

**Music and Children with Autism Spectrum Disorders:
Potential Autonomic Mechanisms of Social Attention Improvement**

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ABSTRACT

Autism Spectrum Disorders (ASD) are an urgent health concern as new reports indicate approximately 1 in 110 children are affected by ASD (Centers for Disease Control and Prevention, 2009). Although children with ASD struggle with social interactions, quantitative meta-analyses have revealed that traditional social skill interventions only produce minimal effects (Bellini, Peters, Benner, & Hopf, 2007). Due to these minimal effects, this study diverged from the common understanding of social skill deficits and introduced an autonomic nervous system circuit as one root of social behavior problems. Children with ASD show a “fight-flight” (i.e., sympathetic) state at baseline and to unfamiliar individuals (e.g., Bal et al., 2010; Vaughan Van Hecke et al., 2009). Research indicates, however, that music has the ability to calm cardiovascular functioning (Iwanaga, Kobayashi, & Kawasaki, 2005) and improve social behaviors in children with ASD (Whipple, 2004). This study recruited participants ($N = 23$) between 4-7 years old with a previously diagnosed ASD. Each participant was assigned to a Music group, $n = 11$, or an Audiobook group, $n = 12$. The 90-minute experimental session consisted of a receptive vocabulary assessment and psychophysiological monitoring during a baseline video, social engagement task, listening period, and a recovery video. A soothed autonomic state was measured by increased high frequency heart rate variability and decreased heart rate. Results indicated a significant soothing effect for the Music group. Moreover, the Music group evidenced a significant increase in social attention (e.g., joint attention and sharing emotions) relative to the Audiobook group. Mediation analyses may reveal partial mediation for the soothed autonomic state on the relationship between group and social attention improvements. Thus, these results suggest that social skill interventions may not be targeting a core element of social deficits (i.e., over-aroused autonomic state).

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“Music makes me forget myself, my actual position; it transports me into another state...I feel what I do not really feel, I understand what I do not really understand, I can do what I can’t do.”
Leo Tolstoy, *The Kreutzer Sonata*

1.0 - Introduction

Autism Spectrum Disorders (ASD) are an urgent health concern as prevalence rates continue to increase. New reports indicate approximately 1 in 110 children are affected by ASD (Centers for Disease Control and Prevention, 2009). Children with ASD struggle with social interactions, including eye contact, vocalizations, and facial affect. This is apparent not only in diagnostic criteria outlined by the Diagnostic and Statistical Manual for Mental Disorders – 4th Edition (DSM-IV; American Psychiatric Association, 2000), but also by simply interacting with a child with ASD. The visible social skill deficits found in children with ASD make them easy targets for bullying, teasing, peer rejection (Knott, Dunlop, & Mackay, 2006), and subsequent social isolation (Chamberlin, 2001). Unfortunately, quantitative meta-analyses have revealed that traditional social skill interventions only produce minimal effects (Bellini, Peters, Benner, & Hopf, 2007). Therefore, the current study diverges from the common understanding of social skill deficits and interventions and introduces an autonomic nervous system circuit that may be one root of social behavior problems.

1.1 - Autism Spectrum Disorders (ASD)

ASD are a continuum of disorders that include Autism on the severe end and Asperger’s disorder and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) on the milder end. In general, these disorders consist of a syndrome of symptoms affecting social behavior, communication, and repetitive or restricted behaviors and interests. ASD is primarily characterized by a lack of social understanding and atypical social development. Social impairment is described by the DSM-IV as marked impairment in the use of nonverbal behaviors (e.g., eye contact, facial expression), failure to develop peer relationships, a lack of social or emotional reciprocity, and a lack of spontaneous seeking to share enjoyment or interest with other people (American Psychiatric Association, 2000). Individuals with ASD can also experience impairments in communication shown by a delay or lack of the development of spoken language, impairment in the ability to initiate or sustain conversation, a lack of varied or

spontaneous play, and repetitive language. These significant deficits interfere with the skills to create and maintain human relationships, which in turn can affect many aspects of a child's development (Brown, 1994; Tustin, 1981; Wing & Gould, 1978).

Despite research efforts, prevalence rates of ASD continue to rise in the U.S. Although ASD was considered to occur in as few as 1 in 500 individuals at the writing of the last DSM (DSM-IV; American Psychiatric Association, 2000), a new study by the Centers for Disease Control and Prevention (CDC) suggests these rates underestimate the current prevalence of ASD. CDC results show that ASD could occur at a rate as high as 1 in 110 individuals (CDC, 2009). The increasing prevalence rates and the detrimental effect of ASD symptoms result in an overwhelming need to study mechanisms underlying social dysfunction in children with ASD.

1.2 - The Polyvagal Theory and the Social Engagement System

The Polyvagal Theory (Porges, 1995, 1998, 2001, 2003, 2005, 2007, 2008) offers a theoretical position from which social engagement deficits in ASD (e.g., eye contact, facial expression, head orienting) can be understood. Porges proposes that the mammalian autonomic nervous system is phylogenetically organized in three broad physiological circuits that promote social communication (e.g., facial expression, vocalization, listening, head orienting), mobilization (e.g., fight-flight behaviors), and immobilization (e.g., feigning death, behavioral shutdown).

These three physiological circuits (i.e., social communication, mobilization, immobilization) are composed of an autonomic nervous system and a neurological system component, which together foster specific behaviors (e.g., eye contact via the social communication circuit). Due to primary deficits in social engagement, children with ASD appear to exhibit deficits in the social communication physiological circuit (i.e., myelinated vagus [ANS component] and nucleus ambiguus [central nervous system component]). The social communication circuit is a sub-theory of the Polyvagal Theory: the Social Engagement System or a set of cranial nerves that control organs implicated in social communication (Porges, 1998, 2007, 2008). These cranial nerves (i.e., V, VII, IX, X, XI) control: laryngeal and pharyngeal muscles - V and IX (e.g., vocalization), eyelid opening - VII (e.g., looking), facial muscles - VII and IX (e.g., emotional expression), autonomic self-soothing - X (e.g., decreased heart rate), and head turning muscles - XI (e.g., social gesture and orientation). Due to the interconnections between the cranial nerves, measurement of one nerve (i.e., myelinated vagus - piece of the

Social Engagement System and social communication physiological circuit) may provide insight into the functioning of all Social Engagement System nerves (and therefore, insight into social engagement).

The cranial nerves that comprise the Social Engagement System are not only a set of nerves with a proposed common purpose (i.e., social engagement), but they are also controlled by the same neurological components (i.e., upper motor neurons connect to the lower motor neurons, which connect to the Social Engagement System cranial nerves), thus, allowing the nerves to work together in a coordinated fashion to achieve the social function. This coordinated social response, however, is not characteristic of children with ASD. The DSM-IV (American Psychiatric Association, 2000) criteria specifically mark ASD deficits in the same social behaviors (e.g., eye contact, facial expression, language, vocalization/verbalization) as identified by the Social Engagement System and Polyvagal Theory. As such, the Polyvagal Theory may provide new, biologically-based insight into social skill deficits in ASD that could improve social skill interventions, which to date have shown minimal effectiveness (Bellini, Peters, Benner, & Hopf, 2007).

1.3 - Autonomic Dysfunction in ASD

According to the Polyvagal Theory and its relevance for the Social Engagement System, social dysfunction seen in ASD should be paired with physiological dysfunction (i.e., myelinated vagus). In support of this suggestion, children with ASD show decreased vagal activity, which is indicative of dysfunction in the myelinated vagus nerve, to unfamiliar individuals and during baseline when compared to typically developing children (Bal et al., 2010; Ming, Julu, Brimacombe, Connor, & Daniels, 2005; Vaughan Van Hecke et al., 2009).

Myelinated vagus nerve activity can be measured through high frequency heart rate variability (HF HRV), a measure derived from an electrocardiogram (ECG) signal. HF HRV is the average time in between heartbeats (i.e., interbeat interval) that varies due to respiration (inhalation/exhalation; De Meersman & Stein, 2007). HF HRV is regulated by the myelinated vagus, which also regulates parasympathetic nervous system activity. Driven by the parasympathetic nervous system, the myelinated vagus nerve provides a “brake” that decreases cardiac activity. The vagus nerve extends parasympathetic fibers into all organs (e.g., lungs, stomach, intestines, heart) except for the adrenal glands. Thus, when this “brake” is applied, parasympathetic activity increases, with concomitant decreases in heart rate (HR) and increases

in HF HRV. As such, decreased HF HRV, as seen in children with ASD, indicates vagal withdrawal or a decrease in parasympathetic activity of the heart. Also, since vagal activity is withdrawn and parasympathetic activity is reduced, HR increases via sympathetic control. HR is the average number of heart beats per minute in a certain time period. HR has both sympathetic and parasympathetic influences (Berntson et al., 1997). The research findings on reduced vagal activity in children with ASD suggest that they could be in a “fight-flight” (mobilized) state at baseline and when around unfamiliar individuals. The Polyvagal Theory suggests that the measurement of this physiological state provides insight into social response deficits, like those seen in children with ASD.

Laboratory studies have shown that autonomic dysregulation occurs in individuals with ASD when compared to a typically functioning population (Bal et al., 2010; Bolte, Feineis-Matthews, & Poustka, 2008; Jansen et al., 2006; Jansen et al., 2003; Zahn, Rumsey, & Kammen, 1987). The most commonly reported is a dysregulation of HR and HRV (Bal et al., 2010; Bolte et al., 2008; Jansen et al., 2006; Jansen et al., 2003; Vaughan Van Hecke et al., 2009; Zahn et al., 1987).

Current research suggests that HF HRV may be suppressed in different situations for individuals with ASD (Vaughan Van Hecke et al., 2009). In particular, Vaughan Van Hecke et al. demonstrated that children with an ASD had a decrease in Respiratory Sinus Arrhythmia (RSA – another measure of HF HRV) when watching a video of an unfamiliar person, whereas children without an ASD did not. Vaughan Van Hecke et al. attributed this decrease in RSA to a state “mobilization” (fight-flight response) to unfamiliar individuals. The decrease in RSA, or vagal withdrawal, could potentially disable the child from effectively engaging in social situations with unfamiliar individuals. When typically developing children were shown the video with an unfamiliar person, their nervous system was preparing the child to engage (i.e., increase in RSA). Notably, the RSA of children with an ASD returned to baseline when interacting with a familiar person (i.e., their parent), perhaps indicating that autonomic dysregulation occurs only in social situations with unfamiliar individuals.

Research also indicates that children with an ASD may be chronically “mobilized.” Children with ASD have shown elevated HR and reduced parasympathetic activity during baseline compared to typically developing children (Bal et al., 2010; Ming, Julu, Brimacombe, Connor, & Daniels, 2005; Vaughan Van Hecke et al., 2009). According to the Polyvagal Theory,

these results suggest that children with ASD live in a heightened autonomic state that may prevent appropriate responding to their social environment. This heightened physiological “fight-flight” state may also contribute to the aversive response children with ASD have to social situations and may promote disengagement with others, especially with unfamiliar people.

1.4 - Music Promoting Social Engagement in Individuals with ASD

Based on the notion that children with an ASD may be in a chronic state of mobilization that interferes with their social engagement, the current study sought to physiologically soothe (i.e., increase HF HRV and decrease HR) children with ASD through music in order to enhance spontaneous social engagement. In support of this possibility, Whipple (2004) conducted a meta-analysis of 13 studies ($N = 96$) of music interventions for children and adolescents with autism (ages 2 ½ - 21). The dependent variables examined in this meta-analysis were social behaviors (i.e., challenging behaviors), communication (i.e., vocalization, speech, and eye contact), and cognitive skill (i.e., academic tasks, vocabulary acquisition, and following directions for motor tasks). The overall effect size for this study was $d = .77$ (range $d = .09 - 1.71$) and a mean weighted correlation of $r = .36$ ($p = .00$). Whipple concluded that the benefits of music were undifferentiated for treatment design, age of subjects, music used, treatment methodology, or profession of the music provider. However, O’ Loughlin (2000), a study included in Whipple (2004), found that receptive vocabulary and social skills moderated the effect of music on children with autism (i.e., the effects of music were attenuated in children with lower receptive vocabulary and social skills). Although the findings of Whipple (2004) seem to indicate a robust effect of music on social and cognitive skills in children and adolescents with autism, this effect may be moderated by receptive vocabulary and social skills. Additionally, Porges et al. (unpublished) found that children with ASD showed improved social engagement with a music intervention, but only if they had auditory hypersensitivities.

A recent study also supports the calming effect of music in individuals with ASD, such that challenging behaviors (i.e., self-injurious, stereotypical, and aggressive behaviors) were reduced (Lundqvist, Andersson, & Viding, 2009). Lundqvist et al. studied 20 individuals, aged 22 to 57 years old ($M = 37$ years, $SD = 9.9$), with developmental disabilities, 10 of whom had been diagnosed with an ASD. Individuals listened to a music recording (Bindu’s “Listen to your heart” performed on guitar, percussion, and keyboard) for 10 - 20 minutes once a week for 5 weeks. Behavior was assessed before treatment, after each session, and after the entire treatment.

Overall, participants' self-injurious, stereotypic, and aggressive behaviors decreased, especially in participants diagnosed with an ASD. Lundqvist et al. call for the use of psychophysiological measurement (e.g., HR and HF HRV) to determine the potential mechanisms that account for their observed behavioral change.

