to a modified PDA inside a specialized enclosure that can be comfortably clipped onto a participant's belt or pants with minimal restriction of mobility. Two electrocardiogram (ECG) electrodes were placed on the right clavicle and the lower left rib while four impedance cardiography (IMP) electrodes were placed on the back on the vertebra prominens (i.e., C7) and lower-middle spine and on the chest at the suprasternal notch and the xiphoid process (i.e., the top and bottom of the sternum respectively). Also, two GSC electrodes were placed about an inch apart on the palm of the non-dominant hand. Psychophysiological measures examined in the present study include heart rate (HR), respiratory sinus arrhythmia (RSA), pre-ejection period (PEP), and galvanic skin conductance (GSC). Similar Mindware system configurations have been used widely across previous

psychophysiological studies (e.g., (G. G. Berntson et al., 2004; Curtin, Lozano, & Allen, 2007; Del Giudice, Hinnant, Ellis, & El-Sheikh, 2011).

All autonomic data were cleaned in 50 second epochs using Mindware software analysis programs. ECG was cleaned using HRV 3.0.25 which allows for manually examining and correctly identifying R-peaks of the QRS complex (the common ECG indicator of ventricular depolarization) in addition to removal of incorrectly identified peaks. Additionally, data in an epoch were only used in statistical analyses if at least 25 seconds of continuous, viable data is present within the 50 second intervals. HR and RSA scores were then obtained from this cleaned data using this software. Impedance cardiograph data will similarly be cleaned using IMP 3.0.25 in 50 second intervals, and PEP scores were calculated using this program. Lastly, GSC data was similarly cleaned and extracted using EDA 3.0.25, again in 50 second intervals. Stimulus clips and blocks were signified by event markers alongside the autonomic data which allowed for ensuring that data periods were correctly organized and identified based on the stimulus presented at that time.

Questionnaires. Demographic information were collected including gender, age, race, and socioeconomic status. Physical health related information was also gathered including height, weight, and BMI using a clinical scale. The Depression Anxiety Stress Scale (DASS; Lovibond & Lovibond, 1995) a 42-item self-report measure was used to assess levels of depression, anxiety, and stress. Specific ratings of momentary emotions (happy, sad, angry, afraid, surprised, and disgusted) were also provided by participants following each 150 second block of stimuli using a scale of 1-7. Lastly concerning auditory-related measures, participants were asked the question “Do you have a hearing problem now” in order to screen for hearing loss. This single question has been shown to be as effective at screening for hearing loss when

compared to a commonly used 10-item screening tool called the Hearing Handicap Inventory for the Elderly-Screening (HHIE-S; (Gates, Murphy, Rees, & Fraher, 2003). Participants were also asked to indicate and describe the nature of any prior musical training.

Analytic Strategy

The following list identifies the specific statistical analysis strategies that were used to test each hypothesis:

- 1. Participants will demonstrate autonomic nervous system responding to the auditory stimuli.** To test whether participants show autonomic responses to the stimuli, a series of Repeated Measures ANOVAs were used with stimulus block as the predictor and each autonomic indicator (HR, PEP, GSC, RSA) as the outcome.
- 2. Participant will experience emotions congruent with the stimulus.** To test how self-reported emotion ratings changed across blocks, A series of Repeated Measures ANOVAs were conducted to see if there was a main effect of stimulus block on emotion rating (separately for ratings of happy, sad, angry, afraid, surprised, and disgusted) across 7 blocks (baseline, laughing, crying, yelling, happy music, sad music, and angry music).
- 3. Participants' autonomic responding will differ across emotion type.** To test this hypothesis and the following hypothesis as well, a series of 2x3 Repeated Measures ANOVAs were used to test for main effects of stimulus (vocalization or music) and emotion (happy, sad, angry) on ANS levels (separately for HR, PEP, GSC, and RSA).
- 4. Participants' autonomic responding will differ across social and nonsocial stimuli.** For this hypothesis, the analysis described for hypothesis 3 was again used, and main effects and interactions involving stimulus type were examined.

5. Autonomic responses will be associated with self-reported emotions. Exploratory analyses were conducted to examine the possible association between ANS responding and self-reported emotions. Bivariate correlations were conducted between self-reported emotion ratings and autonomic scores within the corresponding block of stimuli.

Data Preparation

First, to create our autonomic variables, the three 50-second epochs of autonomic data for HR, PEP, GSC, and RSA within each stimulus block were averaged to provide a single value for each of the 6 blocks (24 total, across the 4 indices). This data was then examined for outliers and missing data. Outliers were winsorized when deemed appropriate and missing data was cautiously imputed with mean values. Because physical movement was minimized in the current study, very few artifacts and noise were apparent in physiological signals and therefore missing values due to invalid signals were very rare. Distributions for this data were then examined and were deemed acceptable regarding meeting assumptions of normality. Throughout all of our repeated measures analyses, in cases where sphericity could not be assumed (tested with Mauchly's W), Greenhouse-Geisser adjustments to degrees of freedom were employed. Furthermore, in the RM ANCOVA analyses, results should be interpreted with caution in cases where there are significant interaction effects with covariates because this indicates that the assumption of homogeneity of regression slopes was violated.

Results

Do participants demonstrate ANS responding compared to baseline?

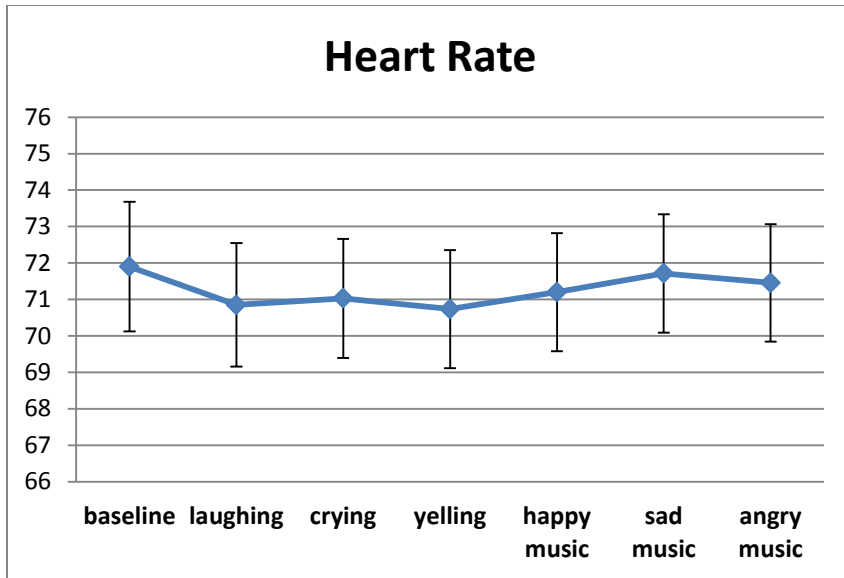
First it should be noted that though we collected data through three baseline conditions (white noise, pink noise, and silence), we decided to use white noise as our neutral baseline condition for the following analyses. Throughout the following sections, all "baseline"

conditions are referring to the white noise condition. This was decided after initial preliminary analyses (available from author upon request) indicating that pink noise conditions had some strange effects on autonomic reactivity. Additionally, white noise is by far the more commonly used type of neutral condition in the prior auditory literature. We decided against using silence because of the obvious drawback of this condition being that it did not control for non-emotional auditory effects.

To test whether the participants in this study exhibited autonomic responding to the emotional stimuli presented, a series of Repeated Measures ANOVAs were conducted to see if there was a main effect of stimulus block on ANS levels (separately for HR, PEP, GSC, and RSA, respectively) across 7 blocks (150 second averages of baseline, laughing, crying, yelling, happy music, sad music, and angry music). Post-hoc pairwise comparisons of Estimated Marginal Means were used to examine significant changes of the blocks when compared to baseline. Additionally, all graphs in the figures below display means as well as standard error values in the form of error bars.