1.5 - Music and Autonomic Soothing

Labbe, Schmidt, Babin, and Pharr (2007) explored the physiological effects of music (i.e., heavy metal, classical, self-selected) and silence on emotional state and physiological arousal (i.e., HR, respiration, and skin conductance) in a typically developing population. College-aged participants ($N = 56$, $M_{\text{age}} = 22.56$) were randomly assigned to one of four conditions: heavy metal, classical, self-selected music or silence. Participants assigned to the self-selected music condition were instructed to “bring a compact disk with 20 minutes of music that they believed was relaxing.” Following a cognitive stress test (i.e., mathematical operations, memorizing, verbal analogies, and spelling), participants listened to music or sat in silence for 20 minutes. Notably, Labbe et al. increased listening period length (10 minutes vs. 20 minutes) from previous studies in order to achieve a more valid indicator of the effects of the experimental conditions. Data from the last 5 minutes of the stress test and listening period were used to calculate averages.

Participants self-reported a decrease in state anxiety on the State Trait Anxiety Inventory for the self-selected ($t(13) = 3.27$, $p = .01$) and classical ($t(15) = 3.07$, $p = .01$) music conditions. Additionally, participants reported increased ratings in relaxation on the Relaxation Rating Scale for the self-selected ($t(13) = -6.25$, $p = .00$), classical ($t(14) = -5.14$, $p = .00$), and silence ($t(9) = -5.07$, $p = .00$) conditions. All groups experienced a decrease in skin conductance, whereas, groups listening to classical ($t(14) = 2.36$, $p = .03$) and heavy metal ($t(13) = 2.42$, $p = .03$) music experienced lower respiration rates than self-selected music or silence groups. Only the self-selected music condition ($t(13) = 4.56$, $p = .00$) experienced a significant decrease in cardiovascular arousal (i.e., HR).

Unlike Labbe et al., Witvliet and Vrana (2007) selected music based on valence and arousal, not genre. They measured ECG and EMG to music stimuli that varied in valence (positive or negative) and arousal (high or low) on undergraduate college students ($N = 67$, $M_{\text{age}} = 20$). They found that heart rate was higher during high-arousal compared to low-arousal music

($F(1, 61) = 14.65, p < .001$). Witvliet and Vrana (2007) did not calculate HRV data with spectral analysis; therefore, their results did not elucidate the sympathetic and parasympathetic mechanisms affecting the heart.

In contrast, Iwanaga, Kobayashi, and Kawasaki (2005) used spectral analysis to analyze HRV and were able to find differential effects for HF HRV. All participants (19 - 27 years old; $N = 13$) listened to sedative music, exciting music, and no music at separate experimental sessions and on separate days. Their findings showed that participants had higher HF HRV when listening to the sedative music than when listening to the exciting music. The authors suggested that higher HF HRV to the sedative music was an indication of parasympathetic activity of the heart as well as a relaxed state. The sedative music and no music conditions had similar effects on the heart.

The decrease in self-reported anxiety, increase in self-reported relaxation, decrease in HR, and increase in HF HRV point to the psychological and physiological soothing effects of self-selected calming music, sedative music, and low-arousal music. To date, however, autonomic mechanisms that may underlie the benefits of music in children with ASD have not been investigated (Lundqvist et al., 2009).

1.6 - Alternative Explanatory Variables

Three potentially confounding variables of social engagement and/or autonomic response were measured in this study: anxiety, fear, and disruptive behavior. Specifically, anxiety, which may be found in up to 84% of children with ASD (White, Oswald, Ollendick, & Scahill, 2009), was hypothesized to confound autonomic response. This is in accordance with both theoretical models (e.g., tripartite model; Clark & Watson, 1991) and empirical evidence (e.g., Yeragani, Rao, Pohl, Jampala, & Balon, 2001). In accordance with Yeragani et al. (2001), children with co-morbid anxiety were expected to show greater sympathetic activation (i.e., higher LF HRV) and lower parasympathetic activation (i.e., lower HF HRV). Moreover, this “fight-flight” state in children with co-morbid anxiety and ASD was predicted to inhibit effective social engagement per the Polyvagal Theory (e.g., Porges, 2007). Similarly, high levels of fear were expected to correlate with increased autonomic response (i.e., “fight-flight” state) and decreased social engagement. The experience of cardiac acceleration (i.e., sympathetic response) with fear is consistent with both theory (e.g., Barlow, 2002) and empirical evidence (e.g., Levenson, Ekman, & Friesen, 1990). The “flight-flight” state, derived from higher levels of fear, was expected to

correspond with less social engagement (e.g., Porges, 2007). Lastly, disruptive behavior was hypothesized to confound social engagement (i.e., more disruptive behavior correlated to lower levels of social engagement). Past research supports the negative correlation between disruptive behavior and social engagement (Lee, Odom, & Loftin, 2007). Fear, anxiety, and disruptive behavior were examined in exploratory analyses and were controlled for if they systematically related to autonomic state and social engagement behavior.

1.7 - Hypotheses

The current study used music to regulate a defensive or mobilized autonomic state (i.e., HR and HF HRV) to an unfamiliar person in children with ASD to promote social engagement behaviors (e.g., eye contact, attentional control, vocalization). It was hypothesized that music, as compared to a audiobook group, would regulate the autonomic response of children with ASD (i.e., decrease HR and increase HF HRV) to produce a “self-soothing” effect. In accordance with the Polyvagal Theory, it was also hypothesized that the Music group’s soothed autonomic state would produce a subsequent increase in one-on-one social engagement. Research indicates that deficits in receptive vocabulary and social skills can attenuate the effects of music (O’Loughlin, 2000), and auditory hypersensitivities may potentiate the effects of music (Porges et al., unpublished). To address these potential confounds, groups were matched based on receptive vocabulary and auditory hypersensitivities, and social skills aptitude was measured by parent-report. Additionally, fear, anxiety, and disruptive behavior were measured in order to address confounds of autonomic state and/or social engagement.

2.0 - Method

2.1 - Participants

Twenty-three children ($n_{males} = 18$, $n_{females} = 5$), aged 4 years 3 months to 7 years 9 months, with a prior DSM-IV diagnosis of an ASD (i.e., Autism, $n = 12$; Asperger’s Disorder, $n = 10$; PDD-NOS, $n = 1$) and no severe tactile hypersensitivities (because of the use of adhesive electrodes on the skin) were sampled from the Southwest Virginia area. Participants received \$20 compensation for completing the experimental session (*Note*: Some participants did not receive compensation as funding was received after their participation). For a proper fit of the LifeShirt®, the device used to obtain the cardiovascular measures, the child’s abdomen had to measure at least 20 inches around and their chest had to measure at least 21 inches. Children with any ASD were allowed to participate in this study since prior studies have found that the

physiological and music effects related to social engagement are not specific to one particular ASD (Porges, unpublished; Vaughan Van Hecke et al., 2009). Participants were recruited through the Virginia Tech Autism Clinic, electronic autism listservs, emails sent out to local autism organizations, and parent support groups. Participants were matched between groups according to Peabody Picture Vocabulary Test third edition (PPVT-III) standard score and by parent-reported auditory hypersensitivities on the Short Sensory Profile.

2.2 - Measures

The following measures were used to obtain demographic information and assess for sensory issues, social responsiveness, communication and language skills, social engagement (e.g., eye contact, verbal and nonverbal behaviors, joint attention), fear, anxiety, disruptive behavior, and autonomic responses.

Demographic Survey (Appendix A). This demographic survey obtained information about the parent (e.g., education level, relation to the child, income), the child (e.g., age, race, education level), the child's current diagnosis, and the child's current symptoms.

Short Sensory Profile (Dunn, 1999). This 38-item questionnaire uses a 5-item Likert scale (1 = Always to 5 = Never) to distinguish between the following symptoms often found in children with ASD: tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-responsive/seeks sensation, auditory filtering, low energy/week, visual/auditory sensitivity. Scores were summed in each of the aforementioned domains to determine a child's score. For the current study, the most important differentiation was determining children with tactile and auditory hypersensitivities. Children with severe tactile hypersensitivity were excluded from this study due to the use of adhesive electrodes that attach to the skin. Since current research suggests that children with auditory sensitivities show increased social engagement to music (Porges et al., unpublished), groups were also matched according to auditory hypersensitivities. Reported internal consistency estimates (range = .47 to .91) and standard error of measurement (range = 1.0 to 2.8) support instrument reliability, and high correlations with measures of sensory perception and behavioral regulation support convergent and discriminant validity (Dunn, 1999). For this study, internal consistencies were as follows: tactile sensitivity (Cronbach's $\alpha = .71$), taste/smell sensitivity (Cronbach's $\alpha = .92$),

movement sensitivity (Cronbach's $\alpha = .56$), under-responsive/seeks sensation (Cronbach's $\alpha = .77$), auditory filtering (Cronbach's $\alpha = .70$), low energy/week (Cronbach's $\alpha = .88$), and visual/auditory sensitivity (Cronbach's $\alpha = .47$).

Social Responsiveness Scale (SRS; Constantino, 2002). This 65-item questionnaire uses a 4-item Likert scale (1 = Never true to 4 = Almost always true) to measure severity of ASD symptoms as they occur in the natural social setting, as reported by the parent. More specifically, this measure assessed a child's social impairments, social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance, and autistic preoccupations and traits (Constantino, 2002). This quick parent report (15-20 minutes) allowed for a quantitative estimate of severity of social symptoms related to ASD. The brief administration period of this assessment lends itself well to use in the experimental setting and has been used in many previous studies on children with ASD (e.g., Constantino & Todd, 2003; Duvall et al., 2007; Posey et al., 2004). Scores on the SRS were summed to create an overall total score that indicates the severity of social deficits. In addition to the overall score, there are five subscale scores: social awareness, social cognition, social communication, social motivation, and autistic mannerisms. The psychometric properties of the SRS have been tested in over 1,900 children, aged 4-15 years (Constantino & Todd, 2003, 2000). For these subjects, the reported three-month test-retest reliability is 0.88 for clinical subjects. In a more recent study ($N = 15$), the SRS demonstrated a 27-month test-retest reliability of 0.83 ($p < .0001$; Constantino et al., 2003). For the present study, the internal consistencies were as follows: total score (Cronbach's $\alpha = .93$), social awareness (Cronbach's $\alpha = .63$), social cognition (Cronbach's $\alpha = .75$), social communication (Cronbach's $\alpha = .78$), social motivation (Cronbach's $\alpha = .70$), and autistic mannerisms (Cronbach's $\alpha = .73$).

Preschool Anxiety Scale (PAS; Spence, Rapee, McDoanld, & Ingram, 2001). This 34-item parent report (approx. 10 minutes) assesses anxiety in a child 2.5 - 6.5 years old. Each item was answered "0" (Not true at all) to "4" (Very often true). Scores were summed to get an overall measure of anxiety. This questionnaire has good psychometric reliability and validity (Spence et al., 2001). For this study, the PAS showed excellent internal consistency (Cronbach's $\alpha = .92$).

Fear Survey Schedule for Infants & Preschoolers (FSSIP; Warren & Ollendick, 2001). The FSSIP (approx. 10 minutes) assessed young children's fear of different situations (e.g., going to the hospital). Each of the 92-items in this measure can be answered as “None,” “Some,” or “A lot.” Items are summed to create an overall measure of fear. This measure has good reliability and validity (Warren, Ollendick, & Simmens, 2008) and showed excellent reliability in the present study (Cronbach’s $\alpha = .95$).

Developmental Behavior Checklist, Parent Version (DBC-P; Einfeld & Tonge, 1992, 1995, 2002). The DBC is a 96-item questionnaire completed by parents reporting for individuals with development/intellectual disabilities, aged 4 - 18 years old, for problems over a six-month period. Each behavioral description was scored either 0 = “not true as far as you know,” 1 = “somewhat or sometimes true,” or 2 = “very true or often true.” Scores were summed for 6 dimensions: total behavior score, disruptive/antisocial, self-absorbed, communication disturbance, anxiety, and social relating. This measure has shown good reliability and validity (Einfeld & Tongue, 2002). For this study, the total behavior problem score showed excellent internal consistency (Cronbach’s $\alpha = .94$).

Peabody Picture Vocabulary Test, Third Edition (PPVT-III; Dunn & Dunn, 1997). The PPVT-III measures receptive language skills (understanding and comprehension of spoken words) in a format that is conducive to measuring language skills in children with ASD. PPVT-III procedures require no reading or writing. The examiner orally presented a stimulus word with a set of pictures (usually 5 sets), and the participant selected the picture that best represented the words’ meaning. The PPVT-III is significantly correlated to the Vocabulary Comprehension Index on the Wechsler Intelligence Scale for Children, Third Edition, $r = 0.75, p < .01$ (Tannenbaum, Torgesen, & Wager, 2006). As such, the PPVT-III is a good assessment of vocabulary skills and was used to match groups based on receptive vocabulary/language abilities. The PPVT-III score was calculated by subtracting the number of errors the child makes from a total ceiling score. The raw score was converted into a standard score. Although age equivalents have been used to match groups in children with ASD (e.g., Rogers, Young, Cook, Giolzett, & Ozonoff, 2008), age equivalents are not interval data; therefore, age equivalents are inappropriate for parametric statistical comparison (Mervis & Klein-Tasman, 2004). The standard score ($M = 100, SD = 15$), a measurement of relative standing among chronologically-

aged peers, was used to match groups. The PPVT has been used in experimental studies to assess receptive vocabulary in children with autism (e.g., Badawi, 2006) and has demonstrated good psychometric validation (Williams & Wang, 1997).

Social Interaction Coding Scale (SICS; Bazhenova, 2006). The SICS is a 10-minute, semi-structured, play-based, observational assessment of social engagement skills in children aged 2-6 years old (Bazhenova, 2006). The quick administration of the SICS provides a significant benefit over the more commonly used Autism Diagnostic Observation Scale (ADOS; Lord et al., 2000), which can take up to 1 hour. Although the psychometric validity of the SICS has not been reported, the SICS will be used instead of the ADOS in order to keep the experimental session within a reasonable time limit for one session. The SICS assessed social engagement behaviors (e.g., joint attention, eye contact) that are considered to be connected to the autonomic pathways of the Social Engagement System, as explained by the Polyvagal Theory (Porges, 2001, 2003, 2007). Through the experimenter's presentation of various toys (e.g., balloons, bubbles, hat), the child was observed playing with the toy, interacting with the experimenter (e.g., eye contact), using verbal phrases (e.g., "May I have a turn?"), joint attention, and other social engagement behaviors. Each activity or toy was presented in a flexible manner and some were repeated at the child's request. The SICS administration was kept at 10 minutes. Social engagement behaviors were quantified by coding the child's behaviors in the following domains: response to the experimenter's verbal and gesture prompts, sharing (i.e., joint attention and emotions), eye gaze, verbalization, vocalization, requests, action, ignore, communicative and conventional gestures. Each domain was scored by the frequency that the child engaged in the behavior or response. Response to a verbal prompt was defined as a response that was elicited when the examiner did not use any gestures or movements when communicating with the child (i.e., only words). Response to gesture prompt was defined as a response that was elicited when the examiner used any kind of gesture or movement that was or was not accompanied by a verbal request (e.g., making a toy spin). Sharing (i.e., 'child share') was defined as directing positive emotions, sharing information, joint attention, and showing/sharing toys with the examiner. For this study, sharing is also more descriptively referred to as social attention. Eye gaze was defined as when the child made eye contact with the examiner. Fleeting gazes (i.e., when the child surveyed or looked around the room and at one point met the eyes of the examiner), however, were not coded as eye contact. Verbalization was defined as any word/word

approximation, speech utterance (appropriate/inappropriate to the situation), echolalic speech, or spontaneous speech. Vocalizations were defined as any sound (vowel, guttural or consonant vocalization) that was not a verbalization. Requests were defined as all instrumental behaviors oriented towards getting something from the examiner (e.g., toy, help). Requests included using words to request and using gestures to request, but a child grabbing an object from the examiner was not coded as a request. Actions were defined as any goal-oriented motor act contingent upon what had been prompted or part of a share or request (e.g., looking at an object the examiner is holding). Hand flapping or stereotyped movements were not coded as actions. Ignore was defined as when a child ignores the examiner's verbal or gesture prompt. Communicative gestures were defined as a child using the examiner's hand to communicate a desire (e.g., putting the examiner's hand on toy). Conventional gestures were coded as gestures used to convey a message to the examiner (e.g., shaking head, shrugging shoulders, pointing). In the interest of time, trained coders coded in The Observer ® XT (Noldus Information Technology) independently and completed consensus coding on disagreements.

LifeShirt® (Vivometrics). The LifeShirt® is an ambulatory physiological monitoring system. In the current study, the LifeShirt® was used to measure autonomic functioning (i.e., HR, HRV, and respiration). The study required that the participants must be without severe tactile hypersensitivities since adhesive electrodes were used to monitor cardiac functioning. For this study in particular, there were many benefits of using LifeShirt® over typical laboratory physiology measurement systems. Specifically, the LifeShirt® is worn like a vest or shirt and hides electrodes, electrode wires, and respiration straps. Especially for children with ASD, this system provided a more familiar and comfortable apparatus. Additionally, the LifeShirt® provides an unmatched ability to measure ambulatory autonomic response (Heilman & Porges, 2007), allowing the child to move freely during the semi-structured play and listening periods of the study. Heilman and Porges (2007) compared the LifeShirt® to the Biopac MP35 (Biopac Systems, Goleta, CA, USA), a frequently used physiological monitoring system; they found that the LifeShirt® is both accurate in the detection of R-waves and in the timing of R-R intervals (Heilman & Porges, 2007), which are necessary values for accurate calculation of HR, HF HRV, and LF HRV.

2.3 - Groups

Based on vocabulary scores on the PPVT-III, 23 participants were matched to the Music or Audiobook group ($n_{\text{music}} = 11$, $n_{\text{book}} = 12$). The auditory stimulus was the experimentally manipulated variable by which children were matched: the first child was randomly assigned to the Music group and their counterpart was assigned to the Audiobook group. Due to auditory hypersensitivities and the need to ensure volume is consistent across participants, maximal loudness was calibrated to approximately 75 decibels. The control group, Audiobook, was selected due to the need to differentiate between auditory stimuli. Studies with music versus no-music groups have been criticized for their inability to attribute their results specifically to music (Nantais & Schellenberg, 1999). The present study hypothesized that social engagement improvement would only be seen in the Music group.

2.4 - Procedure

To determine eligibility of participants, the experimenter conducted a phone interview with the parent prior to the experimental session. The experimenter confirmed with the parent that their child had a prior diagnosis of an ASD and then explained the procedures of the study, especially those related to physiological monitoring. Specifically, the experimenter received verbal confirmation that the parent believed their child would be able to withstand the adhesion and removal of the electrodes, as well as 38 minutes of physiological monitoring with the LifeShirt®. In order to fit in the LifeShirt®, the experimenter confirmed that the child's abdomen was at least 20 inches around and their chest was at least 21 inches around. The experimenter verbally administered the Short Sensory Profile to the parent to verify their child did not have severe tactile hypersensitivities. If the participant was eligible, an experimental session was scheduled. Both the parent and child were asked to attend the laboratory session.

Upon arriving at the lab, the experimenter explained the procedures of the study to the parent and child and obtained consent (see Appendix B for Parental Permission Form for Child, Appendix C for Parent Subject Consent Form, and Appendix D for Child Verbal Assent Document/Script) from the parent and verbal assent from the child. After obtaining consent/assent, the parent completed the demographic form, SRS, PAS, FSSIP, and DBC. While the parent completed the questionnaires, the child participated in the laboratory session. The parent was told that they could watch their child behind a one-way window while they completed the questionnaires. The entire experimental session was videotaped from this point. First, the

child completed the PPVT-III (10-15 minutes). This was scored immediately and based on their standard score and the parent-reported auditory hypersensitivities, the child was placed into either the Music or Audiobook group. After matching the child to a group, he/she self-selected 5 songs (i.e., lullabies) or 1 audiobook for the listening period. Participants were allowed to listen to 18-second excerpts of the 10 pre-selected, age-appropriate lullabies to select 5 total songs. Or, the child listened to 30-second excerpts from 6 books-on-tape to select 1 audiobook.

Next, the experimenter attached the LifeShirt® to the child. Special attention and care was made to ensure the comfort of the child. After attaching the LifeShirt®, the child watched a 3-minute section of *National Geographic's Animal Holiday*, a nature video geared for children 4 - 10 years old, to gather a 3-minute baseline. During this time, the experimenter downloaded either the child's selected 5 songs or audiobook to an iPod (Apple).

Next the SICS (Pre-task SICS) was administered by the experimenter (10 minutes). After the SICS, the child listened to either the music or audiobook (12 minutes). During this listening period, with the experimenter still present, the child sat at a table and quietly colored. After the listening period, the child was administered the SICS (Post-task SICS) by the experimenter (10 minutes). In prior studies, the SICS has been used effectively as a pre and post measure without significant carry-over effects (Porges et al., unpublished). Upon completion of the SICS, the child watched *National Geographic's Animal Holiday* during a recovery period of 3 minutes. Lastly, the LifeShirt® was removed and any questions the parent or child had about the study were answered. The experimental session lasted approximately 90 minutes.

2.5 - Psychophysiological Data Reduction

A research assistant placed event markers in the psychophysiological data at the following points: 1) beginning/end baseline, 3 minutes; 2) beginning/end Pre-task SICS, 10 minutes; 3) beginning/end listening period (i.e., task), 12 minutes; 4) beginning/end Post-task SICS, 10 minutes; 5) beginning/end recovery, 3 minutes. The research assistant observed the experimental session through a one-way window.

HR was measured in beats per minute based on the average of interbeat intervals. HF HRV was measured by conducting spectral analysis to derive high frequency power bands. HF HRV represents the heart period variance centered at the respiration frequency of 0.15-0.40 hz and has been accepted as a measure of vagal reactivity (De Meersman & Stein, 2007). Contrary to some researchers (e.g., Grossman, 1992), respiration was not controlled when examining HF

HRV in order to preserve the natural respiratory influence on HF HRV (Porges, 2007). Lastly, low frequency HRV (LF HRV) was examined as an exploratory measure of sympathetic influence. LF power indicates the variance of the heart period spectrum that is centered at the respiratory frequency of .03 and .15 Hz (De Meersman & Stein, 2007). LF power, although debated, can be considered a measure of sympathetic influences on the heart (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Despite evidence to support the interpretation of LF HRV (e.g., Montano et al., 1994) as a measure of cardiac sympathetic activity, current research (e.g., De Meersman & Stein, 2007) suggests that vagal or parasympathetic influence may confound LF HRV, particularly at baseline.

Both HF HRV and LF HRV are reported in normalized units (n.u.) as well as absolute power, as suggested by the Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996). N.u. are derived by comparing the absolute value of each power element (e.g., HF) to the total power minus the very low frequency component (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Thus, n.u. reflect the dynamic change in the implicated autonomic branches (i.e., parasympathetic vs. sympathetic). The Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996) state that n.u. should be reported with absolute values of LF and HF power to describe the total power distribution of the spectral components.

3.0 - Results

3.1 - Descriptives

Descriptives were conducted on all demographic variables (i.e., child gender, child age, child minority status, child diagnosis, parental education, and household income) to characterize the sample. Regarding race, 1 participant self-reported as African American, 1 participant Asian, and 20 Caucasian (one parent did not answer this question). The participants had been previously diagnosed with Autism ($n = 12$), Asperger's Disorder ($n = 10$), or PDD-NOS ($n = 1$). Most parents reported their highest education as college degree or beyond: high school graduate ($n = 1$), some college ($n = 5$), college degree ($n = 10$), some graduate studies ($n = 2$), graduate degree ($n = 4$). Additionally, family income was fairly evenly distributed from \$20,000 to \$100,000 and above: \$20,000-\$39,999 ($n = 3$); \$40,000-\$59,999 ($n = 6$); 60,000-79,999 ($n = 3$); \$80,000-

\$99,999 ($n = 4$); \$100,000 and above ($n = 1$). Means and standard deviations were also calculated for the PPVT-III, SICS, SRS, FSSIP, PAS, DBC, HR, and HF/LF HRV data and were broken down by group (Tables 1-3). The low sample size of female children in this study precluded comparison of gender using independent t-tests, due to the lower power affiliated with a small sample size. No demographic effects were noted consistently across variables (i.e., systematically related to both the independent and dependent variables); thus, they were not controlled in the remaining analyses. Although no group differences systematically varied across the variables, significant group differences were found: DBC total score ($t(21) = 2.51, p < .05$), Music ($M = 58.36, SD = 22.68$), Audiobook ($M = 80.00, SD = 18.67$); Pre-task SICS conventional gestures ($t(20) = 2.35, p < .05$), Music ($M = 1.64, SD = 2.34$), Audiobook ($M = 6.18, SD = 5.98$); Post-task SICS ignore ($t(20) = -2.66, p < .05$), Music ($M = 8.36, SD = 7.38$), Audiobook ($M = 2.00, SD = 2.90$). Thus, the Music group showed significantly less disruptive behavior, fewer conventional gestures (e.g., nodding) at pre-task, and more ignores post-task, relative to the Audiobook group.

Since groups were matched by PPVT-III standard score and parent-reported auditory hypersensitivities, t-tests were run to ensure no group differences existed on these variables: PPVT-III ($t(21) = .98, p = .34$); auditory hypersensitivities ($t(21) = .57, p = .57$).

3.2 - Correlations

In order to assess if individual differences were related to any outcomes and would need to be used as control variables, correlations were conducted between questionnaires (i.e., FSSIP, SRS, PAS, DBC) and SICS domains and questionnaires and physiological epochs (Tables 4-5).

Correlations were conducted between the SICS scores and the SRS, FSSIP, PAS, and DBC (Table 4) to test for confounding effects of social responsiveness, fear, anxiety, and disruptive behavior on social engagement. Results indicate that the SRS social cognition scale was significantly correlated to Pre-task action, Post-task share, Pre- and Post-task request. Furthermore, SRS motivation was significantly correlated to Post-task ignore. The FSSIP was significantly correlated to Pre- and Post-task response to verbal prompt, Pre-task verbalization, Pre-task vocalizations, and Pre-task requests. The PAS was significantly correlated to Pre-task response to gesture prompt and Post-task vocalizations. The DBC total score was not significantly correlated to any SICS domains.