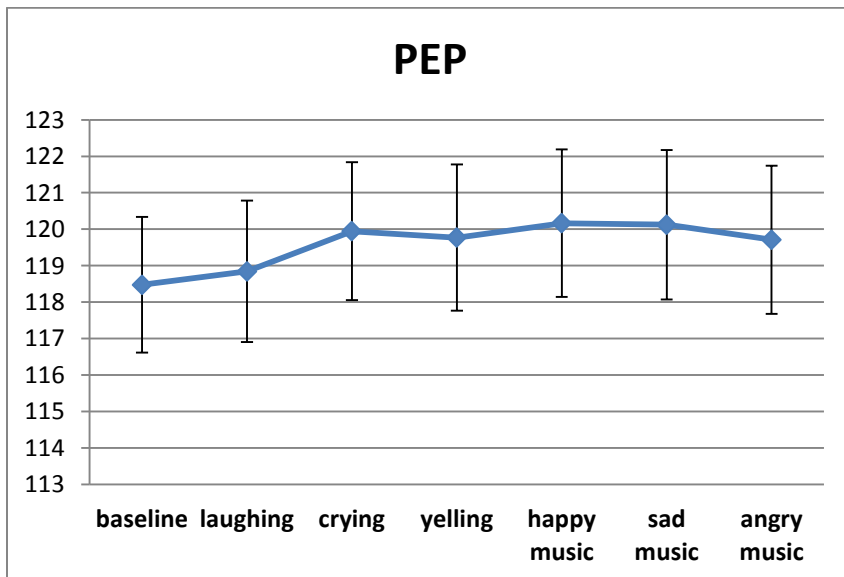
Heart Rate. Heart rate levels demonstrated trend levels significance in changes across blocks (see Figure 1), $F(4.05, 198.25)=2.25, p=.064$. Follow-up Pairwise Comparisons indicated HR was significantly lower in laughing ($p=.012$) and yelling ($p=.034$) conditions compared to baseline. Other blocks were not significantly different from baseline.

Figure 1. Average Heart Rate across stimulus blocks



Pre-ejection Period. PEP demonstrated trend level significance in changes across blocks (see Figure 2), $F(4.20, 201.66)=2.21, p=.066$. Follow-up comparisons indicated that PEP was significantly higher in crying ($p=.034$), happy music ($p=.045$), and sad music ($p=.039$) blocks than compared to the baseline.

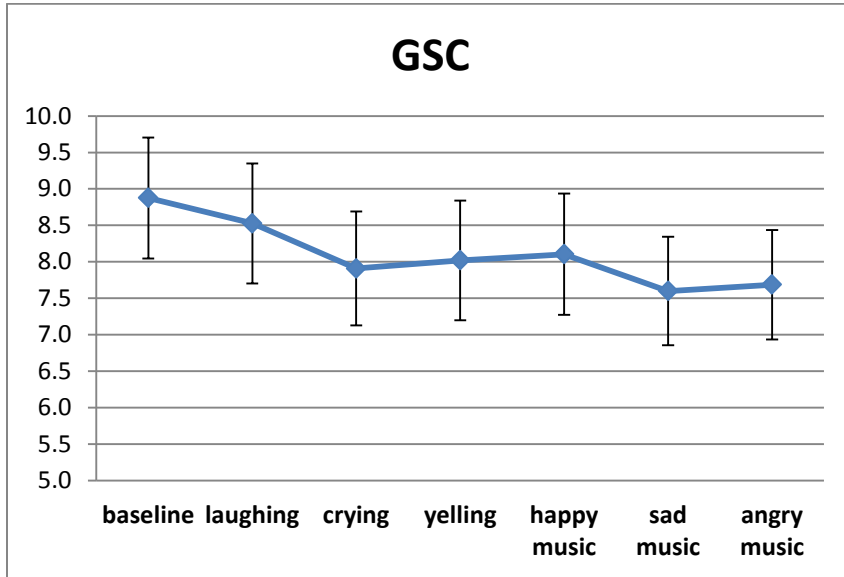
Figure 2. Average PEP across stimulus blocks



Skin Conductance. GSC changed significantly across blocks (see Figure 3), $F(2.92, 143.18)=5.16, p=.001$. Follow-up comparisons demonstrated that GSC was lower in crying

($p=.003$), yelling ($p=.02$), happy music ($p=.02$), sad music ($p=.001$), and angry music ($p=.008$) blocks when compared to baseline.

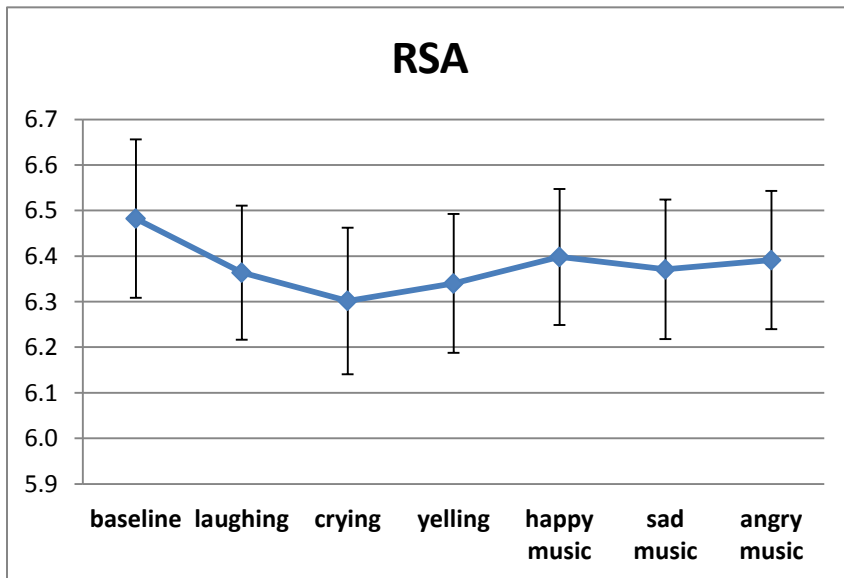
Figure 3. Average GSC across stimulus blocks



Respiratory Sinus Arrhythmia. RSA did not show significant differences across blocks

(see Figure 4), $F(4.03, 197.60)=.83$, $p=.51$.

Figure 4. Average RSA across stimulus blocks



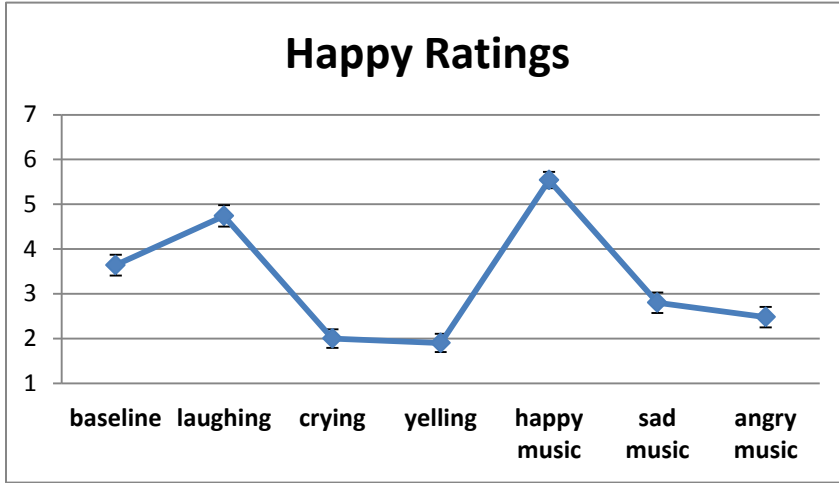
In summary, we generally found sympathetic deactivation as indicated by changes in GSC and trend level changes in heart rate and PEP.

Are participants' reported emotions congruent with emotions conveyed by stimuli?

Next, analyses focused on whether participants' self-reported emotions changed immediately following each block. A series of Repeated Measures ANOVAs were conducted to see if there was a main effect of stimulus block on emotion rating (separately for ratings of happy, sad, angry, afraid, surprised, and disgusted) across 7 blocks (baseline, laughing, crying, yelling, happy music, sad music, and angry music). Post-hoc pairwise comparisons of Estimated Marginal Means were used to examine significant changes compared to baseline. Again, in cases where sphericity could not be assumed, Greenhouse-Geisser adjustments to degrees of freedom were used.

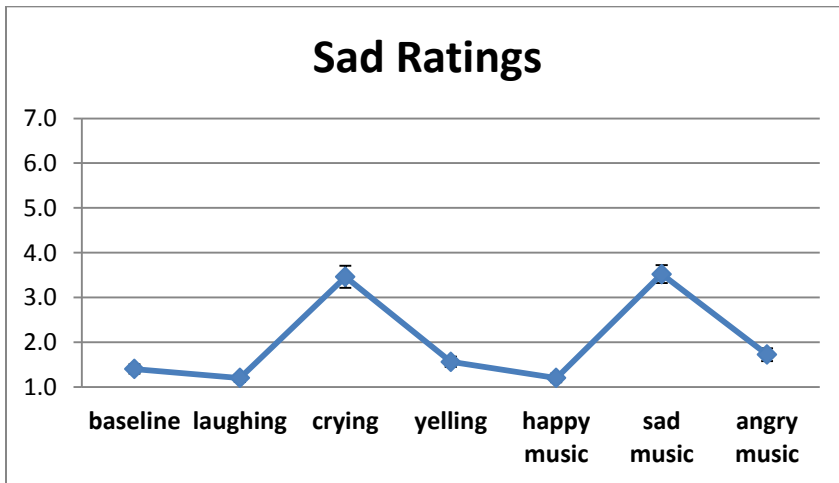
Happy. Happy ratings were significantly different across blocks (see Figure 5), $F(3.95, 193.49)=75.01, p<.001$. Follow-up Pairwise Comparisons indicated Happy ratings were significantly higher in laughing and happy music conditions compared to baseline, as expected. Ratings were significantly lower in crying, angry, sad music, and angry music conditions compared to baseline (all $p's<.001$). Other blocks were not significantly different from baseline.