Correlations were also conducted between LF HRV, LF HRV n.u., HF HRV, HF HRV n.u., and the SRS, FSSIP, PAS, and DBC (Table 5) to test for the confounding effects of social responsiveness, fear, anxiety, and disruptive behavior on autonomic response. The SRS social awareness scale was significantly correlated to Recovery LF HRV. SRS social cognition, social communication, and total score were significantly correlated to baseline RR, task RR, and recovery RR. SRS motivation was significantly correlated to baseline HR, baseline LF HRV, task HR, and recovery HR. SRS autistic mannerisms was significantly correlated to recovery HF HRV. The FSSIP was not significantly correlated to any autonomic measures. The PAS was significantly correlated to task HF HRV, task LF HRV, and recovery RR. DBC total score was significantly correlated to recovery LF HRV.

Systematic correlations were not observed between social responsiveness, fear, anxiety, disruptive behavior, social engagement, and autonomic variables; thus, no covariates were used throughout the remaining analyses.

3.3 - Hypothesis-Testing

Since no systematic between-group differences were found, analyses of variance (ANOVA) were conducted for all analyses below. All tests conducted were one-tailed due to *a priori* hypotheses.

Social Engagement. A 2 (Group: Music vs. Audiobook) x 2 (Time: Pre-task vs. Post-task) Mixed Factorial ANOVAs were conducted to test for the main effect for group, the main effect for time, and the Group x Time interaction (see Table 6).

The main effect of group on social engagement was significant for verbalizations ($F(1, 21) = 3.16, p = .04$), ignores ($F(1, 21) = 3.67, p = .03$), and conventional gestures ($F(1, 21) = 5.22, p = .02$). Specifically, the Music group evidenced fewer verbalizations and conventional gestures and more ignores, pre- to post-task SICS, relative to the Audiobook group. No other significant group main effects emerged.

The significant main effects for time (see Table 6) on Pre-task SICS to Post-task SICS were as follows: gaze ($F(1, 21) = 3.10, p = .04$), verbalizations ($F(1, 21) = 3.77, p = .03$), actions ($F(1, 21) = 3.86, p = .03$), vocalizations ($F(1, 21) = 3.49, p = .04$), and conventional gestures ($F(1, 21) = 3.00, p = .04$). For gaze, verbalizations, and conventional gestures, the Music and

Audiobook group both showed a significant decrease (Pre- to Post-task). The Music and Audiobook groups both evidenced a significant increase (Pre- to Post-task) for actions and vocalizations. No other significant time main effects emerged.

Results indicate a significant Group x Time interaction effect for only ‘child shares,’ $F(1, 21) = 6.43, p = .01$ (see Figure 1). The significant interaction effect observed in ‘child shares,’ $F(1, 21) = 6.43, p = .01$, indicated a significant increase in ‘child shares’ for the Music group and significant decrease in ‘child shares’ for the Audiobook group. Post-hoc analyses (i.e., one-way ANOVA) revealed no significant between group differences at Pre-task ($F(1, 21) = .14, p = .36$) or Post-task ($F(1, 21) = 1.05, p = .16$) for the SICS ‘child shares’ measure.

Autonomic Response. 2 (Group) x 3 (Time: baseline, task, and recovery) Mixed Factorial ANOVAs were conducted to test for a significant main effect for group and time, as well as a Group x Time interaction for HR, LF HRV, and HF HRV (see Table 7).

A significant main effect for group was not observed for HR, $F(1,17) = .56, p = .23$. A significant main effect for time also was not observed for HR, $F(1,17) = .08, p = .45$. There was a marginally significant interaction, Group (Music vs. Audiobook) x Time (baseline, task, recovery) effect for HR ($F(1, 17) = 1.94, p = .08$; see Figure 2), with greater mean HR in the Music Group. A significant interaction effect was observed from HR baseline to HR task ($F(1, 19) = 3.82, p = .03$) such that the Music group HR significantly decreased from baseline to task compared to the Audiobook group, which increased from baseline to task. A significant interaction effect for HR was not observed from task to recovery, ($F(1, 19) = .38, p = .27$). Post-hoc analyses revealed no significant differences between groups at baseline $F(1, 19) = 1.26, p = .14$, task ($F(1, 20) = .09, p = .77$), or recovery ($F(1, 19) = .87, p = .36$).

Mixed Factorial ANOVA revealed no significant main effects for group for HRV measures. Analyses showed a significant main effect for time for HF HRV n.u. ($F(1, 15) = 2.41, p = .05$), such that the Music group HF HRV n.u. significantly increased from baseline to task compared to the Audiobook group, which decreased from baseline to task. No significant main effects for time were found for other HRV measures (i.e., HF HRV, LF HRV, and LF HRV n.u. ($F(1, 15) = .08, p = .46$).

A significant Group x Time interaction effect was observed for HF HRV n.u. ($F(1, 15) = 2.91, p = .04$; see Figure 3). Significant interaction effects were not observed for HF HRV, LF HRV, and LF HRV n.u..

Regarding HF HRV n.u., the Music group increased in HF HRV from baseline to task, and the Audiobook group decreased in HF HRV from baseline (to task. This HF HRV baseline-to-task interaction was marginally significant, $F(1, 18) = 1.87, p = .09$. The task to recovery change in HF HRV was not significant, $F(1, 18) = .70, p = .21$). Post-hoc analyses reveal no significant differences between groups at task ($F(1, 20) = .03, p = .44$) or recovery ($F(1, 18) = .11, p = .37$). Notably, HF HRV n.u. trended towards significance at baseline ($F(1, 18) = 2.60, p = .06$), with higher HF HRV in the Audiobook Group.

Mediation of HR and HF HRV n.u. on ‘Child Shares.’ Mediation analyses were conducted, since interaction effects were observed: there was a significantly greater increase on ‘child shares’ for the Music group ($F(1, 21) = 6.43, p = .01$), significant decrease in HR (baseline to task) for the Music group ($F(1, 19) = 3.82, p = .03$), and marginally significant increase in HF HRV n.u. (baseline to task) for the Music group ($F(1, 18) = 1.87, p = .09$). As such, mediation analyses were conducted to test the mediating effect of autonomic response on the relationship between music and social engagement (specifically, SICS ‘child shares’). Mediation analysis consisted of a 2 (Group: Music vs. Audiobook) x 2 (Time: Pre-task SICS ‘child share’ vs. Post-task SICS ‘child share’) Mixed Factorial ANCOVA that measures the effect of the Group (Music vs. Audiobook) on Pre- and Post-task child share when controlling for physiological response (i.e., HR and HF HRV change scores from baseline to task). If mediation is supported, the interaction effect between group and ‘child shares’ should no longer be significant or substantially reduced.

Mediation of HR on the relationship between group and ‘child shares’ consisted of a 2 (Group: Music vs. Audiobook) x 2 (Time: Pre-task SICS ‘child shares’ vs. Post-task SICS ‘child shares’) Mixed Factorial ANCOVA when controlling for HR response (i.e., task minus baseline change score). When controlling for HR response, the relationship between group and ‘child shares’ was still significant ($F(1, 18) = 5.14, p = .02$), but showed less of an effect than the relationship between group and ‘child shares’ without controlling for HR response ($F(1, 21) = 6.43, p = .01$). As suggested by Baron & Kenny (1986), HR may partially mediate the effect between group and ‘child shares’ (i.e., the effect between the independent and dependent variable was reduced when the mediator was controlled).

Mediation of HF HRV n.u. on the relationship between group and ‘child shares’ consisted of a 2 (Group: Music vs. Audiobook) x 2 (Time: Pre-task SICS ‘child shares’ vs. Post-task SICS ‘child shares’) Mixed Factorial ANCOVA when controlling for HF HRV n.u. response (i.e., task minus baseline change score). The relationship between group and ‘child shares’ was still significant when controlling for HF HRV n.u. response, ($F(1, 17) = 4.91, p = .02$), but this effect was reduced compared to the relationship between group and ‘child shares’ without controlling for HF HRV response ($F(1, 21) = 6.43, p = .01$). HF HRV n.u., therefore, may partially mediate the effect between group and ‘child shares’ (i.e., the effect between the independent and dependent variable was reduced when the mediator was controlled; Baron & Kenny, 1986).

4.0 - Discussion

The hypotheses outlined in this study were generally supported. The music-listening group evidenced a significantly soothed autonomic state (i.e., decreased HR and increased HF HRV n.u.) when compared to the group who listened to the audiobook. Furthermore, the Music group evidenced a significant increase (pre-to-post listening period) on ‘child shares’ when compared to the Audiobook group. The mediating effect of autonomic response (i.e., HR change, HF HRV n.u. change) was tested on the relationship between group and ‘child shares’: HR mediating the relationship between group and ‘child shares’ and HF HRV n.u. mediating the relationship between group and ‘child shares.’ Although both mediation models (i.e., HR and HF HRV n.u.) remained significant after controlling for HR change and HF HRV n.u. change, the relationship between group and ‘child shares’ was reduced in both models, possibly reflecting partial mediation of autonomic state.

These results also lend support, albeit limited, to the tenets of the Polyvagal Theory and the related Social Engagement System (e.g., Porges, 2008). Specifically, HF HRV (measurement of the myelinated vagus) evidenced an increase in the Music group, reflecting an increase in parasympathetic activity (i.e., soothed autonomic state). Porges theorizes that this soothed state, as measured by HF HRV, should produce effective social communication by coordinating the five cranial nerves implicated in the Social Engagement System (i.e., cranial nerves V, VII, IX, X, XI), including the myelinated vagus (cranial nerve X). Results show that soothed HF HRV n.u. in the Music group coincided with improvements in ‘child shares’ in the Music group. Thus, via music, the myelinated vagus was soothed and social attention (i.e., ‘child shares’)

improvements were evidenced post-soothed state. However, the mediation model seemed to only partially support the mediation of HR and HF HRV n.u. The partially mediated effect of HR and HF HRV on the relationship between group and ‘child shares,’ reflects the limitation of measuring only one Social Engagement System cranial nerve (i.e., vagus). In this study, four other cranial nerves (i.e., VII, IX, X, XI) were not quantitatively measured and may limit the mediating effect of physiological soothing between group and social attention improvement.

Notably, increased or soothed HF HRV (myelinated vagus activity) only coincided with an improvement in social attention (i.e., ‘child shares’), a relatively complex interaction. Other measures of social interaction did not evidence a significant improvement; therefore, on the surface these results do not seem to support the Polyvagal Theory. Nevertheless, the other measures of social engagement were relatively simple social behaviors: eye gaze, verbalization, vocalization, communicative gesture (e.g., child putting someone’s hand on a toy to move it), conventional gesture (e.g., shaking head yes/no), action (e.g., movement after prompt), and request (e.g., placing examiners hand on toy). ‘Child shares’ was defined as “behaviors without apparent instrumental goal, performed for the sheer purpose of sharing an interest, emotion, or information” (Bazhenova, 2006). As such, the variable ‘child shares’ will be referred to as “social attention” throughout the rest of the discussion due to the interactive nature of ‘child shares’ and the necessary use of appropriate behaviors to effectively share interest, emotion, or information. Social attention included eye contact, vocalizations, verbalizations, head orienting (i.e., joint attention - looking at a toy, looking up and making eye contact with the examiner, and looking back at the toy), and sharing emotions (i.e., smiling – facial expression and positive/negative emotions). As a result, social attention (i.e., ‘child shares’), as defined by Bazhenova (2006), is an amalgamation of behaviors controlled by Social Engagement System’s five cranial nerves identified by Porges (1998, 2007, 2008): eye contact used in joint attention (cranial nerve VII), facial expression used for sharing emotion and smiling (cranial nerves VII and IX), vocalizations and verbalizations used for sharing information (cranial nerves V and IX), head turning muscles used to orient towards examiner during joint attention (cranial nerve XI), and autonomic soothed state evidenced by increased HF HRV (cranial nerve X). As such, the

measurement of social attention (i.e., ‘child shares’) provided a combined measurement of all Social Engagement System cranial nerves. As predicted by Porges (1998, 2007, 2008), the social attention improvements coincided with a soothed autonomic state.

Notably, the Audiobook group decreased from pre- to post-task SICS. Moreover, HR and HF HRV effects support an increase in arousal during the audiobook listening (i.e., increased HR and decreased HF HRV baseline to task). This suggests that an aspect of the audiobooks may have been arousing, possibly due to anxiety or excitement. The audiobooks may have unintentionally created an aroused state, due to the content of the stories or the voice of the unknown individual telling the story. The increased autonomic state (i.e., increased HR and decreased HF HRV) could reflect similar cardiovascular trends to those seen when children with ASD are exposed to an unfamiliar individual (e.g., Vaughan Van Hecke et al., 2009). Future research should address this potential confound by using a calming, music-less auditory stimuli (e.g., poetry). On the other hand, the findings cannot be attributed solely to this methodological issue, since both groups (i.e., Music and Audiobook) produced significant changes on some of the other SICS measures. If the results were solely due to arousal/excitement increases from the audiobook stimuli, then changes in the SICS measures should only have been evident in the Audiobook group.

The questionnaires administered to test for potential confounding factors (i.e., social responsiveness, anxiety, fear, and disruptive behavior) did not consistently effect the outcome variables (i.e., SICS domains and physiological epochs). This seems counterintuitive, since one would assume, for example, that anxiety would be related to behavioral avoidance of an unknown individual. Yet, if the tenets of the Polyvagal Theory and Social Engagement System are used to understand social deficits found in ASD, these deficits would not be linked to internal traits (e.g., fear, anxiety, temperament, emotion regulation). Instead, social deficits in ASD would be linked to dysfunctional coordination of the cranial nerves implicated in the Social Engagement System (i.e., V, VII, IX, X, XI) and, therefore, to the neurological components where the cranial nerves originate (i.e., upper motor neurons and lower motor neurons). Disruptive behavior was significantly higher in the Audiobook group compared to the Music group. According to previous research, we predicted that disruptive behavior may confound social engagement behavior (i.e., higher disruptive behavior producing lower social engagement; Lee, Odom, & Loftin, 2007). Nevertheless, disruptive behavior was not consistently correlated to

the social engagement measures and therefore was not controlled in the statistical analyses. Still, it could be possible that the differences in disruptive behavior contributed to differences on the social engagement measures in some other capacity, such as having a moderating influence. Similarly, anxiety and fear were not systematically correlated to the outcome variables (i.e., social engagement and autonomic response), but these variables could play a moderating role on the relationship between group and social attention improvements. In particular, these constructs may play a moderating role in the Polyvagal Theory (in addition to neurological control of the Social Engagement System cranial nerves) in that they reflect the fight/flight behaviors purportedly associated with the defensive system. Thus, high anxiety, for example, could facilitate differential autonomic responding, which promotes or inhibits social engagement behaviors. The moderating role of these constructs was not tested herein.

Although future research will need to find significant mediation of autonomic soothing on social engagement improvements to completely support the Polyvagal Theory, these results suggest an alternative understanding of social skill deficits in children with ASD. This understanding rests on the notion that social skill deficits are, in part, a function of an over-aroused autonomic state, indicative of a dysfunctional or uncoordinated Social Engagement System (i.e., cranial nerves V, VII, IX, X, X). Thus, social skill interventions, which presently yield minimal effects (Bellini, Peters, Benner, & Hopf, 2007), may not be targeting a core element of social deficits: an over-aroused autonomic state. Future social skill interventions could include measures of cardiac state to teach biofeedback skills (e.g., monitoring heart rate, identification of dysfunctional physiological responding, and strategies to soothe/extinguish this physiological state).

Moreover, the present study identified one potential medium (i.e., music) that was able to soothe the over-aroused cardiac state found in children with ASD (e.g., Bal et al., 2010). Since this soothed cardiac state was paired with social attention improvements, music could be used in social skill interventions as a medium to evoke socially acceptable behaviors via a calmed autonomic nervous system. This calmed autonomic state may open a window into some basic skills that the child already has therefore, allowing the child to more effectively engage. Music could thus be used as a medium to teach children how to control their autonomic state within a social skills intervention protocol that incorporates biofeedback, relaxation training, or priming with music. For instance, social skills interventions could start every session with biofeedback or

relaxation training (i.e., learning how to calm one's autonomic state) via music. This soothed state would then prepare a child to more effectively participate in a session, increasing the child's understanding and retention of the social skills taught. As such, this soothed physiological state derived from music may help to augment the effects of social skills interventions.

Interestingly, LF HRV was significantly positively correlated with HF HRV and HF HRV n.u. Some researchers suggest that LF HRV may be used as an indicator of sympathetic activity (Montano et al., 1994); however, in this study the high positive correlations between LF HRV and HF HRV suggest that it is measuring the same construct as HF HRV. It is fairly well established that HF HRV measures parasympathetic activity (De Meersman & Stein, 2007). We would assume that LF HRV and HF HRV should be negatively correlated due to the reciprocal nature of sympathetic and parasympathetic activity (i.e., sympathetic activity increases, parasympathetic activity decreases). The HRV measures in this study, however, do not reflect this reciprocal relationship. Thus, it appears that LF HRV in this study is not necessarily a measurement of sympathetic activity.

4.1 - Limitations

A significant limitation of this study is not acquiring the N-size needed for adequate power. Prior to running the study, a power analysis using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) for a 2 x 2 repeated measures, between factors ANOVA was conducted using a large effect size of $f = .40$ and alpha of .05. The results of this power analysis indicated that $N = 28$ was needed for adequate power (.80). Although an N-size of 28 was sought, a sample size of 23 was obtained due to recruitment difficulties. A power analysis for a 2 x 2 repeated measures, between factors ANOVA conducted for 23 participants, using a large effect size of $f = .40$ and alpha of .05, found that power = .61. Since power of .80 is typically considered adequate (Cohen, 1990), this study was underpowered. Furthermore, in order to detect a medium effect (i.e., $f = .25$) with a 2 x 2 repeated measures, between factors ANOVA with an alpha of .05 and adequate power (.80), a sample size of 86 would have needed to be collected. To detect a small effect (i.e., $f = .10$), with the same parameters, 526 children would have needed to participate in the study to obtain adequate power.

Another significant limitation of this study was the coding procedures. In the interest of time, the independent coders were not able to achieve 70% reliability prior to coding the study videotapes. In order to achieve 70% reliability, coders would have needed to invest about 6-12

months to achieve reliability – past the time the research assistants would be available. As such, consensus coding was used.

Since ANOVA analyses were used in order to determine the main effects of group and time as well as the Group x Time interaction, ANCOVA was used to test mediation. Researchers suggest that ANOVA is a limited test of mediation (Fiske, Kenny, & Taylor, 1982). Moreover, a Sobel test was not conducted due to the lack of regression coefficients. To show a significant drop in the direct effect (i.e., relationship between independent and dependent variables), and confirm psychophysiological partial mediation occurred, a Sobel test would need to be conducted (Holmbeck, 2002). Therefore, partial mediation seemed to occur in this study, but a Sobel test would need to confirm a substantial reduction in the direct effect when the mediator was included in the model.

Although it was predicted that all social engagement measures (e.g., gaze, verbalizations, gestures, ignores) would significantly improve after music listening, only the measure of social attention (i.e., ‘child shares’) showed a significant Group x Time interaction. The measure of social attention could have been a stronger variable to test due to the complex behaviors necessary to successfully meet definitional criteria of social attention. Since this was the only social engagement variable to show a significant interaction of several that were predicted, it is possible that the effects are erroneous.

Lastly, groups were matched by auditory sensitivity due to current research that suggests children with ASD and auditory sensitivities show increased social engagement to music (Porges et al., unpublished). The Short Sensory Profile was used to assess for auditory sensitivities. The scale used (i.e., visual/auditory sensitivity) showed unacceptable internal consistency (Cronbach’s $\alpha = .47$). Therefore, groups may not have been matched accurately due to the limited reliability of the visual/auditory sensitivity scale.

4.2 - Future Directions

Future studies should include a larger sample size in order to detect full mediation of autonomic response and potential increases in “simple” social engagement behaviors (e.g., eye contact). Other studies should address video coding limitations by extending the timeline for study completion in order to ensure reliability can be achieved between coders. Also, the Social Interaction Coding Scale needs further validation in order to discern the constructs measured.

Specifically regarding results found in this study, future studies should objectively measure social attention (e.g., through eye tracking) in order to precisely quantify social attention improvements after music listening. Additionally, using quantitative measures of other Social Engagement System cranial nerves (e.g., facial electromyography) could provide further support of the Polyvagal Theory. Broadly, this study lends support to the autonomic mechanisms (i.e., soothing) that encourage social attention improvements. Future studies should identify other mediums – other than music – able to soothe the over-aroused autonomic state often found in children with ASD.

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Table 1

Descriptives for PPVT-III, SRS, FSSIP, PAS, and DBC by Group

	PPVT	SRS	SRS	SRS	SRS	SRS	SRS	FSSIP	PAS	DBC
	Mean	Total	Aware	Cog	Comm	Moti	Manner	Mean	Mean	Total
	(SD)	Mean	Mean	Mean	Mean	Mean	Mean	(SD)	(SD)	Mean
		(SD)	(SD)	(SD)	(SD)	(SD)	(SD)			(SD)
Music	93.75	79.73	71.91	80.00	78.09	70.73	80.73	44.91	.95	58.36*
(<i>n</i> = 11)	(17.93)	(9.56)	(11.23)	(8.74)	(9.42)	(14.12)	(9.84)	(21.67)	(.59)	(22.68)
Audiobook	104.00	82.42	79.08	80.08	80.42	71.50	83.08	37.50	.90	80.00*
(<i>n</i> = 12)	(19.76)	(6.52)	(9.94)	(7.81)	(7.38)	(10.35)	(6.74)	(20.66)	(.61)	(18.67)

Note. * Between-group means are significant at the 0.05 level (2-tailed). PPVT = Peabody Picture Vocabulary Test (third edition); SRS = Social Responsiveness Scale, Aware = Social Awareness, Cog = Social Cognition, Moti = Social Motivation, Manner = Autistic Mannerisms; FSSIP = Fear Survey Schedule for Infants & Preschoolers; PAS = Preschool Anxiety Scale; DBC Total = Developmental Behavior Checklist total score.

Table 2

Descriptives for SICS by Group

	Pre ChV Mean (SD)	Pre Gaze Mean (SD)	Pre Verb Mean (SD)	Pre Action Mean (SD)	Pre Ignore Mean (SD)	Pre Vocal Mean (SD)	Pre Convlg Mean (SD)	Pre Comg Mean (SD)	Pre ChG Mean (SD)	Pre Sh Mean (SD)	Pre Req Mean (SD)	Post ChV Mean (SD)	Post Gaze Mean (SD)	Post Verb Mean (SD)	Post Action Mean (SD)	Post Ignore Mean (SD)	Post Vocal Mean (SD)	Post Convlg Mean (SD)	Post Comg Mean (SD)	Post ChG Mean (SD)	Post Sh Mean (SD)	Post Req Mean (SD)
Music (n = 11)	8.64 (8.36)	16.00 (9.30)	34.36 (28.86)	18.36 (10.13)	8.27 (8.25)	8.36 (9.73)	1.64* (2.34)	.27 (.91)	12.27 (6.41)	5.82 (6.34)	8.00 (7.93)	8.09 (8.07)	14.36 (12.14)	32.45 (27.81)	23.82 (14.25)	8.36* (7.38)	13.00 (15.19)	1.27 (1.35)	.27 (.91)	12.27 (4.61)	7.27 (8.38)	9.09 (12.61)
Audiobook (n = 12)	8.13 (6.82)	21.64 (13.92)	59.55 (32.15)	18.73 (6.83)	3.91 (8.83)	5.45 (7.24)	6.18* (5.98)	0.00 (0.00)	10.00 (3.69)	6.73 (4.86)	11.91 (9.49)	7.45 (5.45)	16.45 (12.44)	51.82 (30.76)	20.36 (4.78)	2.00* (2.90)	8.09 (13.38)	4.27 (5.14)	.09 (.30)	10.91 (3.02)	4.36 (4.30)	12.45 (9.61)

Note. * Between-group means are significant at the 0.05 level (2-tailed). Pre = Pre-task SICS, Post = Post-task SICS; ChV = Response Verbal Prompt, Verb = Verbalization, Vocal = Vocalization, Convlg = Conventional Gesture, Comg = Communicative Gesture, ChG = Response to Gesture Prompt, Sh = Share, Req = Request.

Table 3

Descriptives for baseline, task, and recovery heart rate (HR,) and low and high frequency (n.u.) heart rate variability (LF HRV; HF HRV) by Group

	Baseline	Task	Recovery	Baseline	Task	Recovery	Baseline	Task	Recovery
	HR	HR	HR	LF HRV	LF HRV	LF HRV	HF HRV	HF HRV	HF HRV
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
	(SD)	(SD)	(SD)	(SD)	(SD)	(SD)	(SD)	(SD)	(SD)
Music (<i>n</i> = 11)	106.52 (13.61)	103.49 (9.81)	106.46 (19.44)	.46 (.17)	.43 (.09)	.45 (.21)	.33 (.13)	.35 (.07)	.34 (.13)
Audiobook (<i>n</i> = 12)	100.13 (12.44)	104.90 (12.33)	100.49 (9.53)	.41 (.12)	.43 (.09)	.43 (.15)	.41 (.11)	.35 (.09)	.36 (.13)

Note. * Between-group means are significant at the 0.05 level (2-tailed). ** Between-group means are significant at the 0.01 level (2-tailed).