Figure 5. Happy ratings across stimulus blocks



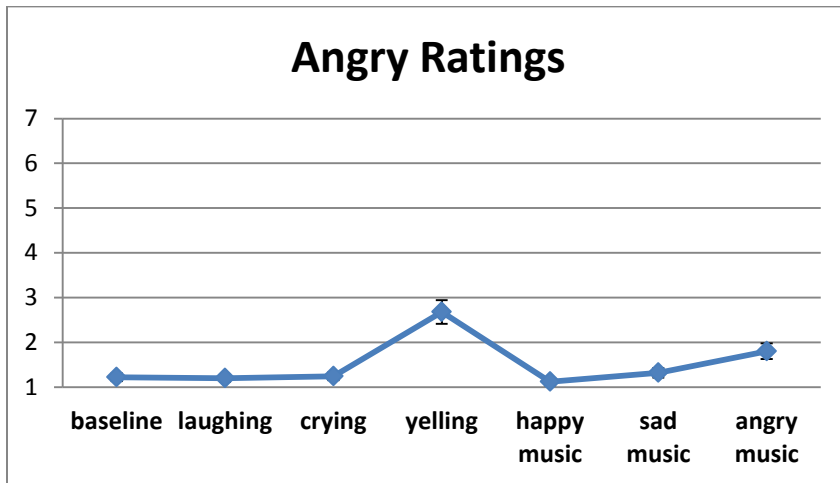
Sad. Sad ratings were significantly different across blocks (see Figure 6), $F(2.95, 144.38)=62.54, p<.001$. Follow-up comparisons indicated Sad ratings were significantly higher in crying ($p<.001$), sad music ($p<.001$), and angry music ($p=.02$) blocks compared to baseline, as expected.

Figure 6. Sad ratings across stimulus blocks



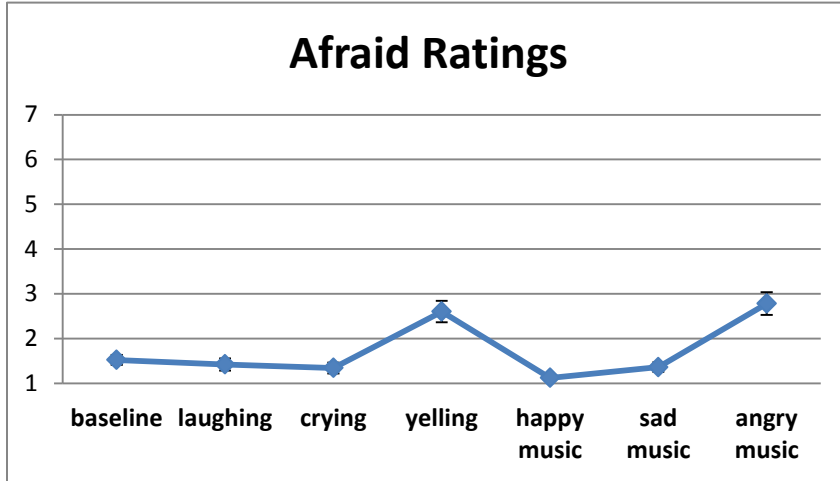
Angry. Angry ratings were significantly different across blocks (see Figure 7), $F(2.23, 109.22)=20.79, p<.001$. Follow-up comparisons indicated Angry ratings were significantly higher in yelling ($p<.001$) and angry music ($p=.003$) blocks compared to baseline, as expected.

Figure 7. Angry ratings across stimulus blocks



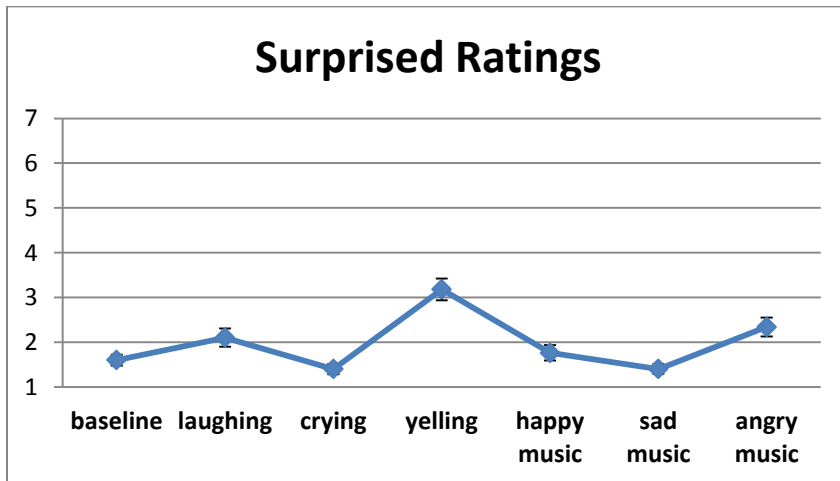
Afraid. Beyond the targeted emotions of happy, sad and angry, we also explored participant responses to the other basic emotions. Afraid ratings were significantly different across blocks (see Figure 8), $F(3.07, 150.55)=22.45, p<.001$. Follow-up comparisons indicated Afraid ratings were significantly higher in yelling ($p<.001$) and angry music ($p<.001$) blocks and significantly lower in happy music ($p<.001$) blocks compared to baseline.

Figure 8. Afraid ratings across stimulus blocks



Surprised. Surprised ratings were significantly different across blocks (see Figure 9), $F(4.15, 203.48)=19.33, p<.001$. Follow-up comparisons indicated Surprised ratings were significantly higher in laughing ($p=.03$), yelling ($p<.001$), and angry music ($p=.001$) blocks compared to baseline.

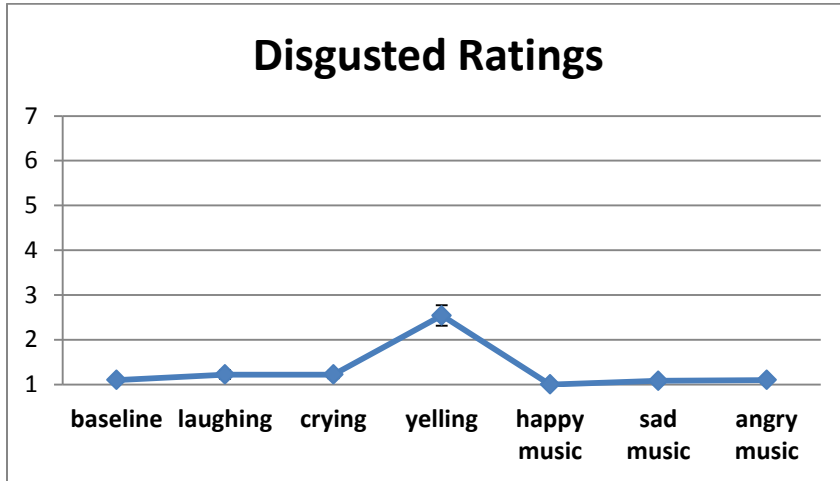
Figure 9. Surprised ratings across stimulus blocks



Disgusted. Disgusted ratings were significantly different across blocks (see Figure 10), $F(1.91, 93.58)=29.50, p<.001$. Follow-up comparisons indicated Disgusted ratings were

significantly higher in yelling ($p < .001$) blocks compared to baseline, while all other blocks were not different from baseline.

Figure 10. Disgusted ratings across stimulus blocks



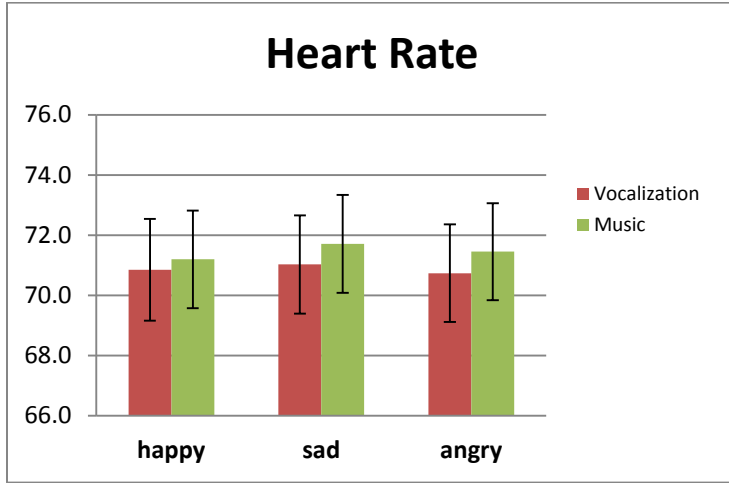
In summary, we found the expected congruent emotion ratings to increase in response to our stimuli and additionally found some emotional changes in the additional basic emotions of fear, surprise, and disgust.