Table 4

Correlations between FSSIP, SRS, PAS, DBC, and Pre-task/Post-task SICS Domains

	FSSIP	SRS aware	SRS cog	SRS comm	SRS moti	SRS manner	SRS total	PAS	DBC total	A_ChV	A_Gaze	A_Verb	A_Act	A_Ignore	A_Vocal	A_Convg	A_Comg	A_ChG	A_Sh	A_Req	B_ChV	B_Gaze	B_Verb	B_Action	B_Ignore	B_Vocal	B_Convg	B_Comg	B_ChG	B_Sh
SRSaware	-.04																													
SRS cog	.12	.51**																												
SRScomm	.09	.70**	.57**																											
SRSmoti	.41*	.49**	.45*	.49**																										
SRSmanner	.10	.54**	.58**	.52**	.69**																									
SRS total	.09	.81**	.73**	.80**	.72**	.84**																								
PAS	.73**	.12	.28	.16	.47*	.22	.20																							
DBCtotal	-.05	.25	.25	.03	.26	.23	.21	.27																						
A_ChV	.53**	-.12	.17	.09	.23	.02	.03	.37*	.03																					
A_Gaze	-.06	-.17	.22	-.02	-.01	.14	.02	.15	.03	.02																				
A_Verb	.40*	.01	.31	.25	-.03	.17	.18	.32	.07	.35	.57**																			
A_Action	.31	.13	.39*	.33	.29	.21	.30	.25	-.14	.56**	.25	.45*																		
A_Ignore	-.16	.25	.13	.14	.18	.03	.21	-.28	.12	-.29	-.59**	-.53**	-.01																	
A_Vocal	-.37*	.09	-.08	-.24	.07	-.05	-.01	-.34	.24	-.34	-.38*	-.71**	-.42*	.47*																
A_Convg	-.08	.01	-.28	-.27	-.14	-.07	-.21	-.09	.19	.22	.13	.04	-.07	-.43*	.06															
A_Comg	.01	.31	-.02	.31	.14	.21	.24	-.18	-.35	-.26	-.35	-.32	-.36	.15	.34	-.17														
A_ChG	-.12	.08	.02	-.03	.10	-.08	.06	.04	.00	.19	.20	-.01	.45*	.01	.09	.05	-.30													
A_Sh	.24	-.19	.12	.12	.18	-.07	-.01	.27	.06	.57**	.54**	.49*	.41*	-.52**	-.28	.18	-.21	.39*												
A_Req	.45*	.27	.38*	.29	.17	.30	.30	.27	-.06	.52**	.25	.64**	.75**	-.33	-.48*	.26	-.18	.19	.37*											
B_ChV	.43*	-.22	.20	.06	.07	-.03	-.03	.26	.04	.84**	.03	.44*	.52**	-.30	-.32	.19	-.26	.24	.62**	.57**										
B_Gaze	-.14	-.11	.28	.00	.20	.14	.10	.11	-.01	.19	.72**	.21	.38*	-.44*	.03	.14	-.25	.32	.61**	.22	.17									
B_Verb	.28	-.05	.29	.19	-.12	.08	.12	.23	.12	.38*	.48*	.93**	.36	-.52**	-.62**	.00	-.31	.00	.58**	.56**	.52**	.20								
B_Action	.11	-.12	.25	.23	.10	.13	.19	.01	-.20	.60**	.25	.38*	.62**	-.22	-.24	-.07	-.15	.42*	.68**	.47*	.60**	.50**	.48*							
B_Ignore	.28	.27	.33	.28	.39*	.19	.34	.01	-.09	.10	-.51**	-.39*	.12	.72**	.40*	-.33	.34	.01	-.33	-.11	-.03	-.31	-.44*	-.07						
B_Vocal	-.30	.15	-.22	.01	.04	.00	.03	-.39*	-.10	-.28	-.37*	-.64**	-.42*	.26	.80**	.18	.67**	-.11	-.20	-.36**	-.32	.03	-.59**	-.14	.34					
B_Convg	-.05	-.08	-.26	-.32	-.03	-.05	-.21	.00	.26	.04	.19	-.08	-.28	-.40*	.25	.78**	-.16	-.15	.15	.01	.01	.34	-.13	-.14	-.33	.34				
B_Comg	.10	.31	-.09	.33	.17	.17	.25	-.14	-.33	-.27	-.39*	-.25	-.42*	.10	.29	-.20	.95**	-.32	-.23	-.21	-.28	-.32	-.26	-.18	.28	.60**	-.15			
B_ChG	-.13	-.12	.04	-.15	.22	.29	.08	-.07	-.05	-.13	.03	-.29	-.13	.03	.28	-.05	.14	.08	-.14	-.28	-.25	.05	-.31	-.06	.21	.10	-.05	.12		
B_Sh	.17	-.05	.42*	.22	.35	.12	.22	.33	-.01	.44*	.48*	.27	.49**	-.25	-.10	-.09	-.19	.53**	.81**	.27	.51**	.74**	.32	.72**	-.04	-.13	.03	-.25	-.03	
B_Req	.27	.13	.37*	.24	.08	.14	.26	.12	.05	.65**	.24	.59**	.55**	-.34	-.29	.14	-.12	.28	.66**	.74**	.70**	.33	.69**	.77**	-.19	-.22	-.02	-.14	-.35	.53**

Note. * Correlation is significant at the 0.05 level (1-tailed). ** Correlation is significant at the 0.01 level (1-tailed). SRS = Social Responsiveness Scale, aware = Social Awareness, cog = Social Cognition, moti = Social Motivation, manner = Autistic Mannerisms; FSSIP = Fear Survey Schedule for Infants & Preschoolers; PAS = Preschool Anxiety Scale; DBC Total = Developmental Behavior Checklist total score; A = Pre-task SICS, B = Post-task SICS; ChV = Response Verbal Prompt, Verb = Verbalization, Vocal = Vocalization, ConvG = Conventional Gesture, Comg = Communicative Gesture, ChG = Response to Gesture Prompt, Sh = Share, Req = Request.

Table 5

Correlations between FSSIP, SRS, PAS, DBC, HR, HF HRV, HF HRV (n.u.), LF HRV, and LF HRV (n.u.)

	FSSIP	SRS aware	SRS cog	SRS comm	SRS moti	SRS manner	SRS total	PAS	DBC total	Base HF	Base HR	Base HFnorm	Base LF	Base LFnorm	Task HR	Task HF	Task HFnorm	Task LF	Task LFnorm	Rec HR	Rec HF	Rec HFnorm	Rec LF
SRsaware	-.24																						
SRScog	.19	.45																					
SRScomm	.22	.41	.60 [*]																				
SRSmoti	.57 [*]	.22	.40	.21																			
SRSmanner	.18	.50 [*]	.47	.41	.65 ^{**}																		
SRStotal	.21	.63 [*]	.69 ^{**}	.67 ^{**}	.66 ^{**}	.86 ^{**}																	
PAS	.72 [*]	.17	.53 [*]	.37	.65 ^{**}	.35	.46																
DBCtotal	-.28	.40	.02	-.04	-.03	-.12	.02	.15															
BaseHF	-.25	.21	.15	.30	-.46	-.34	-.22	-.16	.12														
BaseHR	.23	-.06	.20	-.14	.55 [*]	.21	.28	.28	.16	-.62 [*]													
BaseHFnorm	-.25	.39	-.10	.21	-.19	.00	-.04	.08	.31	.63 [*]	-.41												
BaseLF	-.09	.00	.06	.29	-.54 [*]	-.43	-.32	-.15	-.04	.94 ^{**}	-.72 ^{**}	.49 [*]											
BaseLFnorm	.24	-.11	.13	-.27	.21	.09	.07	.12	-.01	-.63 [*]	.29	-.83 ^{**}	-.51 [*]										
TaskHR	-.04	.04	.02	-.06	.51 [*]	.26	.24	.06	.21	-.38	.82 ^{**}	-.02	-.57 [*]	-.12									
TaskHF	.11	.31	.35	.33	.26	.25	.28	.64 ^{**}	.37	-.12	.22	.31	-.23	-.04	.23								
TaskHFnorm	.14	.10	.11	.41	-.22	-.05	.13	.27	.23	.28	-.13	.41	.39	-.30	-.20	.10							
TaskLF	.11	.32	.35	.32	.26	.26	.29	.64 ^{**}	.37	-.13	.22	.29	-.25	-.02	.22	.99 ^{**}	.07						
TaskLFnorm	.18	-.26	-.23	-.23	.05	-.02	-.20	-.08	-.44	-.27	-.38	-.43	-.14	.46	-.45	-.12	-.64 ^{**}	-.10					
RecHR	.31	-.11	.32	.17	.54 [*]	.39	.39	.40	.00	-.19	.68 ^{**}	.06	-.29	-.29	.70 ^{**}	.19	.15	.18	-.58 [*]				
RecHF	-.14	.03	.14	.25	-.44	-.48 [*]	-.30	-.14	.09	.92 ^{**}	-.35	.52 [*]	.89 ^{**}	-.63 [*]	-.19	-.17	.39	-.18	-.48 [*]	.03			
RecHFnorm	-.15	.44	.02	.14	-.27	-.23	-.15	.15	.25	.62 [*]	-.28	.83 ^{**}	.49 [*]	-.65 ^{**}	-.10	.37	.36	-.41	-.07	.60 [*]			
RecLF	.26	-.58 [*]	-.06	.26	-.18	-.27	-.13	-.08	-.60 [*]	-.07	.01	-.29	.17	-.04	-.11	-.25	.34	-.26	-.01	.07	.14	-.21	
RecLFnorm	.20	-.21	-.10	.15	.09	.19	.17	.03	-.35	-.54 [*]	-.18	-.55 [*]	-.33	.56 [*]	-.35	-.01	-.12	.00	.67 ^{**}	-.42	-.66 ^{**}	-.61 [*]	.37

Note. * Correlation is significant at the 0.05 level (1-tailed). ** Correlation is significant at the 0.01 level (1-tailed). SRS = Social Responsiveness Scale, aware = Social Awareness, cog = Social Cognition, moti = Social Motivation, manner = Autistic Mannerisms, FSSIP = Fear Survey Schedule for Infants & Preschoolers, PAS = Preschool Anxiety Scale; DBC Total = Developmental Behavior Checklist total score; Base = Baseline, Rec = Recovery; HR = Heart Rate, HF = High Frequency Heart Rate Variability, LF = Low Frequency Heart Rate Variability, norm = Normalized Units.

Table 6

Social Interaction Coding Scale (SICS) Mixed Factorial ANOVA Group (G), Time (T), and Group x Time (G x T) effects

	F-value	p-value
Verbal Prompt (G)	.01	.47
Verbal Prompt (T)	1.18	.29
Verbal Prompt (G x T)	.22	.33
Gaze (G)	.66	.22
Gaze (T)	3.10*	.04*
Gaze (G x T)	.84	.19
Verbalizations (G)	3.16*	.04*
Verbalizations (T)	3.77*	.03*
Verbalizations (G x T)	1.37	.13
Actions (G)	.17	.34
Actions (T)	3.86*	.03*
Actions (G x T)	1.12	.15
Ignores (G)	3.67*	.03*
Ignores (T)	.50	.49
Ignores (G x T)	.61	.23
Vocalizations (G)	.71	.21
Vocalizations (T)	3.49*	.04*
Vocalizations (G x T)	.26	.31
Conventional Gestures (G)	5.22*	.02*
Conventional Gestures (T)	3.00*	.04*
Conventional Gestures (G x T)	1.39	.13
Communicative Gestures (G)	.68	.21
Communicative Gestures (T)	1.00	.33
Communicative Gestures (G x T)	1.00	.16
Gesture Prompt (G)	1.64	.11
Gesture Prompt (T)	.11	.37
Gesture Prompt (G x T)	.11	.37
Requests (G)	.03	.44
Requests (T)	.25	.31
Requests (G x T)	.03	.44
Shares (G)	.16	.35
Shares (T)	.37	.55
Shares (G x T)	6.43**	.01**

Note. * Between-group means are significant at the 0.05 level (1-tailed). ** Between-group means are significant at the 0.01 level (1-tailed).

Table 7

HR, HF HRV, HF HRV n.u., LF HRV, LF HRV n.u. Mixed Factorial ANOVA Group (G), Time (T), and Group x Time (G x T) effects

	F-value	<i>p</i> -value
HR (G)	.56	.23
HR (T)	.08	.45
HR (G x T)	1.94	.08
HF HRV (G)	.92	.18
HF HRV (T)	.27	.38
HF HRV (G x T)	.26	.77
HF HRV n.u. (G)	.82	.19
HF HRV n.u. (T)	2.41*	.05*
HF HRV n.u. (G x T)	2.91*	.04*
LF HRV (G)	.55	.24
LF HRV (T)	.48	.31
LF HRV (G x T)	.52	.30
LF HRV n.u. (G)	.16	.35
LF HRV n.u. (T)	.08	.46
LF HRV n.u. (G x T)	.21	.41

Note. * Between-group means are significant at the 0.05 level (1-tailed).

Figure Captions

Figure 1. Results for Pre-task and Post-task Social Interaction Coding Scale (SICS) by group (i.e., Music vs. Audiobook).

Figure 2. Results for heart rate (HR) over time (i.e., baseline, task, and recovery) by group (i.e., Music vs. Audiobook).

Figure 3. Results for high frequency heart rate variability normalized units (HF HRV n.u.) over time (i.e., baseline, task, and recovery) by group (i.e., Music vs. Audiobook).