Does participants' autonomic responding differ across stimulus type or emotion?

Next, I was interested specifically in testing whether autonomic responding differed across stimulus type or stimulus emotion presented within a given block. A series of 2x3 Repeated Measures ANOVAs were conducted to test for main effects of stimulus (vocalization or music) and emotion (happy, sad, angry) on ANS levels (separately for HR, PEP, GSC, and RSA). Post-hoc pairwise comparisons again were used to examine changes between individual blocks.

Heart Rate. A trend towards significance of stimulus was indicated in HR (see Figure 11), $F(1,49)=3.47$, $p=.068$. With HR, there was no significant interaction between stimulus and emotion, and post-hoc comparisons across blocks were not significant.

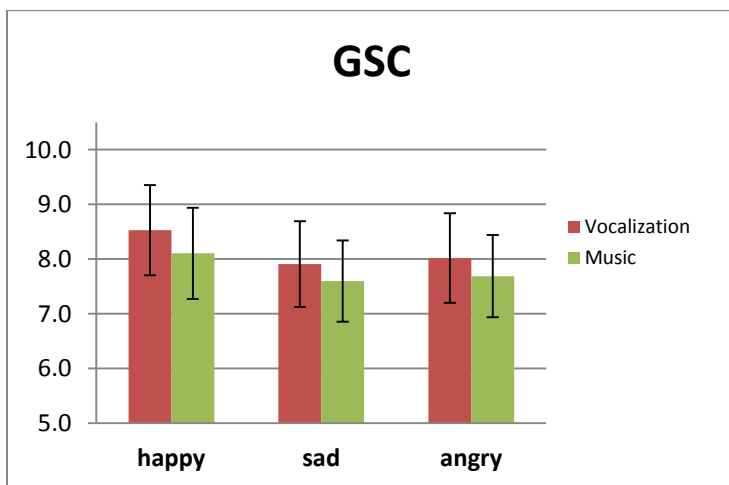
Figure 11. Heart Rate across emotional stimulus blocks (vocalizations and music)



Pre-ejection Period. In this analysis, no main effects (or interactions between stimulus and emotion) were found for PEP.

Skin Conductance. For GSC, a main effect of emotion was found (see Figure 12), $F(1,35, 66.02)=8.55, p=.002$. Regarding main effects of stimulus, a trend was found, $F(1,49)=3.71, p=.06$. There was not a significant interaction of stimulus. Post-hoc comparisons between emotions indicated differences in GSC between happy and sad ($p=.000$) as well as between happy and angry ($p=.02$) emotions.

Figure 12. GSC across emotional stimulus blocks (vocalizations and music)



Respiratory Sinus Arrhythmia. For RSA, no main effects or interaction effects were found.

Does participants' autonomic responding differ across stimulus type or emotion when controlling for baseline levels?

Next, we again tested for effects of stimulus and emotion while controlling for baseline ANS levels. A series of RM ANCOVAs were conducted to test for main effects of stimulus (vocalization or music) and emotion (happy, sad, angry) on ANS levels (separately for HR, PEP, GSC, and RSA) while including baseline ANS levels as a covariate. Post-hoc comparisons of estimated marginal means were again used to examine significant changes between individual blocks.

Heart Rate. For heart rate, no significant effects were found when controlling for baseline heart rate levels. That is, our trend level heart rate effect found above did not persist in this analysis.

Pre-ejection Period. For PEP, no significant effects were found when controlling for baseline PEP levels, as expected from analyses above.

Skin Conductance. For GSC, main effects did not persist for stimulus or emotion. Instead, there were significant interaction effects of stimulus*baseline, $F(1, 48)=4.19, p=.046$, and emotion*baseline, $F(1.38, 66.51)=10.81, p<.001$. A follow-up RM ANOVA using a categorical variable for baseline GSC (separated into 3 levels by using .5 SD below and above the mean to indicate low, average, and high) was used to produce the graphs in Figure 13 and 14. Pairwise comparisons from this analysis indicated that participants with high baseline GSC ($n=12$) showed higher GSC in happy music compared to sad music blocks ($p<.001$), higher GSC in happy music compared to angry music blocks ($p<.001$), higher GSC in crying compared to sad

music ($p=.003$), and higher GSC in yelling compared to angry music. Pairwise comparisons also indicated that participants with average baseline GSC ($n=20$) showed higher in laughing compared to crying blocks ($p=.01$) as well as higher GSC in laughing compared to angry blocks. This suggests that effects may be driven by differences in baseline GSC levels.

Figure 13. GSC across emotional stimulus blocks (vocalizations and music) in participants with average GSC baseline levels

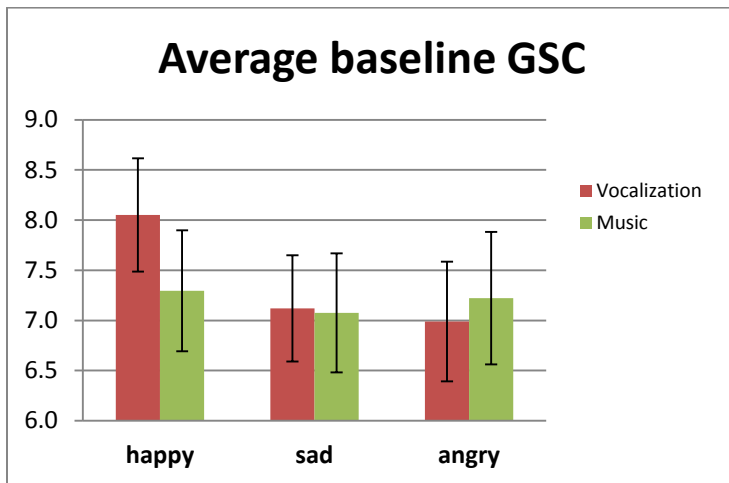
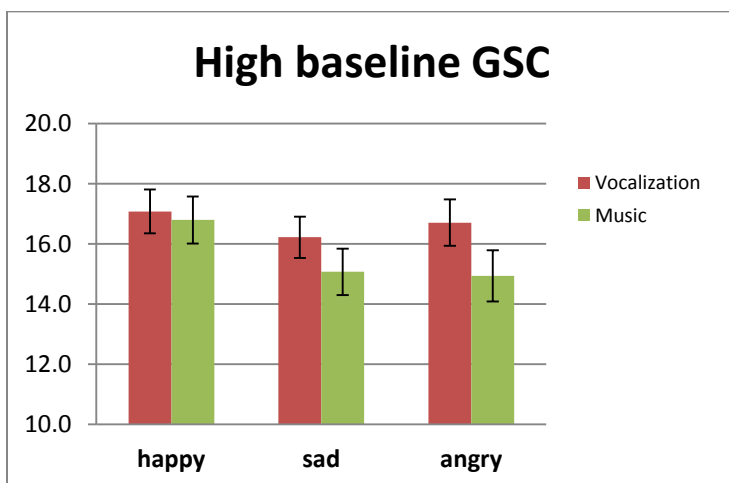


Figure 14. GSC across emotional stimulus blocks (vocalizations and music) in participants with high GSC baseline levels

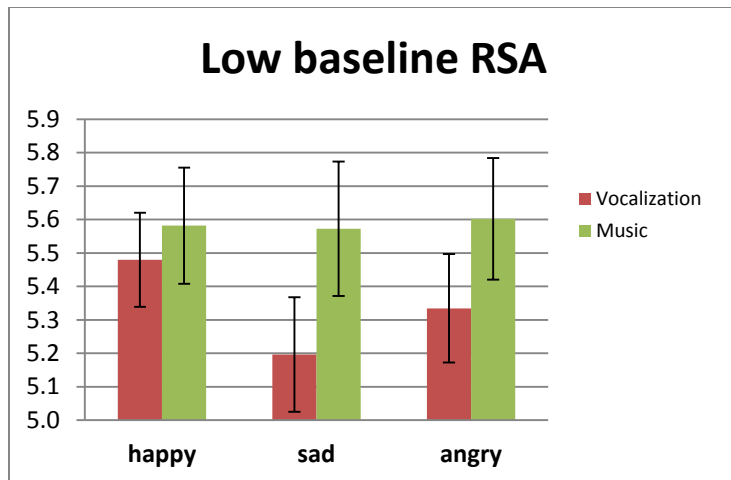


Respiratory Sinus Arrhythmia. For RSA, main effects of stimulus type and emotion were not significant, but there was a significant interaction of stimulus by emotion see (Figure 15), $F(2, 96)=3.22, p=.04$. Post-hoc pairwise comparisons were not significant. There was also a significant 3-way interaction between stimulus, emotion, and baseline, indicating that this stimulus by emotion interaction effect differed based on differences in baseline levels. A follow-up RM ANOVA using a categorical variable for baseline RSA (i.e., the same strategy that was used above for GSC; see Figure 16), and pairwise comparisons from this analysis indicated that participants with low baseline RSA ($n=16$) showed lower RSA in crying compared to laughing blocks ($p=.043$) and lower RSA in sad music compared to crying blocks ($p=.029$). This suggests that the effect is driven by differences in baseline levels of RSA.

Figure 15. RSA across emotional stimulus blocks (vocalizations and music) in all participants



Figure 16. RSA across emotional stimulus blocks (vocalizations and music) in participants with low RSA baseline levels



Does ANS responding differ across stimulus type or emotion when controlling for various covariates?

Next, we wanted to also test for effects of stimulus and emotion while controlling for other various covariates (task order, sex, age, depression, and anxiety) so a series of RM ANCOVAs were again conducted to test for main effects of stimulus (vocalization or music) and emotion (happy, sad, angry) on ANS levels (separately for HR, PEP, GSC, and RSA) while including individual covariates. Post-hoc pairwise comparisons of means were again used to examine for significant changes between individual blocks.

Task Version. As previously stated in the methods section, the order of stimulus presentation (i.e., vocalizations or music first) was pseudo-randomized across participants in order to experimentally minimize effects that might have appeared due to the order in which each type of stimulus was presented. Though some participants heard voices first and some heard music first, all participants heard these 2 groups of 3 blocks with the same sequence of conveyed emotions: happy, then sad, then angry (i.e., laughing, crying, yelling, or happy music, sad music, angry music). To ensure that no effects were being driven by differences due to task version, RM ANCOVAs were again run, this time with task version as a covariate.

Again run separately for each ANS variable, this series of RM ANCOVAs did not demonstrate any significant main effects or interaction effects for HR, PEP, GSC, or RSA. Though our effects did not persist when controlling for task order, this may be due to a lack of sufficient statistical power. Additionally, the lack of interactions found with task order as a covariate suggests that differences due to task order did not drive any particular effects.

Sex. Sex was included as the covariate in this set of RM ANCOVA analyses. Here, our trend level heart rate effects were again found but our skin conductance and RSA effects did not persist.

Heart Rate. For heart rate, a trend towards a main effect of stimulus was shown, $F(1, 48)=3.49, p=.068$ (see Figure 11 above for visual representation of these same means). Post-hoc comparisons did not show any significant differences between individual blocks.

Pre-ejection Period. No significant main effects or interactions of stimulus or emotion were found for PEP when controlling for sex.

Skin Conductance. Again, no main effects or interactions of stimulus or emotion were found for GSC when controlling for sex.

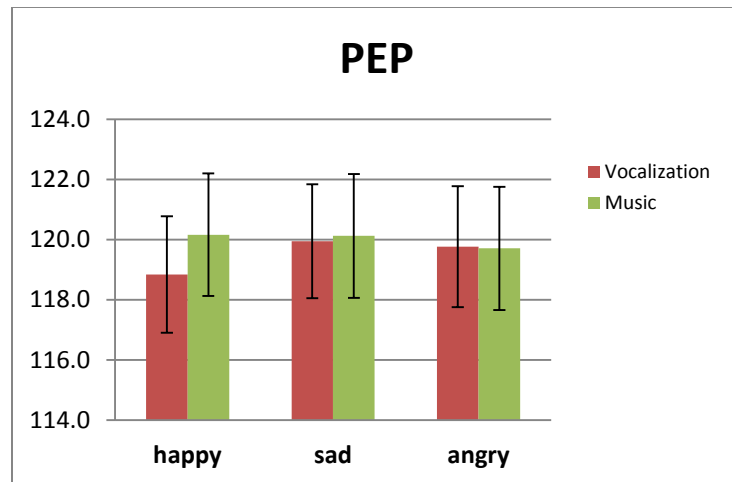
Respiratory Sinus Arrhythmia. Lastly, again no effects of stimulus or emotion were found for RSA when controlling for sex.

Age. Participants' reported ages in years were included as the covariate in the following set of RM ANCOVAs. Here an effect of PEP emerged and RSA effects were found, however our GSC effects again disappeared, indicating that skin conductance responding was not the same for all ages.

Heart Rate. No main effects of stimulus or emotion were found for heart rate when controlling for age. Additionally, no interaction effects were shown.

Pre-ejection Period. For PEP, there was a trend towards significance for the main effect of stimulus, $F(1,47)=3.93$, $p=.053$ (see Figure 17). Pairwise comparisons demonstrated that PEP was significantly lower in laughing compared to happy music blocks ($p=.036$) as well as lower in laughing compared to crying blocks ($p=.031$).

Figure 17. PEP across emotional stimulus blocks (vocalizations and music)



Skin Conductance. For GSC, no significant main effects or interactions of stimulus or emotion were found when controlling for age.

Respiratory Sinus Arrhythmia. For RSA, there was a trend towards significance for the main effect of emotion, $F(2, 96)=2.91$, $p=.059$, (see Figure 15 above for visual representation of these estimated marginal means). Post-hoc pairwise comparisons did not show any significant effects between blocks.

Depression. Depression was measured through the DASS depression subscale. These scores were used as a covariate in the following analyses. Here, no effects were found and no effects persisted from the previous analyses.

Heart Rate. No main effects of stimulus or emotion were found for heart rate when controlling for depression. Additionally, no interaction effects were shown.

Pre-ejection Period. Similarly, no main effects of stimulus or emotion were found for PEP when controlling for depression. Also, no interaction effects were found.

Skin Conductance. Again, no main or interaction effects of stimulus or emotion were found for GSC when controlling for depression.

Respiratory Sinus Arrhythmia. Lastly, no main or interaction effects were found for RSA when controlling for depression.

Anxiety. Anxiety was measured through the DASS anxiety subscale. These anxiety scores were used as a covariate in the following RM ANCOVA analyses. Here, our GSC effects persisted, but no other effects were found.

Heart Rate. No main effects of stimulus or emotion were found for heart rate when controlling for anxiety. Additionally, no interaction effects were shown.

Pre-ejection Period. Similarly, no main effects of stimulus or emotion were found for PEP when controlling for anxiety. Also, no interaction effects were found.

Skin Conductance. For GSC, there was a main effect of stimulus, $F(1,48)=5.02$, $p=.03$, and emotion, $F(1.35, 64.82)=6.77$, $p=.006$ (see Figure 12 above for visual representation of these estimated marginal means). Post-hoc pairwise comparisons demonstrated that GSC was higher in laughing compared to crying blocks ($p=.008$) and GSC was higher in happy music compared to sad music blocks ($p=.003$).

Respiratory Sinus Arrhythmia. Lastly, no main or interaction effects were found for RSA when controlling for anxiety.

Are autonomic responses associated with self-reported emotions?

To test for associations between autonomic levels and self-reported emotions, bivariate correlations were conducted between autonomic indices (HR, PEP, GSC, and RSA) and the self-

reported emotion ratings (happy, sad, angry, afraid, surprised, and disgusted) for concurrent blocks.

Laughing block. For the laughing block, no significant correlations were found of emotion ratings with HR, PEP, GSC, or RSA.

Crying block. Regarding the crying block, heart rate was found to be negatively associated with happy ratings, $r(50)=-.418$, $p=.003$ as well as afraid ratings, $r(50)=-.286$, $p=.044$.

Yelling block. For the yelling block, heart rate was negatively associated with happy ratings, $r(50)=-.317$, $p=.025$ and PEP was positively associated with sad ratings, $r(49)=.285$, $p=.047$.

Happy music block. Regarding the happy music block, no significant correlations were found between emotion ratings and any ANS indices.

Sad music block. Similarly for the sad music block, no significant correlations were found between emotion ratings and ANS variables.

Angry music block. For the angry music block, heart rate was found to be negatively associated with happy ratings, $r(50)=-.30$, $p=.033$. Also, GSC was found to negatively correlate with surprise ratings, $r(50)=-.30$, $p=.032$ and positively correlate with disgust ratings, $r(50)=.40$, $p=.004$.

Though block-congruent emotion rating associations with ANS (e.g., happy ratings within happy stimulus blocks) were not found, some patterns indicating happy ratings being associated with ANS activity in negative blocks emerged. However, these associations should be interpreted with caution due to high number of analyses conducted and their exploratory nature.