Figure 1

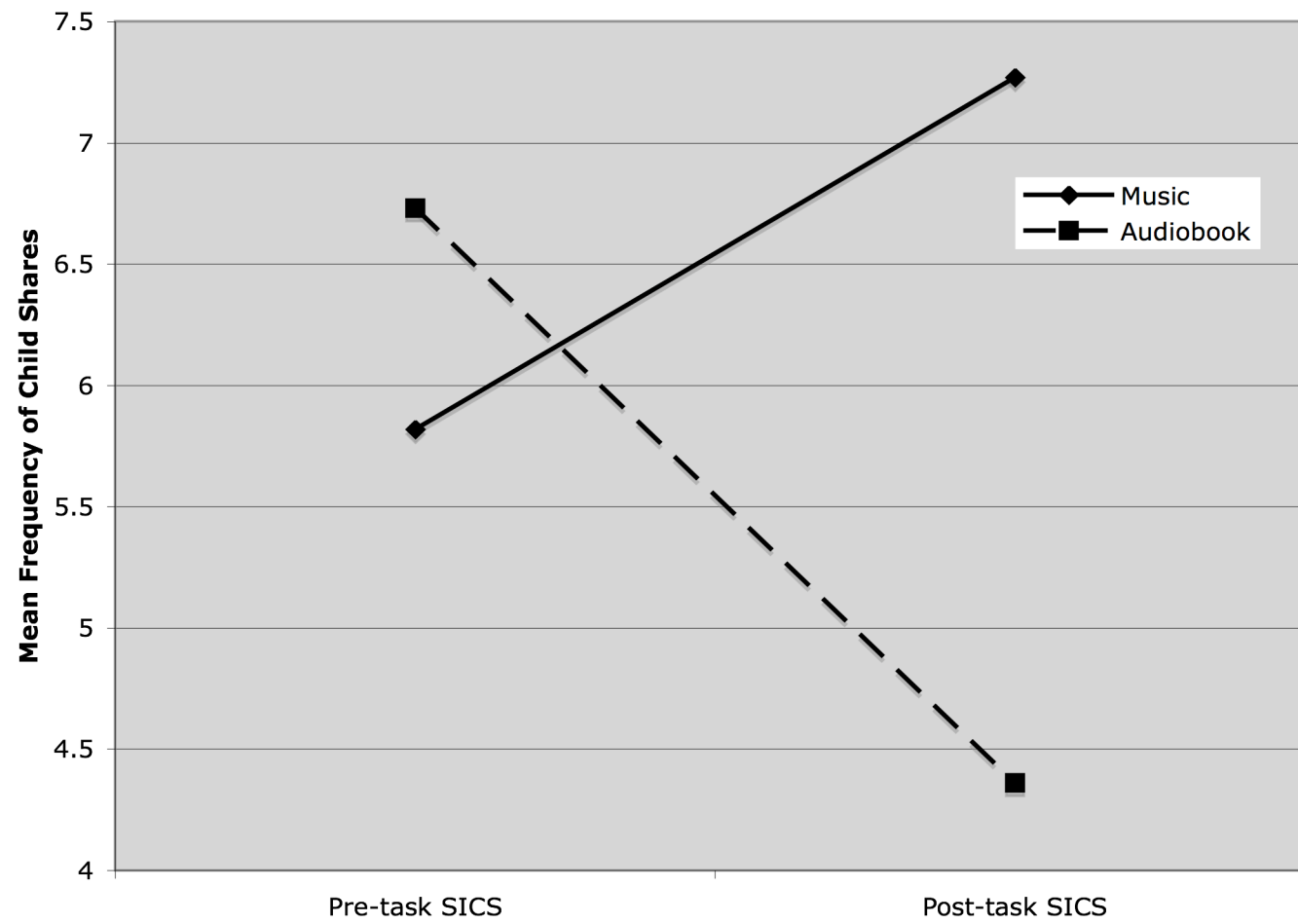


Figure 2

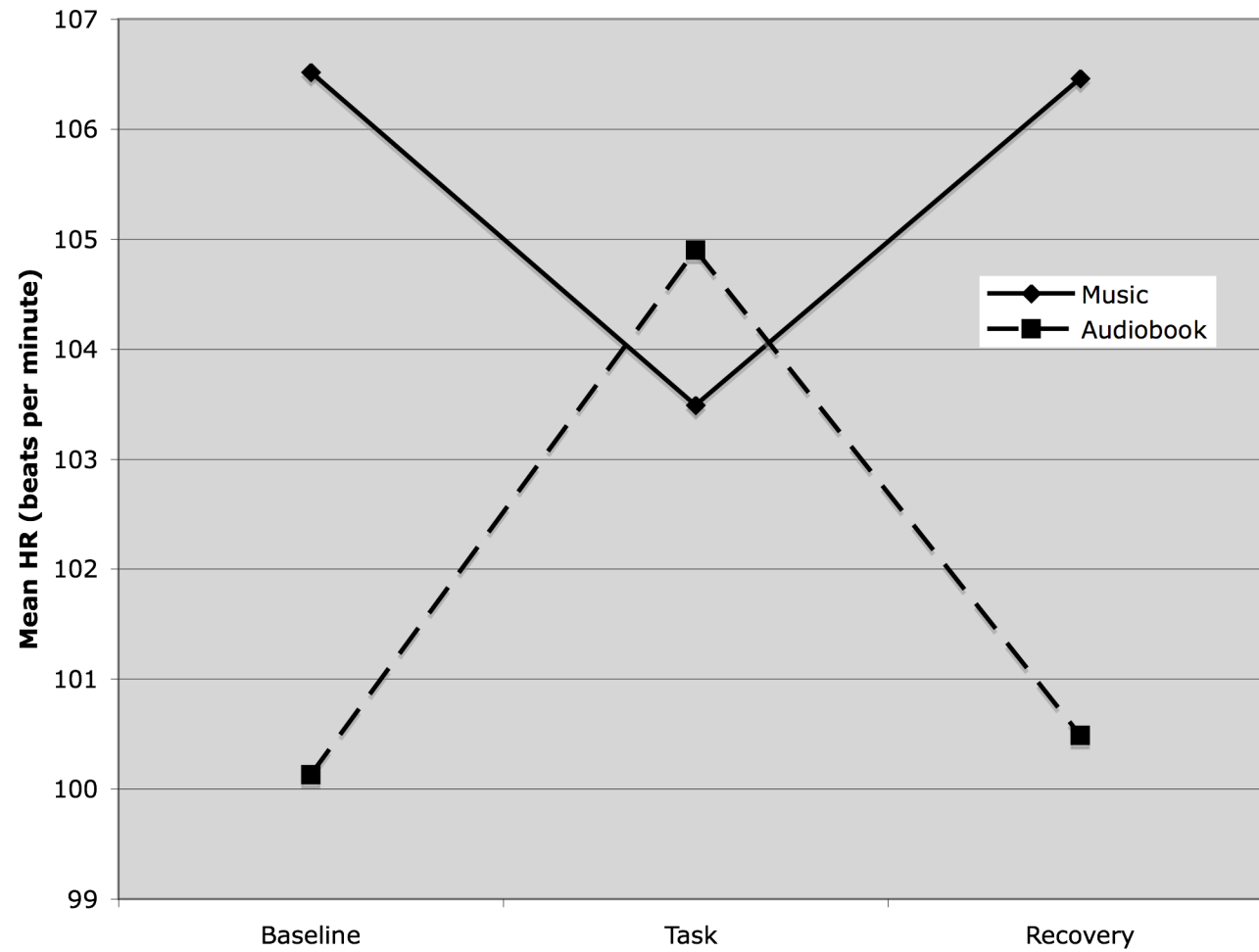
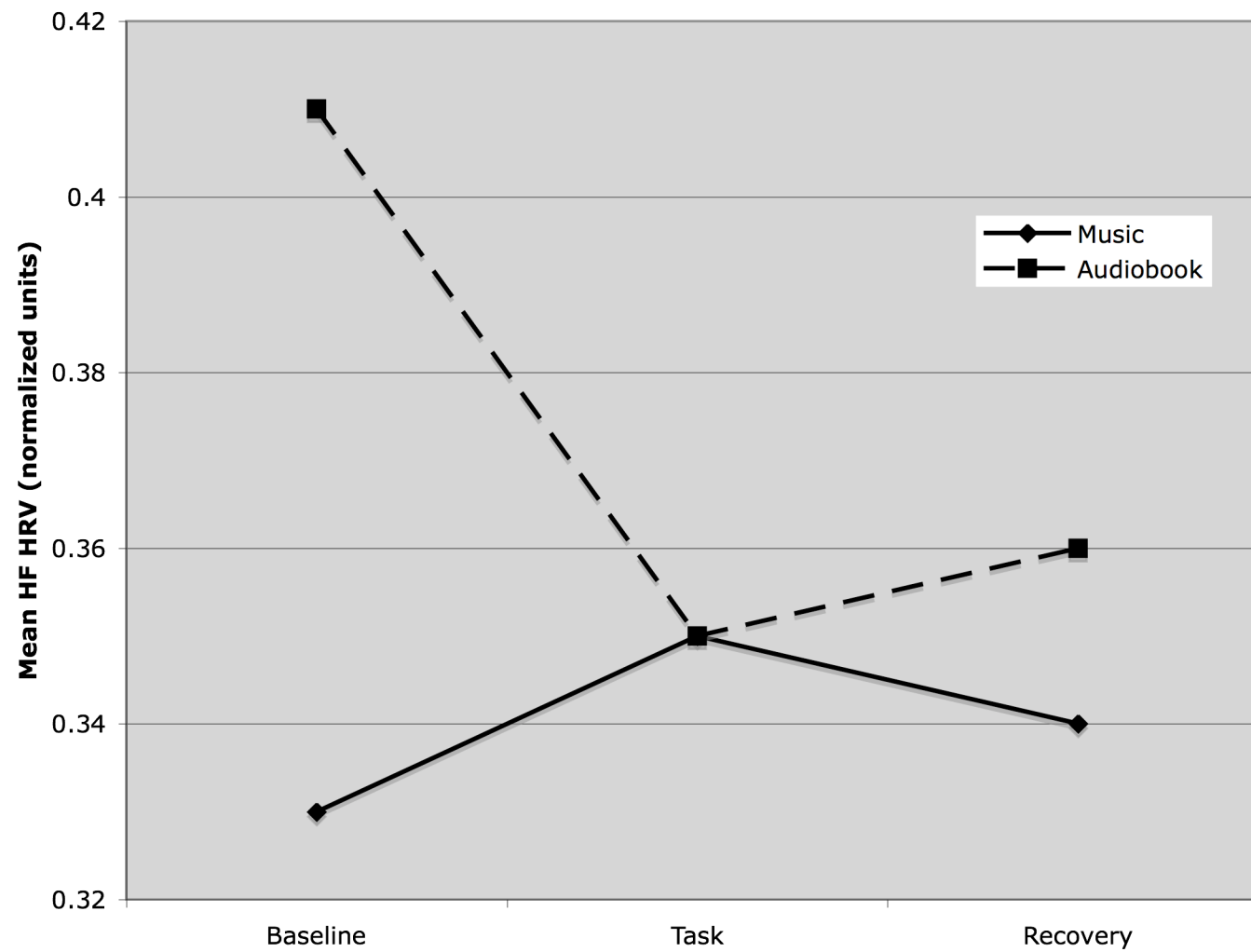


Figure 3



Demographic Survey

Subject #: _____

GENERAL INFORMATION ABOUT THE PARENT

What relation are you to the child?

- ____ Mother
- ____ Father
- ____ Stepmother
- ____ Stepfather
- ____ Adoptive Mother
- ____ Adoptive Father
- ____ Legal Guardian
- ____ Other Relative (please specify): _____

What is your race/ethnicity? (optional)

- ____ African American
- ____ Asian
- ____ Caucasian/European American
- ____ Native American
- ____ Latino, Hispanic, or Chicano
- ____ Other (please specify): _____

What is your highest level of completed education? (optional)

- ____ Some High School
- ____ High School Graduate
- ____ Some College
- ____ College Degree
- ____ Some Graduate Studies
- ____ Graduate Degree

Which of the following is closest to your annual household income? (optional)

- ____ Under \$20,000
- ____ \$20,000 - \$39,999
- ____ \$40,000 - \$59,999
- ____ \$60,000 - \$79,999
- ____ \$80,000 - \$99,999
- ____ \$100,000 and above

GENERAL INFORMATION ABOUT THE CHILD

When is your child's birthday?

____ Month ____ Day ____ Year

How old is your child?

____ Years ____ Months

What is your child's gender?

____ Male

____ Female

What is your child's race/ethnicity? (optional)

____ African American

____ Asian

____ Caucasian/European American

____ Native American

____ Latino, Hispanic, or Chicano

____ Other (please specify): _____

What level of education has your child completed?

____ None

____ Preschool

____ Kindergarten

____ Elementary School

Specify highest grade completed: _____

Does your child take any medications?

____ Yes ____ No

If yes, please specify what medications: _____

GENERAL INFORMATION ON DIAGNOSIS AND PROFESSIONAL SERVICES

What is your child's current Autism Spectrum Disorder diagnosis?

____ Autism or Autistic Disorder

____ Asperger's Disorder

____ Childhood Disintegrative Disorder

____ Rett's Syndrome

____ Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS)

____ Other (please specify): _____

How old was your child when he/she got this diagnosis?

____ Years ____ Months

Have any of the child's siblings been diagnosed with Autism Spectrum Disorder?

____ Yes

____ No

If Yes, please specify which disorder: _____

Does your child have any other symptoms or diagnoses? (check all that apply)

- ☐ Anxiety Disorder
- ☐ Attention Deficit Hyperactive Disorder
- ☐ Obsessive Compulsive Disorder
- ☐ Central Auditory Processing Disorder
- ☐ Depression
- ☐ Schizophrenia
- ☐ Hearing Impairment
- ☐ Vision Impairment
- ☐ 'Tunnel Vision Syndrome' (peripheral vision, vision perception impairment)
- ☐ Mental Retardation
- ☐ Seizures
- ☐ Dietary Allergies
- ☐ Digestive Problems (constipation, diarrhea, bloating, or abdominal pain)
- ☐ None
- ☐ Other (please specify): _____

If answered yes to dietary allergies, please specify: _____

What type of professional diagnosed your child with Autism Spectrum Disorder?