Discussion

The general purpose of the study was to examine autonomic and emotional responding to different types of auditory stimuli, both vocal and musical sounds. We tested this by presenting stimuli to participants while collecting autonomic data and asking them to provide emotion ratings following each emotion block. We thought autonomic responding to emotional stimuli would be different from baseline levels. This was partially supported, but the direction of these effects was sometimes unexpected. We expected that participants would report experiencing emotions congruent with those conveyed by our stimuli, and this was found to be the case. Lastly, we thought that the ANS would show differential activation across stimulus types (vocalizations and music) and emotions (happy, sad, and angry). Differences across stimuli and emotions were found in some autonomic indices. We discuss these findings in detail in the following sections with a lens towards how this information informs an understanding of autonomic responsivity to emotional stimuli.

Do participants demonstrate ANS responding compared to baseline?

In this section we consider whether emotional stimulus blocks were different from baseline. Compared to autonomic measurements collected while participants listened to neutral stimuli (white noise), our analyses did not demonstrate autonomic responding to the emotional stimuli in the expected direction for all of the ANS indices together. However, some deactivation responses (sympathetic withdrawal) were indicated for sad conditions with specific ANS measures, and this was anticipated. We generally expected to see activation (compared to baseline) in the sympathetic measures (HR, PEP, and GSC) for angry and happy emotion conditions and possible sympathetic withdrawal during sad conditions and the converse for parasympathetic measures (RSA). While sadness is sometimes characterized by an activating SNS response if the participant is crying, none of our participants cried in response to the

emotional stimuli, and therefore a deactivating response was expected. Our findings are summarized in the following paragraphs for heart rate, PEP, GSC, and RSA.

Heart Rate. Regarding heart rate, increases typically indicate sympathetic activation (and parasympathetic withdrawal) while decreases indicate parasympathetic activation (and sympathetic withdrawal). We therefore would have expected heart rate to increase if there was autonomic activation compared to baseline in happy and angry conditions and decrease in sad conditions. However, based on a trend towards significance for overall differences between blocks and significant post-hoc comparisons with baseline levels, we found that heart rate levels were in actually lower in laughing and yelling blocks compared to baseline. This is inconsistent with prior research that has generally shown heart rate to increase in response to happy and angry stimuli (Hamer et al., 2007; Neumann & Waldstein, 2001; Rainville et al., 2006; Ritz, George, et al., 2000).

Pre-ejection Period. For PEP, changes are typically thought to be more specific to the sympathetic branch alone and therefore decreasing or low PEP reflect sympathetic activation between ventricular depolarization and the opening of the aortic valve (and blood then flowing out of the heart). Based on the expectation of sympathetic increases in happy and angry blocks, we expected PEP to decrease in happy and angry blocks, we would have expected PEP to decrease in happy and angry blocks. Past literature has shown this to be relatively consistent for anger (Montoya et al., 2005; Neumann & Waldstein, 2001; Sinha et al., 1992) but not necessarily in happiness where PEP has been shown to increase in response to happy stimuli (Nyklicek et al., 1997). We also expected sad conditions to cause an increase in PEP, indicating sympathetic withdrawal. Our analyses of PEP indicated a trend towards significance in changes across blocks, and follow-ups indicated significantly higher PEP in crying, happy music, and sad music

blocks. Higher PEP within the crying and sad music blocks is consistent with prior research demonstrating a deactivating sadness response (Kreibig, Wilhelm, Roth, & Gross, 2007; Marsh, Beauchaine, & Williams, 2008). Furthermore, happy music has also been shown to increase PEP in prior studies (Nyklicek et al., 1997).

Skin Conductance. For GSC, sweat glands are controlled by the sympathetic nervous system and therefore increases reflect sympathetic activation while decreases reflect sympathetic inhibition. We therefore expected GSC to increase during happy and angry conditions and decrease in sad conditions. Our findings indicated significantly lower GSC in crying, yelling, happy music, sad music, and angry music conditions compared to baseline. While these decreases were expected and are consistent with prior literature for sadness (Christie & Friedman, 2004; Gross & Levenson, 1997; Marsh et al., 2008; Tsai, Levenson, & Carstensen, 2000), these decreases were not expected for the angry blocks or happy music blocks. It seems to be the case that our participants tended to have higher skin conductance in response to our baseline stimulus compared to the emotion blocks. This could also be partly due to an initial increase in arousal when first hearing auditory stimuli (or reading instructions regarding the task) that habituated over the course of being presented sounds repeatedly for around 25 minutes.

Respiratory Sinus Arrhythmia. For RSA, increases indicate increased parasympathetic control while decreases indicate parasympathetic withdrawal. We expected RSA to decrease during happy and angry blocks and increase during sad blocks. These initial analyses did not demonstrate any significant differences in RSA across blocks.

Though our findings across these four autonomic indices did not demonstrate a consensus in activation patterns regarding the expected directionality of sympathetic or parasympathetic activity, some trend level findings in HR and PEP and significant findings in GSC did

demonstrate expected responses. In the current study, it seems that our baseline condition (listening to neutral white noise) in general elicited more sympathetic activation (or a lack of difference) compared to the emotional stimulus blocks. This makes interpretation of the activation of the ANS within these emotional conditions compared to a neutral auditory stimulus more difficult as autonomic arousal was not just a stress or no-stress response. However, this lack of a clear activation is not entirely unexpected due to the breadth of findings in the emotion literature demonstrating a lack of change in certain indices compared to baseline conditions (e.g., Etzel et al., 2006; Nyklicek et al., 1997) and also because a reduced autonomic response is often of interest as a measure of emotional control (Demaree, Robinson, Erik Everhart, & Schmeichel, 2004; Pu, Schmeichel, & Demaree, 2010). Furthermore, some studies have suggested that expressions of anger do not reliably elicit anger themselves, but rather elicit more fear-like responses which would be characterized by sympathetic deactivation which is closer to what we found (Dimberg & Thunberg, 2007; Jönsson & Sonny-Borgström, 2003). Additionally, with skin conductance in particular, it seems that baseline levels were higher than the emotion blocks, perhaps indicating an initial sympathetic arousal response to starting the sounds that habituated over the course of repeated auditory stimulus presentations. Therefore, while it makes inferring a clear pattern demonstrating a particular type of autonomic responding more difficult, these differences in ANS indices still provide interesting information regarding subtle differences in autonomic arousal in emotion compared to baseline arousal conditions.

Are participants' reported emotions congruent with emotions conveyed by stimuli?

This section will consider whether participants experienced emotions consistent with those expressed by the stimuli. Regarding the self-reported emotion ratings provided following each block, we expected to see higher ratings for emotions congruent with those conveyed in

each block (e.g., higher happy ratings during laughing and happy music stimuli) compared to baseline ratings. This was found to be the case with the three congruent emotion ratings (happy, sad, angry) across both the vocalization and music stimulus types. These patterns of congruent emotional responding help to further validate the emotional stimuli that we employed in the current study. Also interestingly, the additional emotion ratings (afraid, surprised, and disgusted) were found to be higher in the both anger emotion blocks (yelling and angry music). Our findings regarding each rating type are summarized and discussed in the following paragraphs.

Congruent emotions (happy, sad, angry). We first examined the ratings for emotions that were congruent with our stimuli. With respect to happy ratings, our analyses indicated that happy ratings were higher in laughing and happy music conditions compared to baseline while they were lower in the other emotion conditions compared to baseline. These findings demonstrate the expected increases in self-reported happiness during the happy emotion conditions and decreases during the negative emotion conditions (sad and angry). While these patterns of ratings make sense intuitively, they are also consistent with prior literature that demonstrates increases in self-reported happiness to happy or similarly positive (e.g., amusement, contentment) stimuli (Gross & Levenson, 1995; Hawk et al., 2012). While these studies did not specifically report on significant differences in happiness across negative emotion blocks (as is often the case because congruent emotions tend to be the focus of statistical testing), reported mean ratings of happiness do tend to be lower in response to angry and sad stimuli. In sum, evidence indicates that our participants experienced happiness during the happy condition and therefore helps to validate the use of the current study's laughing and happy music stimuli in our sample.

Participants' sad ratings, as expected, were found to be higher in the crying and sad music conditions compared to baseline. Additionally and somewhat unexpectedly, sad ratings were found also to be higher in the angry music condition compared to baseline. However, sad ratings are demonstrably higher in the sad conditions compared to all other blocks while only minimally higher in the angry music block. These findings support the validity of the sad stimuli because participants reported increases in the intended conveyed emotion, but there may also be some lack of emotional specificity as expected with complex emotional stimuli.

Lastly, and again as expected, angry ratings were shown to be significantly higher in the yelling and angry music conditions compared to baseline while anger ratings were unchanged from baseline in other blocks. We can again infer that these stimuli that conveyed anger also elicited anger in our sample and therefore also support the validity of the stimuli. In sum, evidence indicates that our participants experienced congruent emotions in response to our happy, sad, and angry stimuli, thereby validating their use in the current study. This is also consistent with past emotion research that shows emotion recognition and induction capabilities of a variety of auditory stimuli (Eerola & Vuoskoski, 2010; Hawk et al., 2012; Juslin & Laukka, 2003). This helps validate both musical and vocal auditory stimuli as emotionally evocative for relatively specific basic emotions.

Additional emotions (afraid, surprised, disgusted). We included the other 3 basic emotions (e.g., afraid, surprised, and disgusted) as self-report ratings following each block. Because no stimuli were used that explicitly conveyed these emotions, we had no specific expectations for these ratings. They were primarily included as exploratory measures in order to expand the self-reported emotional information we were gathering beyond the three expected emotions. Afraid ratings were shown to be higher in yelling and angry music blocks and lower

in happy music blocks compared to baseline. Surprised ratings were higher in laughing, yelling, and angry music blocks compared to baseline. Lastly, disgusted ratings were higher in only yelling blocks compared to baseline. Past studies using film excerpts as emotional stimuli have found similarly increased fear and disgust ratings in response to angry stimuli (Gross & Levenson, 1995). One study that used the same vocal stimuli as the current study also found apparently elevated disgust ratings (based on reported means) in response to the angry vocalizations (Hawk et al., 2012). Also, previous music studies have indicated overlaps and associations between anger and fear in response to angry or fearful stimuli, and it has been suggested that these two emotions might not be easily distinguished in the context of emotional music; surprise has similarly been suggested to overlap with anger and fear responding as well (Eerola & Vuoskoski, 2010; Juslin, 2000; Kallinen & Ravaja, 2006). In sum, with the exception of surprise in response to laughing, these additional emotion ratings fit with findings from prior literature and may make intuitive sense about the overlap of complicated emotional stimuli.

Does participants' autonomic activity differ across stimulus type or emotion?

Next, because a major goal of the current study was to look for differences in autonomic responding across stimulus types (vocalizations or music) and emotions (happy, sad, and angry), these two variables were our next focus. This comparison between vocalizations and music was not directly investigated in prior studies, lending to the novelty of this dissertation. It was theorized that vocalization stimuli may cause increased physiological arousal compared to less social stimuli (i.e. music) due to this vocal communication being more directly linked to emotional responses and expression that were important for social communication and survival throughout the evolution of humans. We therefore expected to see more sympathetic activation (which is also associated with the motivational fight-or-flight response) in vocalization stimuli

compared to music stimuli. Across emotion conditions, we generally expected to see more sympathetic activation (and conversely, parasympathetic withdrawal) in happy and angry blocks and increased parasympathetic control (and sympathetic withdrawal) in sad blocks. Again organized by ANS indices, we consider whether these expectations were supported by the study findings.

Heart Rate. We expected heart rate to be higher during vocalizations compared to music blocks. Regarding differences in emotion conditions, we also expected heart rate to be higher in happy and angry blocks compared to sad blocks. Without accounting for covariates, our findings showed a trend for heart to be higher in music blocks compared to vocalization blocks. After controlling for baseline heart rate levels, this trend level effect of stimulus disappeared, indicating that these trend-level differences in levels across stimulus types may have been driven by between-subjects differences in baseline levels. These findings did not demonstrate the expected sympathetic increases in vocalizations compared to music but rather somewhat support the converse that more sympathetic activation may be apparent in music conditions. Because heart rate is not considered as precise of a measure of sympathetic activation (compared to GSC or PEP for instance), especially with respect to stimuli that induce only subtle changes (compared to stress tasks which might cause much greater cardiac response), we remain cautious about the interpretation of heart rate. Instead, we argue that more attention should be shown to results of the other autonomic indices which are more distinct indices of sympathetic or parasympathetic activation, respectively. Of note is that these other measures were somewhat more in line with our proposed hypotheses, the extant literature, and with a clearer indication of sympathetic or parasympathetic underlying mechanisms on emotional music and vocalization stimuli.

Pre-ejection Period. Because decreases in PEP indicate sympathetic activation, we expected PEP to be lower during vocalizations compared to music blocks. Regarding differences in emotion conditions, we also expected PEP to be lower in happy and angry blocks compared to sad blocks. However, our analyses did not demonstrate any significant differences or trends in PEP. Similarly, no effects were found when controlling for baseline PEP levels.

Skin Conductance. Increases in GSC indicate sympathetic activation related in part to peripheral (e.g., dermal) sympathetic influences. Therefore, we expected GSC to be higher during vocalizations compared to music blocks. For emotion conditions, we expected GSC to be higher in happy and angry blocks compared to sad blocks. First, without controlling for baseline, we found a trend indicating higher GSC in vocalizations compared to music. This analysis also had a significant main effect of emotion indicating higher GSC in happy blocks compared to both sad and angry blocks. This skin conductance activation in response to happy stimuli has been found previously in the literature (Gerhard Stemmler & Fahrenberg, 1989; Vianna & Tranel, 2006) This greater responding in vocalizations without controlling for covariates does indicate limited confirmation of our hypothesis of increased sympathetic arousal in response to vocalizations compared to music. Higher skin conductance in happy blocks may be indicative of more engagement or increased concentration and attention in response to laughing and happy music sounds compared to the other stimuli. When adding baseline levels of GSC as a covariate, our trend for stimulus type and main effect of emotion were no longer found, but significant stimulus type by baseline and emotion by baseline interactions were found. This suggests that these effects may be driven by differences in baseline levels such that the GSC effect was largely driven by participants with high or average GSC rather than low GSC. We interpret this interaction to mean that some people may be more prone than others to an emotional dermal

response and it is the high dermal responders that showed the emotion-specific GSC responding. Past research has generally shown skin conductance to increase in response to emotionally arousing non-musical auditory stimuli (Bradley & Lang, 2000; Frodi, Lamb, Leavitt, & Donovan, 1978) such as vocalizations. Past research has also shown skin conductance activation in response to music. For example one study showed that music could differentially cause GSC responding such that more emotionally powerful music elicited greater responses compared to less emotional music (Rickard, 2004). In sum, compared to the other autonomic indices, skin conductance seemed to show the most clearly differentiated activation across stimulus types and emotions and largely supported our hypotheses regarding expected increased sympathetic activation in vocalizations compared to music.

Respiratory Sinus Arrhythmia. Because decreases in RSA indicate parasympathetic withdrawal, we expected RSA to be lower during vocalization compared to music blocks. Regarding emotion conditions, we expected RSA to be lower in happy and angry blocks compared to sad blocks. First, when not controlling for baseline levels, no significant effects were found for RSA. When controlling for baseline RSA levels, an interaction indicated that participants with lower baseline showed more RSA withdrawal in crying blocks (specifically compared to laughing and sad music blocks). These findings suggest that certain participants (those with lower baseline levels) experienced more parasympathetic withdrawal and possibly increased arousal or anticipation in response to crying compared to sad music. This parasympathetic withdrawal in response to crying sounds is somewhat consistent with prior studies with mothers and crying infants that suggest parasympathetic withdrawal is indicative of adaptive and nurturing responding to infant distress signals (Frodi et al., 1978; Stallings, Fleming, Corter, Worthman, & Steiner, 2001). This could also be interpreted as these

participants experiencing greater parasympathetic control during sad music compared to crying. This interpretation suggests that sad music was causing a relaxation response (i.e., increased parasympathetic control/activity) which has also been found previously in music studies (Iwanaga, Kobayashi, & Kawasaki, 2005; Iwanaga & Tsukamoto, 1997; Sokhadze, 2007). For instance, Sokhadze (2007) found that listening to either positive or negative music after a stressful task caused quicker autonomic recovery compared to white noise. Regardless, these findings support the inference that crying sounds in particular may be unique as emotional stimuli. Rather than simply inducing a purely empathetic response of sadness in the listener, the social purpose of crying may signal for a need of immediate behavior in the form of social support or comfort to another person which requires controlling parasympathetic responses.

Taking the above information together, clear directionality and consensus of sympathetic and parasympathetic activation across the four autonomic indices was not apparent. Nonetheless, these differences in skin conductance and RSA provide interesting information regarding differential autonomic responding. This makes the current study fit within a large autonomic literature which finds complex and nuanced autonomic responding to emotions rather than the straight-forward (and possibly antiquated) reciprocal activation of a fight-or-flight, stress-responding sympathetic activation and parasympathetic withdrawal (Beauchaine, 2001; P. Ekman et al., 1983; Kreibig, 2010; Robert W. Levenson, 1992). For instance, the more clear and expected findings in skin conductance demonstrating our predicted increased responding to vocalizations indicates that differential sympathetic responding may occur in neurons that target sweat glands but not those that mediate cardiac changes (i.e., those that would cause changes HR or PEP). Additionally, the parasympathetic withdrawal in response to crying (compared to sad

music) perhaps suggests an increased sensitivity to changes in auditory emotional stimuli in this measure of respiratory-mediated heart rate variability.