- ☐ Developmental Pediatrician
- ☐ Psychologist
- ☐ Neurologist
- ☐ Primary Care Physician
- ☐ Psychiatrist
- ☐ Other (please specify): _____

CURRENT SYMPTOMS DISPLAYED BY CHILD

Please check the symptoms currently exhibited by your child:

- ☐ Doesn't respond when called
- ☐ Self-injurious behaviors
- ☐ Destructive behaviors
- ☐ Receptive language delay
- ☐ Expressive language delay
- ☐ No verbal language
- ☐ Apraxia (oral motor, articulation problems)
- ☐ Absent or limited gestures
- ☐ Cognitive delay
- ☐ Strong visual learner
- ☐ Strong auditory learner
- ☐ Gross motor delay
- ☐ Fine motor delay

- ☐ Undersensitive to pain
- ☐ Oversensitive to pain
- ☐ Undersensitive to sound
- ☐ Oversensitive to sound
- ☐ Aggressive to others
- ☐ Has trouble joining a group
- ☐ Happier left alone
- ☐ Frustrated
- ☐ Gets angry easily
- ☐ Cries excessively
- ☐ Hums frequently
- ☐ Insists on sameness
- ☐ Agitated when routine is disrupted
- ☐ Insists on precision
- ☐ Poor eye contact
- ☐ Stomach Pain
- ☐ Constipation
- ☐ Diarrhea
- ☐ Eczema
- ☐ Thrush (white tongue yeast infection)
- ☐ Itchy penis/perineum/all
- ☐ Losing weight
- ☐ Gaining weight
- ☐ Fixation on objects or topics
- ☐ Unusual cravings for certain foods
- ☐ Has known food sensitivity
- ☐ Sustained odd play
- ☐ Echolalia (repeats the same phrase over and over)
- ☐ Does not require long sleep
- ☐ Requires longer than average sleep
- ☐ Does not stay asleep
- ☐ Wakes up at night and does not go back to sleep
- ☐ Takes a long nap daily
- ☐ Tantrums
- ☐ Anxiety
- ☐ Depression
- ☐ Hand flapping
- ☐ Toe walking
- ☐ Spinning self
- ☐ Likes to watch objects spin
- ☐ Rhythmic or rocking behaviors
- ☐ Other types of self-stimulatory behavior (please specify): _____

If answered yes to unusual cravings for certain foods, please specify:

If answered yes to known food sensitivity, please specify:

Appendix B



College of Science
Department of Psychology

Autism Clinic
3110 Prices Fork Road (0355)
Blacksburg, Virginia 24061-0355
540/231-6914 Fax: 540/231-4250

Parental Permission for child to participate in:

The Effect of Music on Autonomic Response in Children with Autism Spectrum Disorders

I. Purpose of this Research Project

The purpose of this study is to research the physiological effects of music on children with Autism Spectrum Disorders (ASDs). ASDs are characterized primarily by a lack of social understanding and social development; we are investigating one potential explanatory mechanism (i.e., autonomic response—heart rate and heart rate variability) of these deficits. Research suggests that children with ASDs have an elevated physiological state to unfamiliar people and therefore we are using music or a book-on-tape to soothe an elevated physiological state. Through this soothed state, social engagement behaviors should increase. For this study we are collecting data from twenty-four children aged 4-7 years old, all previously diagnosed with ASDs.

II. Procedures

For this experimental session your child will be video-taped throughout the entire experimental session, except for adhesion and removal of the LifeShirt®. This experimental session takes place at the Virginia Tech Autism Clinic and will last approximately 90-minutes. The procedures of the experimental session are as follows:

The following are the procedures for the study, for your child. He/she will be:

- Verbally assented.
- Brought into the experiment room
- Given a measure of receptive vocabulary for 10-15 minutes.
- Assisted by the experimenter in putting on the LifeShirt®. The LifeShirt® is a physiological monitor that fits like a vest and measures heart rate and respiration. The electrodes used with the LifeShirt® have a mild adhesive designed particularly for younger children.
- Instructed to watch at 5-minute nature video created for children 4-10 years old entitled, *National Geographic's Animal Holiday*.
- Participating in a 10-minute structured play session with the experimenter.
- Selecting 5 songs or 1 book-on-tape that they would like to listen to during a listening period of 12-minutes.
- Listening to the music while they do whatever they would like in the experiment room (e.g., play with toys, do a puzzle, sit).
- Participating in another 10-minute structured play session with the experimenter.
- Watching another portion of *National Geographic's Animal Holiday*.
- Helped by the experimenter in removing the LifeShirt® and electrodes.

III. Risks

There are no more than minimal risks related to this study. However, electrode removal may be uncomfortable (similar to the pain of removing a band-aid). The experimenter, in removing these electrodes, will make particular caution. The experimenter will warn your child at the beginning of the study of the potential discomfort associated with the electrodes and that it may "hurt like a band-aid" when they are removed. In addition, before removal the experimenter will ask if your child would like to remove the electrodes him/herself, have his/her parent remove them, or have the experimenter remove them. Additionally, electrode gel can cause a localized allergic reaction where the electrode was placed. All other aspects of the study should be familiar to your child and will hopefully be enjoyable.

Invent the Future

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Virginia Tech Institutional Review Board: Project No. 09-272
Approved June 8, 2009 to June 7, 2010

IV. Benefits

There are no direct or indirect benefits to your child or you. There are societal benefits of understanding the physiological mechanisms that may be associated with social deficits in children with ASDs. No promise or guarantees of benefits have been made to encourage your child or you to participate.

V. Extent of Anonymity and Confidentiality

All data related to you and your child will be de-identified with an identification number. All consent forms will be stored in a locked cabinet separate from all other data. In addition, the video of your child and all other data will be labeled with his/her participant identification number and will be placed in a locked cabinet separate from the consent form. The only people with access to this cabinet will be designated research personnel. The video will be viewed by two trained undergraduate research assistants in order to code the structured play situation that my child engaged in. They will be given no identifying information about your child, only your child's participant identification number. It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research. Data will be destroyed 2 years past publication of the results. **If you or your child express any child abuse, or the intent to harm or kill ourselves or someone else, the researchers are legally obliged to inform an authority. In this case, you will be informed of the need to do so, and am encouraged to contact with the researchers the Psychological Services Center (540-231-6914) or other counseling agency. However, any outside counseling sought by the you for yourself or your child will be at your expense, as neither the researchers, nor Virginia Tech, have money set aside for such purposes.**

VI. Compensation

You will not receive compensation for your child's participation in this study.

VII. Freedom to Withdraw

This project has been explained to you and your child and we both have been allowed to ask questions about it. You understand that your child or you do not have to fill out the questionnaires or participate in any way if you do not want to and no one will treat us badly. You or your child can stop part way through or withdraw at any time, if you choose.

VIII. Parent (or Guardian) /Subject's Responsibilities

You voluntarily agree for your child to participate in this study. Your child may participate in a structured-play, watch a video, have his/her physiology monitored, and listen to music or books-on-tape. You understand, however, that you or your child may withdraw at any point and you both are not required to complete any of these activities.

IX. Parent/Guardian's Permission

You have read the Parental Permission Form and conditions of this project. You have had all my questions answered. You hereby acknowledge the above and give your voluntary consent for your and your child to participate in this study.

Parent/Guardian Signature: _____ Date: _____

Should I have any questions about the protection of human research participants regarding this study, I may contact:

Michelle Patriquin, B.S.
Graduate Student
Department of Psychology
540-998-3414
mpatriq@vt.edu

David Moore
Chair, Virginia Tech IRB
Office of Research Compliance
2000 Kraft Drive
Suite 2000 (0497)
Blacksburg, VA 24060
540-231-4991 moored@vt.edu

Virginia Tech Institutional Review Board: Project No. 09-272
Approved June 8, 2009 to June 7, 2010

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David W. Harrison, Ph.D., Chair
Human Subjects Committee
Psychology Department
Virginia Tech
540-231-4422
dwh@vt.edu

Appendix C



College of Science
Department of Psychology

Autism Clinic
3110 Prices Fork Road (0355)
Blacksburg, Virginia 24061-0355
540/231-6914 Fax: 540/231-4250

Parent Subject Consent Form for:

The Effect of Music on Autonomic Response in Children with Autism Spectrum Disorders

I. Purpose of this Research Project

The purpose of this study is to research the physiological effects of music on children with Autism Spectrum Disorders (ASDs). ASDs are characterized primarily by a lack of social understanding and social development; we are investigating one potential explanatory mechanism (i.e., autonomic response—heart rate and heart rate variability) of these deficits. Research suggests that children with ASDs have an elevated physiological state to unfamiliar people and therefore we are using music or a book-on-tape to soothe an elevated physiological state. Through this soothed state, social engagement behaviors should increase. For this study we are collecting data from twenty-four children aged 4-7 years old, all previously diagnosed with ASDs.

II. Procedures

For this experimental session you will sign and agree to the participation of your child in the study at the Virginia Tech Autism Clinic. Then, you will be asked to fill out a measure of ASD severity for your child, fear, temperament, anxiety, emotion regulation, and developmental scales for my child and a demographic questionnaire. After the questionnaires have been explained to you, your child will be brought into the experiment room. You will be allowed to watch the experimenter and your child interact throughout the entire session behind a one-way window while you complete the questionnaires. It will take approximately 40 minutes to complete all questionnaires.

III. Risks

There are no more than minimal risks related to this study and you and your child's participation. However, electrode removal may be uncomfortable (similar to the pain of removing a band-aid) for your child. The experimenter, in removing these electrodes, will take care to gently remove them. The experimenter will warn your child at the beginning of the study of the potential discomfort associated with the electrodes and that it may "hurt like a band-aid" when they are removed. In addition, before removal the experimenter will ask if your child would like to remove the electrodes him/herself, have his/her parent remove them, or have the experimenter remove them. Additionally, electrode gel can cause a localized allergic reaction where the electrode was placed.

IV. Benefits

There are no benefits to you or your child. There are societal benefits of understanding the anxiety, fear, temperament, ASD severity correlates to your child's social engagement and physiology. No promise or guarantees of benefits have been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

All data related to you and your child will be de-identified with an identification number. All consent forms will be stored in a locked cabinet separate from all other data. In addition, the video of your child and all other data will be labeled with his/her participant identification number and will be placed in a locked cabinet separate from the consent form. The only people with access to this cabinet will be designated research personnel. The video will be viewed by two trained undergraduate research assistants in order to code the structured play situation that your child engaged in. They will be given no identifying information about your child, only your child's participant identification number. It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research. Data will be destroyed 2 years past publication of the results. **If you or your child express any child abuse, or the intent to harm or kill yourselves or someone else, the researchers are legally obliged to inform an authority.**

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Virginia Tech Institutional Review Board: Project No. 09-272
Approved July 7, 2009 to June 7, 2010

In this case, you will be informed of the need to do so, and you are encouraged to contact with the researchers the Psychological Services Center (540-231-6914) or other counseling agency. However, any outside counseling sought by you for yourself or your child will be at your expense, as neither the researchers, nor Virginia Tech, have money set aside for such purposes.

VI. Compensation

You will not receive compensation for you and your child's participation in this study.

VII. Freedom to Withdraw

This project has been explained to you and you have been allowed to ask questions about it. You understand that you do not have to fill out the questionnaires or participate in any way if you do not want to and no one will treat you badly. You can stop part way through or withdraw at any time, if you choose.

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You voluntarily agree to participate in this study.

IX. Parent/Guardian's Permission

I have read the Parent Subject Consent Form and the conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this study.

Parent/Guardian Signature: _____ Date: _____

Should I have any questions about the protection of human research participants regarding this study, I may contact:

Michelle Patriquin, B.S.
Graduate Student
Department of Psychology
540-998-3414
mpatriq@vt.edu

Angela Scarpa, Ph.D.
Associate Professor
Department of Psychology
540-231-2615
ascarpa@vt.edu

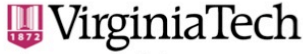
David Moore
Chair, Virginia Tech IRB
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2000 Kraft Drive
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540-231-4991 moored@vt.edu

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VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Virginia Tech Institutional Review Board: *An equal opportunity, affirmative action institution*
Project No. 09-272
Approved July 7, 2009 to June 7, 2010

Appendix D



College of Science
Department of Psychology

Autism Clinic
3110 Prices Fork Road (0355)
Blacksburg, Virginia 24061-0355
540/231-6914 Fax: 540/231-4250

Child Verbal Assent Document/Script:

To be verbally reviewed with the child participant prior to any data collection and/or the child entering the experiment room.

The Effect of Music on Autonomic Response in Children with Autism Spectrum Disorders

I. Purpose of this Research Project

"Some children have a hard time meeting people or children they don't know. This may be because their hearts beat way to fast and they can only feel their hearts beat and can't talk to and or play with other person or child. So, we will be measuring how your heart beats to talking and playing with a person you don't know. You will also get to watch a movie and listen to either music or a book on tape that you pick out so we get to know how your heart beats to that, too!"

II. Procedures

"To measure your heart, we will use something that looks like a lifevest. Have you ever used one of those in the water before? It is pretty neat! This vest is different from a lifevest—it has little stickers that attach to it, that then attach to your skin. Two stickers are placed by your heart and one is placed on your stomach. These stickers help us measure your heart—pretty cool, huh! You will wear this vest for about an hour while we play and when you listen to music or a book-on-tape. Your [mom/dad/grandma/grandpa/etc] will be watching you the whole time through a window we have in this room [point to room], they will be here the whole time. When we take off the electrodes, they may be a little sticky and it can feel like a band-aid to take off. But, [experimenter name] will let you take them off yourself if you want, or your [mom/dad/grandma/grandpa/etc] can help you take them off."

VII. Freedom to Withdraw

"If you do not want to do anything in the study just let [experimenter name] know, and you don't have to do it! You only should do what you want to do, and if you are scared or would like your [mom/dad/grandma/grandpa/etc] to come in the room, just let [experimenter name] know.

IX. Child's Verbal Assent

"Do you have any questions about what I told you? Do you want to do the study?" **[Experimental session will be commenced only if child agrees to participate]**

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Invent the Future

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