Given that there was some suggestion that participants had different autonomic responses to vocalizations compared to music, the question becomes “what does that mean?”. One theoretical proposition of the current study was that differences in vocalization stimuli compared to musical stimuli would be driven by the inherent social (and therefore more salient) nature of vocalizations and lack thereof in music. However, as mentioned above, it should be reiterated that differences between these stimulus types could be driven by unique characteristics of the musical stimuli such as their tendency to possibly increase parasympathetic control by means of a relaxation-like response. In sum, these findings in GSC and RSA suggest interesting ideas supporting potential differences in emotion responding based on the social nature (or musical nature) of the stimuli.

An additional point that should be made here is that a lack of differences being found in some autonomic indices may simply mean that emotional responding to music is equally as substantial as responding to vocalizations. Past musical emotional research has demonstrated considerable interest in the salient emotional effects of music in general (Juslin & Laukka, 2003; Juslin & Sloboda, 2001, 2009) and sometimes argues for similar emotion recognition processes being activated when listening to music. Therefore, while the idea of increased social significance being inherent in vocalizations was proposed in this study, the alternative explanation that music can be an especially unique and potent vehicle for expression that is just as emotionally powerful as nonverbal vocalizations (that were likely well established prior to language and therefore quite early in human evolutionary history) may be indicated by our lack of differences in some autonomic domains. Of course, we do not want to interpret lack of

findings, but this assertion is supported by the baseline differences insofar as the autonomic differences we did find from baseline were parallel for vocal and musical stimuli. This interpretation would thus suggest that both types of stimuli are engaging physiological emotional processes in similar ways. For the many humans who appreciate the emotional power of music, this idea is both intriguing and appealing and warrants more direct investigation in future studies.

Are autonomic responses associated with self-reported emotions?

Lastly, we also explored whether emotion ratings were correlated with autonomic levels within blocks. Within each block, no congruent emotions were shown to be associated with autonomic levels within that block (e.g., happy ratings within happy blocks, etc.). Happy ratings in particular showed up most often, correlating negatively with HR in crying, yelling, and angry music blocks. This possibly suggests that heart rate increases within these negative stimulus blocks were buffered in participants who were happier. This is somewhat reminiscent of studies that have found connections between positive affect and well-being as inhibiting the negative health effects associated with chronic stress and pain (Diener & Chan, 2011; Pressman & Cohen, 2005). This preliminary finding suggests an interesting moderating effect of happiness on heart rate responding to negative stimuli and would be a good area for more direct study in the future.

Additional Considerations

In order to examine our data further, we tried to see if the above differences across emotions and stimuli were still apparent when controlling for various covariates including sex, age, depression, anxiety, and task order. These analyses were exploratory and did not correspond to *a priori* hypothesis that specifically accounted for controlling for covariates. When we controlled for sex, our trend-level heart rate effect remained but our GSC and RSA findings regarding differences between stimulus types did not remain significant. GSC of

emotion remained in both males and females when conducted separately by sex, but the lack of differences across stimulus types may be explained by a loss of power in these probative analyses that split our sample size in half. Past research has shown that females demonstrate increased emotional autonomic responding to music compared to males (McFarland & Kadish, 1991) and greater sensitivity in subjective emotional responding as well (Webster & Weir, 2005).

For age, depressive symptoms, and task order, our skin conductance findings generally did not hold up. Again, it is likely that we do not have a large enough sample to be controlling for these various covariates and still demonstrate the same effects. However, these skin conductance effects discussed above did appear when controlling for trait-based anxiety. Anxiety has long been shown to be closely linked to skin conductance responding such that increased anxiety causes increased sweating on the palm, and specifically research has previously shown trait-level anxiety has been shown to decrease autonomic habituation to repeated auditory stimuli compared to non-anxious people (i.e., anxious people continue to respond regardless of repeated exposure; Lader, 1967; Raskin, 1975). More exploration of these various covariates would be helpful for increasing our understanding of any differential emotional and autonomic effects and would be an important future direction in a study with a larger sample.

Strengths, Limitations, and Future Directions

Though our study has several strengths inherent in the structured, controlled nature of the experimental design and the ability to directly compare responses to the stimuli that were of interest, some limitations in the study were also apparent. First, the appearance of multiple trend-level effects suggests that a larger sample and greater statistical power might have caused

these effects to be clearly significant using the standard p-value threshold of .05. However, the current sample size (n=50) is consistent with prior studies on emotional and autonomic reactivity. While studies certainly exist that utilized larger samples, quite a few studies have been published in the emotion and physiology literature that use less than 50 participants. Additionally, responding to our neutral conditions seemed difficult to interpret based on our preliminary analyses (not reported, analyses available from author upon request). Also, the white noise condition that we chose to employ as our neutral baseline condition in the current analyses appeared to cause greater sympathetic activation in some indices (e.g., GSC) compared to the emotional stimulus blocks. Perhaps we should have had participants sit quietly with headphones on looking at the computer screen for 1-2 minutes in order to allow them to fully acclimate to this situation prior to starting the presentation of white noise.

Additionally, one of the drawbacks of using self-report emotion ratings, as was done in the present study, is that participants may lie or provide ratings that are desired. Future studies comparing vocalizations to music would benefit from also using emotional measures that do not rely on self-report (e.g., facial EMG, facial/behavioral coding) because they would provide important added information regarding emotional responding that may be more valid because of not having these limitations specific to self-report measures. Furthermore, our instructions for participants to place themselves in the same mood as what was expressed in the presented stimuli may have led participants to over-report the emotions that they recognized from the stimuli. However, methodological induction instructions similar to this have been frequently used in several emotion induction studies previously (e.g., Baumgartner, Esslen, & Jäncke, 2006; Esslen, Pascual-Marqui, Hell, Kochi, & Lehmann, 2004; Schneider, Gur, Gur, & Muenz, 1994) and were therefore deemed appropriate for the present experimental protocol.

The use of six 15 second auditory clips that were separated by 10 seconds of rest was used as a way to increase the ecological validity of the study. That is, people do not generally encounter continuous long periods of listening emotional vocalizations such as laughing or crying for multiple minutes without breaks. We believed that such continuous looping of stimuli for the entire 150 seconds of a block may sound awkward and strange to participants rather than emotional. Additionally, previous studies employing vocalizations tend to use stimuli that are typically less than 15 seconds and sometimes as short as 1-2 seconds (referred to as affective bursts; Belin, Fillion-Bilodeau, & Gosselin, 2008; Hawk et al., 2012; Sauter, Eisner, Ekman, & Scott, 2010). While this approach has its advantages with regard to ecological validity, the 10 second periods of silence between stimulus clips may have introduced periods where autonomic activation decreased. Though we presumed that the effects of presenting congruent emotional stimuli repeatedly in succession would have some cumulative effects that would outweigh potential gaps in responding, this is not clear based on the data in the current study's analytic approach because autonomic data was averaged for each 150 second block. Though using the averaging the stimulus periods without the 10 second silence breaks was initially considered, this approach was ruled out in order to allow for valid use of more autonomic measures. For instance, heart rate variability measures such as RSA typically require continuous periods of at least 30 seconds in order to be considered valid. Therefore, using 15 second intervals would have excluded the possibility of using RSA, an important index of vagal tone and parasympathetic activity. Future studies or future analyses of data collected in the current project might benefit from using alternative approaches that examine these various periods more closely whether through the use of shorter blocks, deleting periods of silence, or exploring the speed and duration of responses within blocks.

Implications and Conclusions

The present study provided a novel way to directly compare emotional and autonomic responding to social and nonsocial auditory emotional stimuli. Specifically we employed the mechanism of vocal production to define this difference in the social nature of our stimuli (i.e., our vocalization stimuli were produced by human voices while the musical stimuli were instrumental). Our findings of differential autonomic activation in response to vocalizations can be interpreted as demonstrating more salient emotional responding to vocalizations, which may be conveying a more direct visceral message to the listener. However, musical stimuli may also simply be more complex comparatively and require different emotional processing. Regardless, the consideration and discussion of these implications may point towards several interesting directions for future study in the areas of emotions, empathy, autonomic specificity, and auditory processing.

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Vita

Jeremy C. Peres was born and raised in New Orleans, Louisiana. He obtained his Bachelor of Science Degree in Psychology from the University of New Orleans in 2010. Jeremy then began his doctoral studies in the Applied Biopsychology Program at the University of New Orleans under the direction of Dr. Birdie Shirtcliff and earned his Master of Science Degree in Psychology in 2012.